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An Industry in Transition

Early Glue-Laminated Timber in Switzerland, 1909-1939

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Abstract

By the introduction of glulam in Switzerland in 1908, the initiators promised to upgrade and expand the possibilities of the old building material, timber. The new shapeable and large-scale components established timber in modern building and infrastructure construction. Within this process, not only did the material undergo a transformation, but reciprocally, the new timber as well caused a transformation of the building sector itself. New design and construction procedures required both new technical knowledge and collaborations between different established and emerging specialists leading to a new network of timber structures production in Switzerland.

This project, through a theoretical orientation based on the Actor-Network Theory approach, traces the transformation of an industry in Switzerland through the introduction of glulam and demonstrates that the success of the technology benefited greatly from the already existing crisis in the timber construction sector, as well as the particular Swiss way of the organization of the shifting power and competence towards technical engineering and fabrication. Ironically, the rapid and widespread establishment of glulam was possible primarily because of the high level of craftsmanship and construction expertise on the side of the contractors, but in turn, glulam reduced this latter precisely because of the disempowerment of the construction site.

Considering the high relevance of glulam to our building industry today, and the existing fascination which sees no end in sight for this material-technology, this dissertation offers new perspectives on the contemporary questions about glulam.

Keywords

Glulam, glue-laminated timber, Switzerland, network, craftsmanship, technology, engineered timber, Terner & Chopard, 20^{th} century.

Zusammenfassung

Mit der Einführung des Brettschichtholzes in der Schweiz im Jahr 1908 versprachen die Initiatoren, die Möglichkeiten des alten Baustoffs Holz zu verbessern und zu erweitern. Die neuen formbaren und großflächigen Bauteile etablierten Holz im modernen Hoch- und Infrastrukturbau. Dabei veränderte sich nicht nur der Werkstoff, sondern das neue Holz veränderte auch die Baubranche. Neue Entwurfs- und Konstruktionsverfahren erforderten sowohl neues technisches Wissen als auch die Zusammenarbeit verschiedener etablierter und aufstrebender Spezialisten, was zu einem neuen Netzwerk für die Produktion von Holzkonstruktionen in der Schweiz führte.

Dieses Projekt zeichnet durch eine theoretische Orientierung am Ansatz der Akteur-Netzwerk-Theorie die Transformation einer Branche in der Schweiz durch die Einführung des Brettschichtholzes nach und zeigt, dass der Erfolg der Technologie stark von der bereits bestehenden Krise im Holzbausektor sowie der spezifisch schweizerischen Organisationsform der Macht- und Kompetenzverschiebung hin zur technischen Konstruktion und Fertigung profitierte. Ironischerweise war die rasche und flächendeckende Etablierung des Brettschichtholzes vor allem aufgrund des hohen handwerklichen und bautechnischen Know-hows auf Seiten der Bauherren möglich, wobei das Brettschichtholz letzteres wiederum gerade durch die Entmachtung der Baustelle reduzierte.

In Anbetracht der hohen Relevanz von Brettschichtholz für unser heutiges Bauwesen und der bestehenden Faszination, die kein Ende für diese Werkstofftechnologie in Sicht ist, bietet diese Dissertation neue Perspektiven auf die aktuellen Fragen zu Brettschichtholz.

Schlüsselwörter

Brettschichtholz, Leimholz, Schweiz, Netzwerk, Handwerk, Technologie, Holzbau, Terner & Chopard, 20. Jahrhundert.

Introduction

Building with wood is booming. Glulam is being promoted to become the ubiquitous building material of the near future. Today's possibilities with timber structures of almost all kinds are inevitably linked with the ideas of the pioneer of glue-laminated timber, namely the German master carpenter, Otto Hetzer (1846–1911), and the particular contribution of Switzerland to its early development.

This project is about the early glue-laminated timber in Switzerland. It takes as its starting point a curiosity about a probable set of choices and chances that gave rise to the early development of glulam in this country: what were the background forces that gave rise to this technology in Germany and its exemplary development in Switzerland? Why among all the alternatives for timber construction systems that developed in parallel in the early 20th century, it was glulam that became the dominant solution for responding to the then-existing crisis with structural timber? The curiosity for this subject came in fact from pondering the relations between technology, the material world, humans and society, and the arrangements of knowledge, power, and authority. This project is concerned not only with glulam in Switzerland, but as well with early Swiss glulam. Therefore, Switzerland is considered both as a lens through which we understand and interpret the development of glulam, and as well as an argument, to convey points of view on technological developments in a broader context.[1]

The introduction of new materials into the building industry often leads to controversial debates including technical, political, economic, and social-cultural aspects. These insecurities question the framework of practice within which architects, engineers, contractors, building authorities, scientists, clients, material suppliers, and all other interested, involved, or affected parties perform during design and construction. Glulam was introduced in a rather dynamic context where major institutions were about to be reshaped and their interaction to be established. The same went for the political parties, cooperatives, as well as labour unions, and trade associations. In this project, it will be therefore asked how the introduction of the "new timber" challenged the decision process and the power relation between different parties seeking to identify and clarify the main stakeholders of the design and construction practice of glulam and their interrelation.

The development of glulam, from a technological perspective, does fall into two periods: 1909-1916, and the 1930s. These two decades are of significant importance: during the first period, the mechanization of the constructional design was reached. Becoming the dominant design, the proposed solutions became soon part of the common methods and practices in glulam construction and shaped in fact our contemporary glulam design. The 1930s, on the other hand, are marked by the efforts for

[1] The approach to technology in this research is influenced by Schatzberg, Eric. T*echnology: Critical History of a Concept.* Chicago, University of Chicago Press, 2018. The relation between technology and architecture, has been the subject of Angelil, Marc. *Technique and formal expression in architecture theory in architectural technology from the renaissance to the age of reason.* PhD dissertation, ETH Zurich, 1987. Considering the temporal context of this study (Angelil's dissertation), the notion of architecture can be extended to engineering as well. Therefore, he investigates in a broader context the relation between technology and building construction.

the synthetization of glue, which had a crucial influence on designating glulam as the engineered timber of the 20th century. After this time, glulam benefited from a more sustained enthusiasm than in the early times, therefore the research will be focused mainly on the period 1909-1939.

Questioning about the early glulam, is, in fact, challenging today's most pressing questions from this technology, and in a broader context, addressing the crucial questions facing the world today: the relation of human to nature, the crisis of modernity, sustainability, the degree of human intervention for altering the material world, etc. Considering the relevance of glulam to contemporary building culture, this thesis concerns not only the past but also the future.

To reflect on the questions that concern this project, glulam will be approached in all the different ways, in which it was perceived by the parties involved in its conception and construction. For the engineers, glulam was an opportunity for new ways of design of timber structures; for the architects, it was a shapeless, but shapeable material; for the carpenter-contractors, it was a wood-based material that had to be crafted and fabricated, but it was as well a new timber that allowed for a great degree of prefabrication and reuse; for the workers, it was a new technology that was much less craft and skill-based, undermining their capacities; for the authorities, it was a new material whose practice was not yet regulated; and for the clients, it was the elegant modern timber, but posed sometimes problems of decay and delamination. Glulam will be addressed in this project by all the different ways in which it was perceived.

Research context

Research on the history of glue-laminated timber and early engineered timber

Research on the development of glued laminated timber plays only a marginal role in the most recent research of construction history. Especially for the period right after its emergence, until the Interwar period, there is no research neither on the context of its introduction nor the basic conceptual influences from traditional timber techniques or other well-established building materials.[2]

The years after World War 1 turned out to be the first global climax of industrial large-scale timber construction and benefited from the steel and coal crisis. The efforts to push timber as an equivalent building material can be seen in the 1920s when the first monographs on modern timber construction circulated in many European countries promoting the use of the largely available material. They not only demonstrated the latest technical developments and the finest examples in architecture and engineering but also covered the basic technical knowledge of timber as a construction material. Carl Kersten and Franz Geissler, for instance, presented a comprehensive overview of modern timber

[2] The research for this early period is mainly limited to lisiting the name of the companies who received the patent: Rhude, Andreas Jordahl. “Structural Glued Laminated Timber: History of Its Origins and Early Development.” *Forest Products Journal*, vol. 46, no. 1, 1996, pp. 15–26. – Also, briefly mentioned in Rusak, Mariya. *FACTORY-MADE: the everyday Architeture of Moelven Brug,1955-1973*. PhD dissertation, The Oslo School of Architecture and Design, 2022.

construction techniques in 1921 reflecting the technical development of large-span timber structures from the 18th century until then but also presented a variety of systems and inventions developed by many different building companies at that time.[3] Kersten's book is still one of most important research studies into the historical development and application of modern timber construction during its early days. The most comprehensive study on the origin and development of timber engineering in 1920s was presented by Mathias Seraphin with his dissertation in 2003.[4] Seraphin's study was particularly concentrated on the State of the Art in timber engineering at the turn of the 20th century and the institutionalization of timber construction.

The publications on structural timber in the 1930s were highly influenced by the propaganda campaign to promote the use of this material in the Interwar Period, and the focus was shifted towards the possibilities of this material for future constructions.

In 1936, the American Engineer Thomas R. C. Wilson visited many glued laminated timber structures in Europe and reported on them in a technical bulletin in 1939.[5] Switzerland is considered to show great popularity with glued laminated timber.

A valuable primary source on the early glulam in Switzerland is provided by the visit of the American structural engineer, Max Steinhaus, to the Swiss glulam projects, in 1961. He explained the goal of that travel as to "prepare "the outline of wood construction in the USA" and one of the main topics could be the European influence, particularly that of Switzerland, on the development of timber structures in the United States of North America".[6] During his visit, Steinhaus had the opportunity, not only to visit several glulam buildings, but also to meet many pioneers of glulam construction in Switzerland, and several production workshops that do not exist anymore. The reports prepared by Steinhaus during his visit are preserved at the ETH Zürich University Archives and are an important primary source for this dissertation.

In 1971 the English engineer Lionel G. Booth described early laminated arch structures in Bavaria (Germany), France, and England dating back to 1810s to 1830s and later presented glued laminated timber roofs from the 1840s and 1850s.[7] However, these cases are considered singular examples which demonstrate the early understanding of the method but the quality of the glue and the

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[3] Geissler, F., et al. *Freitragende Holzbauten*, edited by C. Kersten, Berlin, Springer, 1921. – Kersten, C. *Freitragende Holzbauten; Ein Lehrbuch Für Schule Und Praxis*. Berlin, Springer, 1926.
[4] Seraphin, Mathias. *Zur Entstehung des Ingenieurholzbaus - eine Entwicklungsgeschichte*, PhD dissertation, Technical University of Munich, 2003.
[5] Wilson, T.R.C. *The Glued Laminated Wooden Arch*. Technical Bulletin no. 691, United States Department of Agriculture, Washington D.C. 1939, pp. 4-9 & 87-94.
[6] Steinhaus, Max. Archiv schweizerischer, europäischer und arnerikanischer Holzbau- und Holzleimtechnologie; Autographen und Dokumentation meist aus den Jahren 1940 – 1970. ETH Zürich, Handschriften und Autographen der ETH-Bibliothek, 1987, HS 1198:1, 2, 4, 6.
[7] Booth, L. G. "Henry Fuller's Glued Laminated Timber Roof for Rusholme Road Congregational Sunday School and Other Early Timber Roofs." *Construction History*, vol. 10, 1994, pp. 29–45. – Booth, L. G. "Development of laminated timber arch structures in Bavaria, France, and England in the early nineteenth century", *The development of timber as a structural material*, edited by David Yeomans Abingdon, Oxon, Routledge, 1971, pp, 291-304.

predominance of wrought iron must have prevented the technology from spreading. Booth developed an approach to differentiate between different concepts and various contexts and is therefore an important reference for this research.

Charles von Büren's *Neuer Holzbau in der Schweiz* from 1985 connects aspects of modern timber construction with a rich historical basis.[8] In this anthology, Othmar Birkner reconstructs very briefly the conditions for the industrial development of building materials after World War 1.[9] The most recent and most comprehensive study on the development of glue-laminated timber was presented by Christian Müller with his dissertation in 1998. Müller particularly looked at the developments and inventions proposed and carried out by Otto Hetzer between 1891-1910, mainly tracing further developments of glue laminated timber constructions until today. This study has been extended and published shortly after and offers a greater selection of outstanding examples, among which some Swiss projects are presented.[10] Müller focused mainly on the development in Germany and, through the spreading of Hetzer's patent, some major foreign companies. However, Müller also did not discuss different contexts of the development when the patent spread and he also did not discuss the contemporary design and construction practice of glulam. Müller's research is the most important reference research literature for this research project to clarify the technological setting at that time.

The latest publications on modern timber focus entirely on the architectural and engineering potential of the developments in the field.[11] Celebrating the new character and the manifold new possibilities for more capable connections and new component shapes, these accounts mostly do not relate these new developments to traditional construction concepts of timber or other materials. The manipulation of the material compound within a timber component is still the main focus of the timber research of today, together with the development of new connection types.[12]

Research on the development of timber construction in Switzerland

Switzerland does not play an important role yet in the historical research of timber structures and technology in the 20th century.[13] There is also no particular accomplishment accredited in relevant international compendia on building history, however there is a widespread awareness of the

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[8] *Neuer Holzbau in der Schweiz: mit Tradition und Erfahrung zu neuen Gestaltungen in Holz*. edited by Charles Von Büren, Dietikon, Baufachverlag, 1985.
[9] Birkner, Othmar. "Lernen aus Tradition und Erfahrung". *Neuer Holzbau in der Schweiz: mit Tradition und Erfahrung zu neuen Gestaltungen in Holz*. edited by Charles Von Büren, Dietikon, Baufachverlag, 1985, pp. 9-20.
[10] Müller, Christian. Die Entwicklung des Holzleimbaues unter besonder Berücksichtigung der Erfindungen Otto Hetzer- ein Beitrag zu Geschichte der Bautechnik. PhD dissertation, Bauhaus-Universität Weimar, 1998. – Müller, Christian. *Holzleimbau= Laminated timber construction*. Basel, Birkhäuser, 2000.
[11] See e.g. Lennartz, Marc Wilhelm, and Susanne Jacob-Freitag. *New Architecture in Wood: Forms and Structures.* Basel, Birkhäuser, 2016. Lips-Ambs, 1999. – Steurer, Anton, *Developments in Timber Engineering: The Swiss Contribution.* Basel, Birkhäuser, 2005. – Herzog, Thomas et. al. *Holzbau Atlas. (Edition Detail).* Basel, Birkhäuser, 2013. *Glulam handbook, Le Manuel du Bois Lamellé (édition 2018).* Paris, CODIFAB, 2018. – Leloy, Claire. *Histoire du bois lamellé: Le eBook du Centenaire 100 ans de bois lamellé*, https://www.glulam.org/wp-content/uploads/eBookduCentenaire8-Histoire.pdf
[12] See e.g. *Materials and Joints in Timber Structures. Recent Developments of Technology,* edited by Simon Aicher et al. Springer, Netherlands, 2014.
[13] Latham, Bryan, *Timber: its development and distribution; a historical survey*. London, G.G. Harrap, 1957.

achievements during the 18th century by the carpenter family Grubenmann which becomes apparent in accounts of journeys through Switzerland.[14] Steurer looks specifically at the "Swiss contribution" to timber technology and highlights the importance of Swiss engineers for the success of the technology especially at the emergence of glued laminated timber,[15] but did not discuss these influences at all. He presented a collection of important works but did not provide any explanation of what kind and of which influences the "Swiss contribution" was. Since Switzerland does not possess resources such as steel or coal,[16] it is often being considered especially predestined for timber structures due to its massive wood supply and long tradition of timber craftsmanship.[17]

A comprehensive account of developments in modern timber construction in Switzerland has been given by Helmut Kühne in 1979.[18] Later anthologies dealing with exemplary modern timber structures regularly showed Swiss buildings and bridges among those of other countries. Many of these examples, most of which designed by Terner & Chopard, were considered especially elegant and delicate.[19]

Research on the Swiss contribution in early glulam

There is no research on the history of early glue-laminated timber inside or outside of Switzerland. The circumstances of the introduction and the development of engineered timber in the country has been largely neglected. The absence of work in this area was one of the motivations for undertaking this project.

Methodology

This dissertation belongs principally to the field of Construction History, a relatively recent research field, which should "recognise the act of constructing", as Werner Lorenz explains, "as deeply human, and subjective". This history is therefore "much more than the transformation of theoretical knowledge into a functional production", being characterized "by specific technical, economic, social, political, cultural traditions […]". [20]

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14 e.g. Stolper, Hans. *Bauen in Holz. Blockbau, Fachwerk, Plattenbau und Hallenbau.* Stuttgart, Julius Hoffmann, 1933. – or in particular Pope, Thomas. *A treatise on bridge architecture, in which the superior advantages of the flying pendent lever bridge are fully proved.* New York, Niven, 1811.
15 Steurer, Anton. *Developments in Timber Engineering: The Swiss Contribution*. Basel, Birkhäuser, 2005, pp. 96-102.
16 Birkner, Othmar (see note 7 above), p. 10.
17 e.g. Chopard, Charles. "Die Entwicklung des Ingenieur-Holzbaues in der Schweiz". *Holz und Holzbau. Separat-Abdruck einer Artikelserie aus der „Neuen Zürcher Zeitung"*(17 July 1934), no.1289/1290, pp. 42-47 (particularly p. 42).
18 Kühne, Helmut. "70 Jahre Geleimte Holz-Tragwerke in Der Schweiz". *Schweizer Ingenieur und Architekt*, vol. 97, no. 32-33, 1979.
19 e.g. Büren (see note 7 above), pp. 49-50 or Müller, 2000 (see note 8 above) pp. 45, 67 & 71.
20 For a historical overview and reflection on the major questions that concern this field see: Lorenz, Werner. "From Stories to History, from History to Histories: What Can Construction History Do?". *Construction History*, vol. 21, 2005, pp. 31–42. (citations here can be found on page 35 of this article of W. Lorenz).

This dissertation has proceeded on the basis of the Actor-Network Theory, by mapping reciprocal relations between glulam and those involved in its development.[21]

In this project, the actors, namely the individuals, the institutions, and the nation-states are themselves understood as historical and cultural constructs, and not as given facts. The professionals, the institutions, and as well the states, do not arise in a vacuum, there are themselves the historical constructs, whose constitutions always challenge, take up and, to varying degrees, supress earlier power structures.[22] In this research, this perspective towards the actor was necessary in order to approach the question of why the early glulam appeared in Germany and consequently in Switzerland, and not elsewhere.[23]

The technology as well, through its own attributes and properties, does affect its builders and users. Therefore, it is indeed an actor. For example, the materiality of glulam could bring up solutions for the unsettled relationship between those involved parties in the carpentry trade, mainly the master carpenters, the workers, the general contractors, the engineers, the employer, and trade associations, who suffered from an unbalanced dynamic.

The thesis is structured in a way, that each chapter opens a perspective towards the reciprocal relationship between all the mentioned actors, including glulam.

Moreover, in order to understand the transformation of glulam itself, a case study approach is adopted. To do this, an inventory of the glulam structures built in Switzerland during the period 1909-1939 whose data was recorded in the primary and secondary sources, was listed. 261 projects could be found during this research. For some of them, only the function and very approximate location (name of the city) could be identified, and for some others, rich archival documents exist. It should be noted that this inventory is by no means exhaustive. Terner and Chopard claimed that only from 1909 to 1917 alone, they had constructed around 200 glulam projects.[24] Moreover, it's difficult to accurately assess the significance of the early glulam market due to, in some cases, the use of one single plan for multiple projects. For example, the project for an aeroplane hangar in Dübendorf built in 1917 has been used as a model for 20 structures ordered for military use. There are several examples of these

[21] To get an insight in this theory, see Latour, Bruno. *Science in Action: How to Follow Scientists and Engineers Through Society*. Cambridge, Harvard University Press, 1987. In a broader context, in this thesis I was influenced as well by the concept of technical indeterminacy and the approach termed "social construction of technology". In this regard, particularly illuminating book has been: Bijker, Wiebe E. *Of bicycles, bakelites, and bulbs : toward a theory of sociotechnical change*. Cambridge (Mass.), MIT Press, 1999 (originally published in 1995).

[22] For this approach to the actors, which particularly influenced the first chapter of my thesis, I was mainly influenced by Scott, W. Richard. *Institutions and Organizations: Ideas and Interests*. Thousand Oaks (etc.), Sage Publications Inc., 2007 (originally published in 1995). – and several publications by John W. Meyer (prof. emeritus, Stanford University), mainly: Meyer, John W., and Ronald L. Jepperson. "The "Actors" of Modern Society: The Cultural Construction of Social Agency". *Sociological Theory*, vol. 18, no. 1, 2000, pp. 100–120. – Meyer, John W. "The Effects of Education as an Institution". *American Journal of Sociology*, vol. 83, no. 1, 1977, pp. 55-77. – Meyer, John W., and Richard Rubinson. "Education and Political Development". *Review of Research in Education*, vol. 3, 1975, pp. 134-162.

[23] The awareness about institutional conditions operating in wider social systems that resulted in a comparative study between Germany and Switzerland in this dissertation, was mainly influenced by Strang, David, and John W. Meyer. "Institutional Conditions for Diffusion". *Theory and Society*, vol. 22, no. 4, 1993, pp. 487-511.

[24] *Schweiz. A. -G. für Hetzer'sche Holzbaiweisen*, catalogue. Zurich, Fachschriften- Verlag und Buchdruckerei A.G., 1917.

kinds of projects, where several buildings have been erected based on one single plan, without leaving any record of the number, function, and location of these buildings. The inventory of the 261 glulam projects, however, gave enough material to have an overview of the most significant projects, their clients, contractors, etc., and to follow the design and construction development of early glulam projects.

A word should also be said about the comparative nature of this study. Since the contribution of Switzerland to the early development of glulam is investigated in this project, and it is aimed at demonstrating how technology can contain cultural and political properties, a comparative method is therefore adopted in order to highlight the particularities of the Swiss approach. Moreover, given the context of the very early glulam (until the end of World War I), where Germany and Switzerland were almost the only contributors, as well as the developments of glue in the 1930s, where again these two countries played a pioneering role in Europe, the comparison throughout the thesis is carried out between these two countries.

Structure

This thesis sets out topics and perspectives of how the introduction and application of glulam were woven into a politico-economic, cultural, and technological complex of Switzerland in the early decades of the 20th century. Based on these different perspectives, this thesis is structured into five chapters.

Chapter 1

In order to avoid basing this dissertation on abstract personages called "actors" and their capacities as "agency", and before studying the perspectives and actions of the actors, this research studies the actions, debates, lobbying efforts, power constellations, and collective agreements that gave this authority to the actors to influence and shape the course of society. This first chapter, therefore, decodes the historical construct of the actors. Glulam was introduced in a rather dynamic context where the individual-professionals, institutions, and nation-states were to re-establish their interactions.

This chapter is the core part of the dissertation that deals with the question that why glulam technology appeared and developed in the particular context of Germany-Switzerland in the early 20th century. Here the arguments are concerned mainly with the "engineering" aspect of glulam and explain how this attribute challenged the former knowledge-power-authority constellations.

Chapter 2

The adoption and diffusion of technologies are never frictionless. How to manage the friction between the involved (both interested and affected parties) in the course of the development and diffusion of a technology? Chapter two approaches this question, by analyzing and comparing the specific ways of the organization of the production and the market of early glulam, in Germany, and in Switzerland, with a particular emphasis on the role of the early Swiss glulam consortium. This study enables us to discuss how the new technology rebalanced the unsettled relationship between the carpenter-contractors, the general contractors, and the workers, including the relevant institutions and associations.

Chapter 3

Chapter three opens up a new perspective towards a particular Swiss way of business networking, often identified by the cumulated roles of elites in different circles of business, politics, and the military. This specific Swiss way of business networking, effective particularly during the first half of the 20th century, influenced the rapid take-up of glulam technology by the industry. To demonstrate this, the members of the early Swiss glulam consortium as a "cartel of elites" are studied in this chapter. Going beyond the role of the individual, the case study of the SBB demonstrates that on an institutional level, adopting multiple roles had a crucial influence on the rapid and steady development of glulam in Switzerland.

Chapter 4

Chapter four changes gear by analyzing an episode of very early glulam, in which the development of the technology on a technical level is discussed, and the influence of these early steps on shaping our contemporary design of glulam is demonstrated. The principal questions here are about the models used and the references for the structural design of glulam: what was the influence of the design practice of other industrial building materials such as steel and reinforced concrete? How decisions were made to determine relevant construction details such as component shapes, connections, assembly, and erection process of the structures?

This chapter discusses the role of different involved parties in the early development of glulam's construction culture in Switzerland, as well as the influence of the technical knowledge of other construction materials on glulam. Based on case studies, it is shown how glulam structures have been developed and built from the early concept phase. To do so, possible alternative construction concepts, design methods, tendering, and detailed technical planning for construction processes on site will be discussed, and it will be described how a technical and architectural practice was established and cultivated during the first years.

Although in a broader perspective, the organization of the design of early glulam in both Germany and Switzerland is discussed and compared, the case studies are however exclusively selected among the Swiss projects. One of the principal reasons for limiting the case studies to Switzerland is that this chapter is particularly based on archival documents, and since in this dissertation there was access only to the Swiss archives, therefore the focus will be placed on the early Swiss glulam design. Using original documents from local and national archives together with information such as technical reports from the building's lifetime and in-situ observations, both planning and construction processes as well as the performance of these structures but also the entanglement of the involved parties will be determined. This chapter will provide a profound understanding of the first glulam buildings and their practices allowing a better understanding of the implicit construction philosophy we are using today.

Chapter 5

The last chapter is centred on glue, and offers a series of episodes of the role and the significance of early glue, in nominating glulam as the engineered timber of the 20th century for large-scale constructions. The principal argument is then concerned with the role that glue played to ensure that glulam evolve in line with shifting technological paradigms of the first half of the 20th century. It is demonstrated as well how the criteria that pushed the development of glulam in those decades, were, in the last decades of the 20th century, questioning its legitimacy, by rethinking the relations between humans, nature, and the role of engineering and technology.
This chapter gives us the opportunity to have a look at the contemporary practices of glulam, and to question as well the standard positivist narratives of technical progress that pose glulam as an ever-performant material, to achieve ever-stronger structural spans.

Research scope

There were two main criteria involved in defining the scope of this research: first, the research questions, and second, the available archival records.

Several topics, such as a more detailed study of all the problems of decays, delamination, checking, etc., that occurred with the early glulam structures,[25] deeper analysis of today's approaches towards the development of glulam, assessing the significance of the contribution of Switzerland to the development of this technology today, a detailed comparative study of the organization of the market and the supporting network of the technology of glulam and other structural materials like steel and concrete at the first half of the 20th century, despite being interesting questions, have been excluded from this research to keep the focus on the research's principal questions. Besides, there are some other topics that have been discarded due to the unavailability of archival records. Questions such as the detailed organization of the construction site and the carpentry workshop and a comparison between the approaches of the different contractors in this regard, the study of the tools and machinery used in the workshops and on the construction sites and their developments during the early years, assessing the impact of the background of the contractors on the development of glulam within their projects, the economic background of the early glulam consortium and the contractors, detailed study of the role of the actors involved in wood supply, the wood types, etc., are all important questions that have been discarded in this research because the archival documents discussing these topics are unfortunately not available. The early glulam consortium's archives have not been preserved. Two of

[25] A part of this category of research is mentioned in chapter five that is focused on the early glue and its problems. There are also some case studies that investigate the actual performance of early glulam structures. For an example of these studies based on a detailed survey of the building see: Maissen, Manuel et al. "Pioniergeist und Optimismus: Die Hetzer-Dachkonstruktion der Reithalle von St. Moritz". *Bündner Monatsblatt,* vol. 4, 2019, pp. 355-374.

the contractors' company archives were of most interest for this research, since those contractors were master-carpenter contractors whose workshops' main activity was glulam construction. They were as well on the board of directors of the glulam consortium: Zöllig in Arbon and Bugnion in Lausanne. Zöllig left a rich archive of his projects in the State Archives of Thurgau. However, those materials recording his early projects until ca. 1912, and of most interest to this research, were heavily infested with mould due to water damage. Those records were therefore disposed of and do not exist anymore. Regarding Bugnion, after its bankruptcy in 1922 and following the suicide of the owner, the company was sold in an auction to the construction company Dupont & Desarzens, who did not keep the archives of Bugnion. Gribi's company was taken over by Roth AG, which didn't keep the archives of the early projects of Gribi either. Regarding the general contractors, as discussed in chapter three, glulam was not the main domain of activity of their companies, and therefore very few materials were preserved from the early glulam projects. Therefore, archival records that could have illustrated early glulam workshop life, the work process, etc., are almost non-existing.

Since an important part of the early glulam projects was commissioned by the government (at different municipal, cantonal, and federal levels), as well as by the Swiss Federal Railways, a significant part of the documents of early glulam projects was archived by these institutions and constitute an important primary source for this dissertation.

Chapter one

Engineered timber

the German-Swiss path to survival

1. A promising perspective

Frequent reports on the strikes of the carpentry workers at the turn of the 20th century occurring in different Swiss cities, such as Zurich, Lausanne, Bern, Arbon, and St Gallen[1], together with regular articles illustrating the unfortunate professional situation of the master carpenters due to the increasing lack of interest of the building industry for the use of structural timber, depict a situation of constant tension in this branch of the building trade; a situation leading, as the timber industry described it, to a "certain ruin" of this trade.[2]

At the beginning of the 20th century, the timber construction sector was once again under pressure,[3] after first iron and then steel had increasingly replaced the use of wood for structures in the previous century. Then the influence of reinforced concrete grew, and it quickly became widespread in Switzerland. For large-span constructions, timber construction was mainly dependent on large-sized timber, which was often very expensive. Also, due to the strong increase in paper production as well as electricity and telegraph poles, timber prices had risen steadily for which the use of wood in the construction sector was held particularly responsible.[4]

This context, particularly in Germany, gave birth to a market animated by different patented construction systems promising new and more economical use of timber for large-span structures. The forces that wanted to make timber construction competitive again through innovation were increasingly making themselves heard. Among those new construction systems, there was one that drew the particular attention of the Swiss timber industry, by promising a technology that could save this industry by giving an overall solution to all the mentioned challenges.

In March 1908 a new technology got promoted in an article published in the renowned *Schweizer Handwerker-Zeitung* (Swiss Craftsmen's Magazine) that, as it was praised, was going to "inject new life into the old timber building methods". A new timber construction system, whose erection process, as claimed, would take place "in fewer days and with the help of fewer carpenters" than usual timber structures, allowing to "save the carpentry trade a lot of work", and to open up a new field for the use

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[1] The mentioned strikes are dated respectively 1886, 18889, 1903, 1906. For a complete chronology of the strikes of the carpentry workers in Switzerland see Vuattolo, August. *Geschichte Des Schweizerischen Bau- Und Holzarbeiterverbandes 1873 - 1953*. Zurich, Genossenschaftsdruckerei, 1953.

[2] Ragaz -Pfeiffer, Felix. "Verhältnis-Kostenausstellung von Neubauten". *Illustrierte Schweizerische Handwerker-Zeitung*, vol. 25, no. 13, 1909, pp. 201–206. Citation on page 201.

[3] The reasons of which will be discussed in the third chapter.

[4] Moreover, timber was experiencing a gradual replacement by steel and concrete even for small-scale urban constructions and housing. The arguments against timber were mainly based on its ever-increasing prices, which would have resulted, as it was claimed, in the escalation of the total cost of new buildings. The Swiss timber industry association published articles with thorough analysis and comparison of total cost of buildings with different materials, mainly timber, steel and concrete in order to prove that the share of timber in the higher prices is relatively low. For examples, see "Schweizerischer Holzindustrie-Verein". *Illustrierte schweizerische Handwerker-Zeitung, Meisterschaft aller Handwerke und Gewerbe*, vol. 25, no. 13, 1909, p. 204.

of wood for building purposes, which was previously "reserved exclusively for iron, stone, and reinforced concrete construction." This new technology, Hetzer or glulam construction, was to have a crucial influence on the future of timber construction. It was mainly celebrated as a breakthrough to modern timber architecture, where "buildings in all fields could make use of [it, being] cheaper [than other structural materials] with the same load-bearing capacity". [5] This was how glulam was framed and advertised for the Swiss carpenters by Geissler, a German government architect and master builder. [6]

In 1906 Otto Hetzer, the German Grand-Ducal master carpenter from Weimar applied for a patent at the Imperial Patent Office in Berlin, to which, today the glued laminated construction method is attributed. His patent claim read as follows:

> bent wooden structural member consisting of two or more bent long wooden strips, which lie against each other over their entire length and are connected to each other by a bonding agent which is not soluble in moisture.[7]

The following drawing was attached to this explanatory text (Fig. 1). These industrially produced, glue-laminated elements have been used for larger spans since they could be fabricated in theoretically unlimited sizes bringing larger and customized cross-sections and longer components to the building market. The Swiss carpenters showed an early collective favorable attitude towards glulam technology.

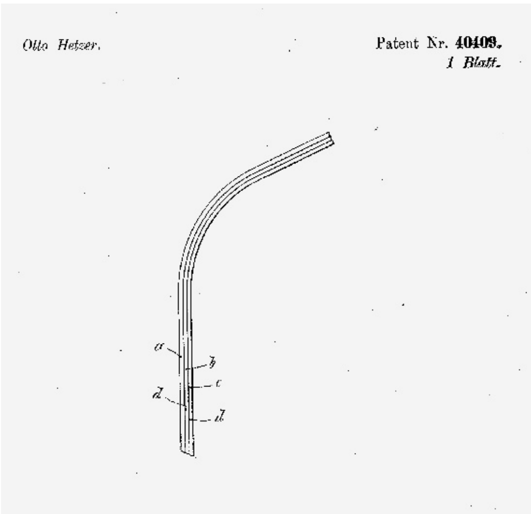

Fig. 1 Illustration in the patent of Otto Hetzer, no. 40409, 1907

[5] Geissler, Franz. "Eine neue Holzbauweise". *Illustrierte Schweizerische Handwerker-Zeitung*, vol. 23, no. 52, 1907, pp. 848-850.
[6] Franz Geissler was one of the key and leading figures of the propaganda of timber in the late 1910s and early 1920s in Germany.
[7] Translated by the author. Original text in the patent registered in Switzerland reads: "Gebogener Holz-Baukonstruktionsteil, gekennzeichnet durch zwei oder mehrere gebogene Langholzstäbe, die auf ihrer ganzen Länge aneinander liegen und durch ein in Feuchtigkeit nicht lösliches Bindemittel miteinander verbunden sind.". Hetzer, Otto. *Gebogener Holz-Baukonstruktionsteil.* Patent no. 40409, Eidgen. Amt für geistiges Eigentum, effective filling date: 13.06.1907.

Although the timber industry was indeed under pressure, and glulam appeared to be advantageous on various levels, it was soon realized that the organization and marketing of the glulam technology needed to be carried out in such a way as to shift its image away from bulky conventional timber structures and to make it more competitive with modern materials such as steel and reinforced concrete.[8] Although thanks to its advantageous cost in comparison to those materials, glulam appeared principally an evident choice to the clients, it was however perceived as timber, a questionable choice for engineering purposes. The early publications on early glulam demonstrate that the new technology, from the beginning on, was not considered as just one among many other patented timber structures, giving rise to some dispersed projects here and there, but in a larger perspective, it was aimed to raise the status of structural timber on a national scale. This outlook, as will be demonstrated in the following sections, played an important role in the way the technology was transferred to Switzerland and brought timber construction, which had remained stagnant since the middle of the 19th century, back to the forefront of development.

2. Transfer of the technology and the role of the engineers

After acquiring the exclusive right to exploit the glulam patent in Switzerland in 1909, the Zurich-based engineers Bernhard Terner (1875-1960) and Charles Chopard (1879-1954), in collaboration with some prominent contractors in timber construction, substantially developed the Swiss path of glulam construction in the early years of their practice as civil engineers.[9]

Born in 1875 in Romania, Bernhard Terner came to Zurich to enroll at the Federal Polytechnic School. Terner completed his studies with a thesis in hydraulic engineering under the supervision of Karl Emil Hilgard and obtained a diploma as an engineer in 1902. His first practical work led him for several years in the field of railway and road construction, before becoming a chief engineer managing the construction of a part of the Bernina Railway. He subsequently went to Bavaria to collaborate in constructing the Wendelstein Railway, where he met his future colleague Charles Chopard.

Born in 1879 and raised in Moutier in the Bernese Jura, Charles Chopard attended the Federal Polytechnic School of Zurich from 1899 to 1903, where Carl Culmann, Wilhelm Ritter, and Ludwig von Tetmajer were among his teachers.[10] Afterward, he started working for the company of Von Roll

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[8] The sceptical attitude of that time towards structural timber, will be discussed later in this chapter. Glulam changed this perception. Giedion, for instance, mentions in 1943 “curved laminated wooden arches”, beside light metal structures as modern materials. Giedion, Sigfried. A*rchtiecture, you and me: the dairy of a development*. Massachusetts, Harvard University Press, 1958. P. 50. (First publication in 1943)

[9] Some sources mention that already before Hetzer’s patent a glulam structure had existed in Switzerland: “the first recorded use of glued laminated arches occurred in 1893 in Basel”. MCnall Andrew, and David Fischetti, “Glued-laminated timber”. *Twentieth-Century Building Materials: History and Conservation,* edited by Thomas C. Jester. Los Angeles, Getty Conservation Institute, 2014, p. 105. However, no primary source proved this claim. In an article, most possibly written by Terner & Chopard, the Swiss Singers' Festival is mentioned to be constructed in Basel in 1893, “the festival hall erected for the occasion aroused general admiration because of its large-span wooden trusses with a span of about 40 meters”. However, it has been a Stephan system, and not glulam. Terner and Chopard do not mention any prior glulam project to their own works. See: “Die Hetzersche Holzbauweise”. *Schweizerische Bauzeitung*, vol. 57/58, no. 16, p. 214.

[10] Information based on the matriculation register of Charles Chopard, student at the ETH Zürich in 1899-1903.

Ironworks in Canton Bern, which was followed by his one-year work for the Gustavsburg bridge construction company in Germany. Then he returned to Switzerland to work in the SBB bridge construction office in Basel. In 1905 he joined the Bavarian bridge construction office for the project of the Wendelstein railways, where he collaborated with Bernhard Terner, with whom he founded an engineering office in Zurich in March 1909, specializing in reinforced concrete structures. Their projects include, among others, the Hotel Bellevue Palace in Bern, the railway station in St Gallen, a road bridge near Eglisau, and the national library in Bern. They collaborated with prominent architects of the time such as Le Corbusier for different projects, including the Cinema Scala in La Chaux-de-Fonds in 1916 for its glulam structure and the concrete structure of the Palais des Nations in Geneva in 1926.[11] In the 1920s Terner & Chopard engineering firm reached its climax through its participation in competitions for bridges and buildings, for which it was often awarded first prizes. The firm was dissolved in 1933. Afterward, Chopard continued the office under his name, and from 1935, Bernhard Terner devoted himself to the establishment of the young state of Israel, as he had founded the company B. & L. Terner engineers in Haifa, together with his son, Leopold, who was also a graduate engineer from the ETH Zurich.[12] Bernhard Terner was active there until his death in 1960.

Chopard is particularly noteworthy among other reasons, for regularly publishing reports in technical and general journals about the development of Swiss Glulam. He worked with organizations such as SBB and EMPA to perform tests on Glulam structures and kept both technical and general audiences updated on the latest developments of Glulam. Additionally, Chopard was one of three representatives from the building industry who served on a committee assigned by SIA to establish building codes for timber construction in 1925.[13] Being bilingual, both French and German speaking, he organized as well the communication within the early glulam licensed contractors, but also with the institutions and authorities of different parts of the country. Chopard passed away in 1954 after a short period of illness.

The fact that their professional experience until the establishment of their engineering office in Zurich has not particularly been marked by timber structures, is not surprising, since in their academic background, timber as a structural material was not developed as such either.

During their studies at ETH Zurich, timber structures rarely appeared in their curriculum, the latter being mainly dominated by reinforced concrete and steel structure. Their academic background in structural timber was basically shaped by the course *Brückenbau* (Bridge Construction) taught by Professor Ritter. During a three-month trip to the United States in 1893, Ritter studied American bridges and used the result of these investigations for developing the essential material for teaching

[11] The project of the cinema la Scala will be discussed in the third chapter. The project of the palais des Nations was never materialized.
[12] This engineering office initially dealt with the project planning and execution of public buildings, but later worked as a representative office for well-known Swiss companies in the machinery and instrument industry.
[13] This subject will be discussed in the fifth chapter.

timber bridge structures at ETH Zurich.[14] In addition to more traditional truss structures (Fig. 2), the structures where timber was treated in a subordinate manner, such as formwork for concrete bridges, and the truss bridges such as Howe, Pratt, and so on, Ritter included one example of a mechanically laminated bridge near Paris (Fig. 3).

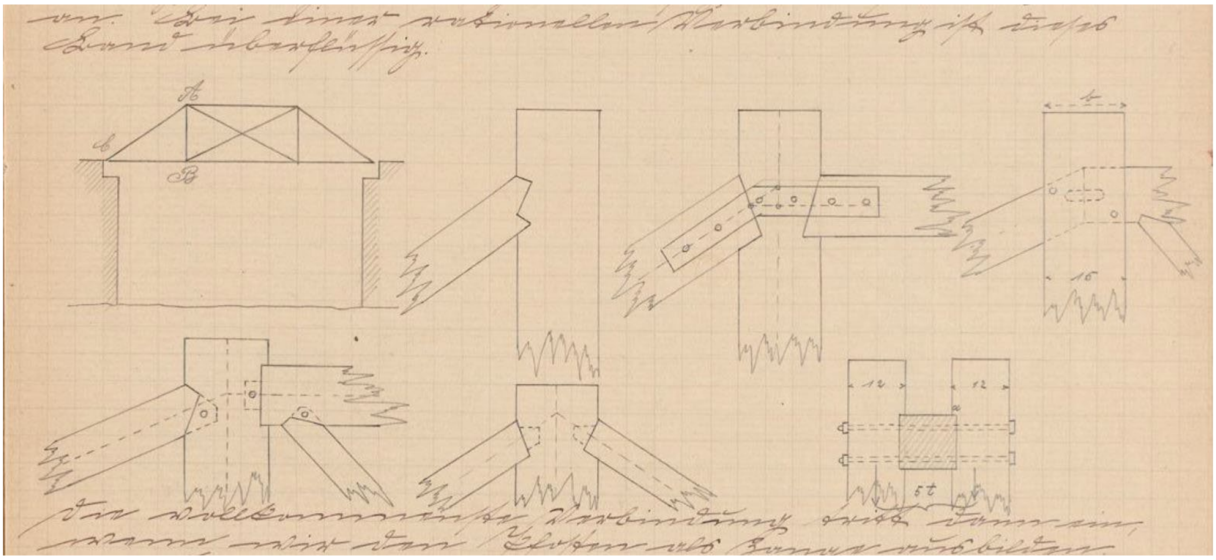

Fig. 2 Different joints of a timber footbridge. Studied in the course "Bridge Construction" by Professor Ritter. Notebook of student Carl Gruber, 1897, p. 52.

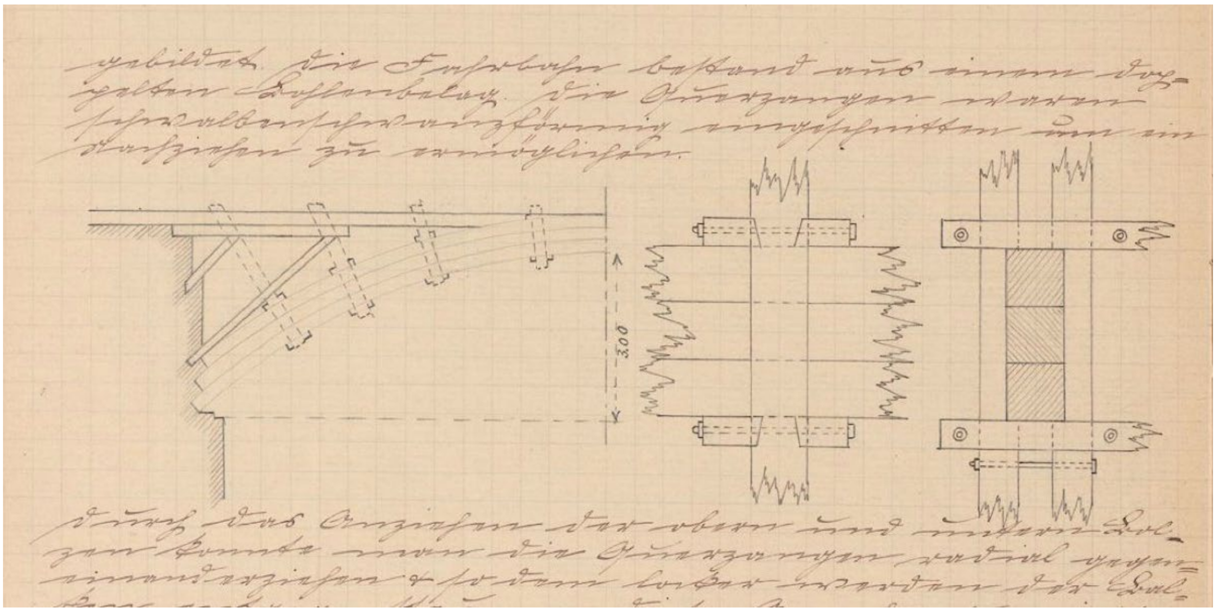

Fig. 3 Example of the mechanically laminated bridge studied in the course "Bridge Construction" by Professor Ritter. Notebook of student Carl Gruber, 1897, p. 67.

Interestingly, the course *Technologie der Baumaterialen I & II* (Technology of Building Materials I & II), taught by Professor Tetmajer, was entirely focused on reinforced concrete and steel, on the material characteristics and their production and fabrication technologies, with no trace of timber as a

[14] Based on this trip, he also published the book: Ritter, Wilhelm. *Der Brückenbau in den Vereinigten Staaten Amerikas: (Berichte der schweizerischen Delegierten von der Weltausstellung in Chicago 1893)*. Zürich, A. Raustein, 1895.

structural material in the cursus, whereas from 1883 to 1896, Tetmajer had been performing tests at the EMPA on buckling strength of construction timber and characteristics of Swiss structural timber. The little background of Terner and Chopard in timber construction, both at the academic level and at their professional working experience gives rise to questions about the interest of the young engineers, in an immature technology that persuaded them to economically invest in the patent and its exclusive right for the whole country, parallel to founding their engineering firm. Although at that time, Otto Hetzer's company had a very successful career in wood processing and parqueting, his new technology, glulam, was in its very early stages, where only very few and not yet widely recognized glulam structures were erected in Germany.[15]
It can, however, be supposed that at the time that Terner and Chopard were jointly working for the Wendelstein Railway in Bavaria, they could have been exposed to glulam, through a project that was known as the first glulam monument introducing this technology to the international public at the Brussels International Exhibition of 1910.

The construction of the Wendelstein Railway was in fact the vision of Otto von Steinbeis, a German entrepreneur and industrial pioneer, who was involved in forestry and agriculture in the Bavarian Alps as well as logging of fir and spruce wood in the Balkans on a grand scale.[16] His company, Otto Steinbeis & Co. sawmill was contracted for the execution of the glulam structure for the pavilion of the German Imperial Railway, standing at the World Fair of Brussels, inaugurated in September 1910, which could have probably whetted the interest of the young engineers in glulam. Although at the time of the fabrication of the glulam girders, the young engineers were back in Switzerland, they, however, continued to collaborate with the Steinbeis company for the construction of the Bernina Railway. The structure of the German Railway hall (Fig. 4), with a span of 43 meters, the result of the collaboration of Peter Behrens from Berlin, as the architect of the project, and Hermann Kügler from Munich, the engineer, could have convinced the young Swiss engineer about the promising future and market of this technology and they could have imaginably been exposed even to the process of fabrication of glulam girders, in the Steinbeis sawmill.

[15] In this website otto-hetzer.de, 4 building are listed as built before the Swiss glulam exploitation right was granted to Terner and Chopard. 1. Sports hall in Celle, 2. Workshop of Otto Hetzer in Weimar, 3. Roof of the Natural History Museum in Altenburg, and 4. the Imperial Sports hall, all built in 1907. The mentioned website is founded by the engineer office Rug GmbH, headed by Prof. Dr. Eng. Wolfgung Rug, whose one of his main research's interest is the early engineered timber structures in Germany. The early publications promoting glulam in 1909, do not refer to other examples, except these 4 ones.
[16] For the biography see *Neue deutsche Biographie*, online version, under the name "Steinbeis". See as well, Berdan, Helga. *Die Machtpolitik Österreich-Ungarns und der Eisenbahnbau in Bosnien-Herzegowina 1872 – 1914.* Master thesis, University of Vienna, 2008, pp. 62-63.

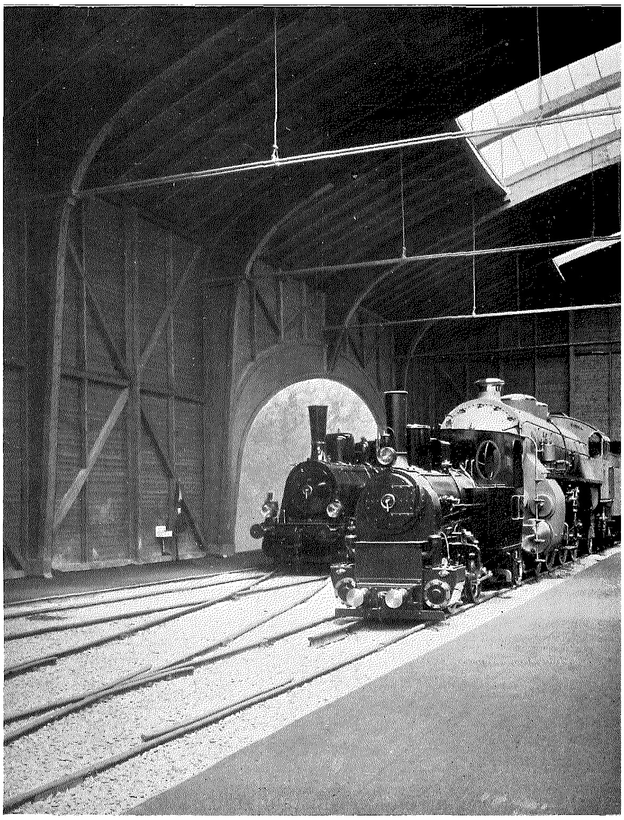

Fig. 4 Brussels International Exposition, 1910: Germany's Railways Pavilion. Collaboration of Otto Hetzer, Architect Peter Behrens, Engineer Hermann Kügler, and Otto Steinbeis & Co sawmill for the execution of the glulam girders

It should however be noted that beyond the evident fact of the existence of local timber resources in the country, the chemical industry which produced glue was then already a well-established and innovative industry with a strong foundation,[17] on which the engineers could rely for the production and further development of the glue. Moreover, it should also be pointed out that the glulam technology did not actually require heavy capital in order to equip the workshops for the purpose of manufacturing glulam. The raw materials were native: both timber and glue. The tacit knowledge of timber craftsmanship had also a rich and long tradition in Switzerland. Necessary, these were however not sufficient conditions to explain the interest and anticipation of the young engineers for the successful implementation and development of the technology.

Despite all this, it is clear that the pure explicit knowledge, in this case, the descriptive patent, has been by no means sufficient to ensure the development of such a craft-based technology.[18] The tacit knowledge has for sure been a determining factor. As Norwegian glulam pioneer Guttorm Brekke (1885–1980), and the patent holder of glulam for Norway and Sweden explains, the purchase of a patent for Glulam technology came with additional benefits. Research done on the archival records of

[17] Tanner, Jakob. "The Swiss Pharmaceutical Industry: The Impact of Industrial Property Rights and Trust in the Laboratory, 1907–1939." *Determinants in the Evolution of the European Chemical Industry, 1900–1939: New Technologies, Political Frameworks, Markets, and Companies*, edited by Anthony Travis et al., Dordrecht, Springer, 1998, pp. 257–271.

[18] In the fourth and the fifth chapter it will be explained why this technology in the first three decades was essentially craft-based.

Brekke by Miryam Rusak shows that the patent included a two-month training course at the Hetzer AG factory in Weimar and comprehensive technical instructions covering all aspects of production. Additionally, while transferring the patent, the recipe for the glue used in the production of Glulam was as well given to the purchaser. The training and technical instructions were meant to ensure that the licensees had the knowledge and resources needed to effectively produce Glulam structures.[19]
A brief comparison between the situation of the transfer of technology in Switzerland to that of other countries from which the data is available reveals some significant differences between the Swiss and other countries, which could help to better understand the particularities of the early Swiss glulam. Hetzer claimed in 1913, that his glulam technology had been patented in 19 countries.[20] In Germany, eight other master carpenters were licensed to use patented glulam. In Austria, the patent was transferred in 1912 to two master carpenters, however, no data about the existence of any early glulam structure there has been recorded.[21] In France, until the Post-War period, no local market was developed based on this patent.[22] For the Italian territories, a Swiss engineer, Emil Burkhard from Zurich who graduated from ETH, had the patent. The patent was transferred to Burkhard at the time he was working for a few years in Milan. Later on, however, he returned to Switzerland and collaborated with Terner and Chopard for developing Swiss glulam. The Market of Italy remained hence undeveloped. In the Scandinavian region, until the end of the First World War, it was merely in Denmark that glulam took some timid steps into the building market, which could, however, not eventually go beyond the limit of a few dispersed projects.[23] In Norway, glulam production started only in 1918, by the Norwegian Brekke who had bought the patent for the use of glulam in Norway, Sweden, "North Russia south to Vilna" and the United States of America, but he exploited the patent only in Norway and Sweden. The first phase of glulam in these two countries was relatively short, from 1918 to 1925, and the technology was re-introduced in the mid-1950s to Norway from the United States.[24] In the period 1909-1917, before glulam production got started in those countries, in

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[19] Cited in Rusak, Maryia. "Wooden churches, managers and Fulbright scholars: Glued laminated timber in 1950's Norway". *History of Construction Cultures, Proceedings of the 7th International Congress on Construction History (7ICCH 2021), July 12-16, 2021,* edited by ascarenhas-Mateus and Paula Pires, Lisbon, Portugal. Taylor & Francis, 2021, pp. 753-742. Rusak consulted the following archival document: Brekke, Guttorm. *Glued laminated timber for the build ing industry*, Report no.2. Industrikomitéen i New York, S-2079/E/Eb/L0034, Box 0010, Folder 0001-C-111r. Rik-sarkivet, Oslo, Norway.

[20] Urban, K. H. *Denkschrift über Hetzer's neue Holzbauweisen, Verfasst im Auftrage des «Schutzverbandes für neue Holzbauweisen».* Weimar, 1913.

[21] Prof. Wolfgung Rug mentions the name of two Austrian master carpenters Josef Lerchbaumer (Klagenfurth), and Georg Otter & Sohn, (Graz), to whome the patent was transferred in 1912. However, no trace of any early glulam structure could be found. Rug, Wolfgang. "100 Jahre Hetzer-Patent." Bautechnik, vol. 83, no. 8, 2006, p. 537.

[22] In Vincennes, a 20 meter-span hall was built by German prisoners after the first world war. Another structure in the Halles district of Paris, has been made almost at the same time, which has been demolished in the 1970s. See: Leloy, Claire. *Histoire du bois lamellé: Le eBook du Centenaire 100 ans de bois lamellé*, https://www.glulam.org/wp-content/uploads/eBookduCentenaire8-Histoire.pdf

[23] "Denmark received its introduction to glued laminated timber in 1914 when H.J. Kornerup-Koch began producing the product under a Hetzer license". Rhude, Andreas Jordahl. "Structural glued laminated timber: History of its origins and early development". *Forest Products Journal,* vol. 46, no. 1, Madison, 1995, p. 1.

[24] Rusak, Maryia. "Wooden churches, managers and Fulbright scholars: Glued laminated timber in 1950's Norway". *History of Construction Cultures, Proceedings of the 7th International Congress on Construction History (7ICCH 2021), July 12-16, 2021,* edited by ascarenhas-Mateus and Paula Pires, Lisbon, Portugal. Taylor & Francis, 2021, p. 736. - Rusak, Mariya. *FACTORY-MADE: the everyday Architeture of Moelven Brug,1955-1973*. PhD dissertation, The Oslo School of Architecture and Design, 2022, p. 46.

Switzerland around 200 glulam structures were constructed, as the early Swiss glulam consortium claimed.[25] In the Netherlands, it was the Dutch company Némaho in the 1920s (which took over some of the employees of the Hetzer companies, after the latter was liquidated in 1926) that worked on the development of glulam.[26] In Belgian, glulam was introduced only in the Post-War period.[27] In America, the technology was transferred through the immigration of Germans in the 1930s.[28] This brief sketch of different countries toward this technology shows that it has been uniquely in Switzerland that they were the engineers, and not craftsmen, who were granted the license to exploit the glulam patent.

At the turn of the 20th century and particularly in Germany, the market of patented timber structures (later called engineered timber structures), developed into a thriving market. The reasons behind the particularities of the German context will be studied at the end of this chapter. However, as Mathias Seraphin explains in his thesis on the origin of timber engineering, this market was quite heterogeneous, with the actors with different backgrounds and starting points applying for patents or the license of the patents of others, ranging from the carpenters, general contractors, engineers, to the government builders, politicians, etc.[29] Regarding the representatives for the technical part, however, a shift from carpenters to engineers can be observed. Although these new products were more and more promoted as engineered products, it can nevertheless be demonstrated that the supporting network of this technology, or the "capacities embodied in hardware or in the skills and knowledge of its builders and practitioners", was headed by the craftsmen, and not the engineers.[30]

This gradual transition of the attribution of the technology, from craftsmen to engineers, as Eric Schatzberg explains in his book on the history of the concept of technology, implies a crucial shift in the reorganization of the network of technology:

> the key role of *Technik* among engineers became clear with the founding of the first pan-German engineering organization, the Verein Deutscher Ingenieure (VDI). In the original 1856 constitution, the VDI defined its principal goal as the advancement of German Technik rather than the promotion of engineers' interests. The organization defined membership almost completely in terms of Technik, with ordinary membership open to practicing Techniker, teachers of Technik or technical sciences, and finally owners and managers of technical establishments. Engineers became so identified with Technik that most German-English dictionaries in the twentieth century gave "engineering" as one translation of Technik.[31]

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[25] *Schweiz. A-G für Hetzersche Holzbauweisen Zürich*. Fachschriften- Verlag und Buchdruckerei A. G. Zürich, 1917.
[26] Leloy, Claire. *Histoire du bois lamellé: Le eBook du Centenaire 100 ans de bois lamellé*, https://www.glulam.org/wp-content/uploads/eBookduCentenaire8-Histoire.pdf
[27] Devos, Rika, and Fredie Floré. "Modern Wood. De Coene at Expo 58." *Construction History*. Cambridge, The Construction History Society vol. 24, 2009, pp. 103–20.
[28] Müller, Christian. Die Entwicklung des Holzleimbaues unter besonder Berücksichtigung der Erfindungen Otto Hetzer- ein Beitrag zu Geschichte der Bautechnik. PhD dissertation, Bauhaus-Universität Weimar, 1998, pp. 76-78.
[29] Seraphin, Mathias. *Zur Entstehung des Ingenieurholzbaus - eine Entwicklungsgeschichte*. PhD dissertation, Technical University of Munich, 2003, p. 252.
[30] "the expression "technological support network" is meant to include many technical capacities of a given society, capacities embodied in hardware or in the skills and knowledge of its people". So, a given dimension of technical capacity is a necessary condition for the emergence of a new technology. Staudenmaier, John M. *Technology's Storytellers: Reweaving the Human Fabric*. Cambridge, Mass. [etc.]: MIT Press, 1989, p. 61.
[31] Schatzberg, Eric. *Technology: Critical History of a Concept*. Chicago, University of Chicago Press, 2018, p. 104.

Schatzberg's interesting remark could eventually lead us to formulate the hypothesis that it might have been a network of carpenters in Switzerland who possibly lobbied for adopting and promoting this new technology and then they assigned figures from the engineering world as the head of an organization to raise the status of glulam from a craft-based material to an engineered material and to develop easier its market. The profession of the engineer has been linked with technical rationality, and this has been specifically the area where natural timber as a structural material has been suffering, as we will see in the following section. Therefore, the Swiss glulam supporting network being headed by engineers arguably influenced and accelerated the early broad acceptance, diffusion, and development of the technology.

In the lack of archival records regarding the early figures pushing the adoption of this new technology in Switzerland, it is hardly possible to give a precise answer about the role of different figures of carpenters or engineers in the transfer of the technology and the development of early glulam. It can, however, be argued that without the background support of the well-established carpenters' network in the country, it would be hard to believe that the engineers Terner and Chopard solely decided to invest in the new technology, considering that their background in timber construction can hardly justify such assumptions in favor of the role of the engineers.

It should be noted here that in the process of development of early glulam, engineers, in different levels, roles, and relations to the new technology were involved. In the present chapter, the focus is on the role of the structural engineers Terner and Chopard, who invested in the patent and established the early network of technology in Switzerland, at a time when timber was not an evident choice for structural purposes. The role of other engineers will be discussed in chapters 3 and 5, discussing respectively the role of the SBB and the EMPA. The following section will demonstrate the attitudes toward structural timber when the engineers and the contractors (mainly carpenter-contractors) came together to promote glulam and consequently, structural timber.

3. Disbelief in structural timber

Wood up to the 1700s was the cherished structural material, in most parts of the world. Besides metal and other materials which were used almost in a subordinate manner, timber was used both for building construction and machine making. [32] However, in the second half of the 19th century, and with the fierce competition between steel and reinforced concrete with timber, the latter tried and

[32] For the history of different uses see Evans, F. T. "Wood since the Industrial Revolution: A Strategic Retreat?" *History of Technology*, vol. 7, 1982. pp. 37-55.

tested for centuries, was almost completely driven out of bridge and hall construction, "relegating to the position of a stepchild".[33]

If there were timber bridges of considerable span, one of the main drivers of the material selection – if other alternative materials and local industry for it existed – was the advantageous price of timber, otherwise, the engineers found it "always much more gratifying […] to construct an [stone] arch, or iron bridge, instead of a timber one".[34]

The ready availability and ease of fabrication of wood being within the limits of human power, tools, and force, set the pattern for extensive use by early carpenters. This was not the case for metals, where the extraction, font, and forming were laborious tasks. The centuries-old experiences, supplemented with intuition and craftsmanship, helped the carpenters to build up a vast knowledge and profound expertise about the material characteristics of wood and the methods of application. Wood is a material whose very dimensions are influenced by various factors. The strength of wood varies in relation to the linear cellular structure of the tree, which makes it non-homogeneous. Grain direction, different density growing circles, the position of growth rings, knots, cross-grain, shakes and checking, and so on, makes it non-uniform as well. To this, it should be added that each species of tree has unique properties, which can be considered, "a different alloy".[35] When structural timber, in the course of the 19th century, was progressively considered outdated, and subsequently many carpentry workshops got closed, a large and detailed body of knowledge about wood disappeared as a result. Dealing with vital flaws, twisted fibers, upsets, loose knots, and so on, in essential locations within a structure needed expertise that could be gained usually only through experience. Accordingly, an engineer "who deal[t] with timber only occasionally easily expect[ed] from it too much or too little".[36] Timber was then considered a building material with a "well-worn path that has hardly changed for thousands of years", and could offer no new possibilities to the engineers and the researchers, for whom, as Robert Friedel explains, "the development and adaption of new materials [was considered] as an ordinary and expected aspect of technological progress".[37]

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33 Pantke, C. "Modern Timber Construction" *Mechanical Engineering*, vol. 61, no, 11, 1939, pp. 791-798, p. 791. For the impact of industrialization on the promotion and decline of materials see Hall, A. Rupert. "Engineering and the Scientific Revolution." *Technology and culture,* vol. 3, no. 4, 1961, pp. 333–341.

34 Haskoll, W.D. *Railways in the East*. London, Atchley & Co., 1863, p.129 (as cited in Bill, Nicholas A. "Timber Bridge Construction on British and Irish Railways, 1840-1870: The Scale of Construction and Factors Influencing Material Selection." *Construction history: journal of the Construction History Group, vol. 31, no. 1,* 2016, pp. 75–98. The citation continues "and he will never select the latter material from choice, knowing very well that it involves renewal at some future time".

35 Markwardt, L. Joseph. "Wood as an Engineering Material". *American Society for Testing materials*. The University of Michigan, vol 43, 1943, p. 3.

36 Pantke, C. (see note 33 above), as cited in Haines, Ch.M., *The industrialization of wood: the transformation of a material.* PhD Dissertation, University of Delaware, 1990.

37 First citation: Gehri, Ernst. "Entwicklung des ingenieurmässigen Holzbaus seit Grubenmann. Teil I: 18. und 19. Jahrhundert". *Schweizer Ingenieur und Architekt,* vol. 101, no. 25, pp. 691-696. Second citation: Friedel, Robert. "Some Matters of Substance". *History from Things. Essays on Material Culture*, edited by Steven Lubar and David W. Kingery, Washington, 1993, 41-50, citation in page 48.

The carpentry trade believed that the use of many "patented materials" with almost assured properties developed this view that the construction in wood was "a manner of the barbarians and semi-cultures".[38] The proliferation of patented materials – such as Eternit and other composite materials – which Werner Sombart (1863-1941) saw as a "shift from organic to inorganic", was the characteristic with which Sombart defined the industrial age, in his *Der moderne Kapitalismus (1919)*, as the era of "the emancipation from the limitations of the organic".[39]

These conceptions shaped the idea of a generation of architects and engineers of the early 20th century about structural timber. Quoting a passage from *the aesthetics of the engineer,* co-authored by Le Corbusier in 1913 describes the attitude toward this material:

> The first effects of the industrial revolution in building construction are manifested by this primordial stage: the replacement of natural materials with artificial materials, heterogeneous and doubtful materials by homogeneous artificial materials tested by laboratories and produced with fixed elements. The fixed material must replace the natural and infinitely variable material. […] profiled irons and, more recently, the reinforced cement, are pure manifestations of calculation, using the material completely and exactly, while the old wooden beam perhaps dissembles some betrayal knot, and its hewing leads to a considerable loss of material. [40]

Surprisingly in this context, Le Corbusier, a bold opponent of the structural timber used glulam for the roof structure of the cinema that he designed in 1916 in collaboration with the engineers Terner and Chopard. He defended his choice of material by referring to the engineers who calculated the glulam structures based on the rules and code defined for concrete structures, according to Le Corbusier, a trustable material.[41] The engineers Terner and Chopard believed that glulam eventually brought trust to timber through the "scientific thoroughness" of the design and calculation of the engineers, which resulted in a "general confidence in this modern construction method". [42] In this context, glulam, being considered a product of the engineers, was promoted to the category of modern and science-based structures. Being crowned by technical rationality, glulam was associated more and more with engineers than with craftsmen.

[38] Original text in German: "[…] die Bauweise in Holz sei eine Manier der Barbaren und Halbkulture". Bringmann, August. *Geschichte Der Deutschen Zimmererbewegung*. Hamburg, Schrader, 1909, p. 109.

[39] Sombert, *die deutsche Volkswirschaft im neunzehnten Jahrhundert*. Berlin, Georg Bondi, 1921. Chap. VIII, Die Technik: "Emanzipation von den Schranken des Organischen", p. 142. which goes much further than "Emanzipation von den persönlichen Schranken menschlicher Arbeitskraft" of Karl Max, and states the gradual replacement of not only humans, but every organic by inorganic material.

[40] Original text in French: « *les premiers effets de l'évolution industrielle dans le "bâtiment" se manifestent par cette étape primordial: le remplacement des matériaux naturels par les matériaux artificiels, les matériaux hétérogènes et douteux par les matériaux artificiels homogènes et éprouves par les essais de laboratoire et produits avec les éléments fixes. Le matériau fixe doit remplacer le matériau naturel, variable à l'infini. […] les fers profilés et, plus récemment, le ciment armé, sont de pures manifestations de calcul, employant la matière totalement et exactement, tandis que l'ancienne poutre en bois recèle peut-être quelque nœud traitre et son équarrissage conduit à une perte de matière considérable ».* Le Corbusier-Saugnier, "l'esthétique de l'ingénieur : maison en série" *Nouvelle Esprit,* no. 13, 1921, p. 1530.

[41] This project will be discussed in chapter three.

[42] The introduction of *Schweiz. A-G für Hetzersche Holzbauweisen Zürich*. Fachschriften- Verlag und Buchdruckerei A. G. Zürich, 1917.

However, besides being the engineers' product, glulam was progressively considered an engineered product. What does it mean to be an engineered product, and what is its relation to the role of the engineers in the early development of glulam? The following section will focus on these questions.

4. Glulam, an engineered product

The first descriptive used for defining glulam is "engineered", or being an engineered entity. The Encyclopaedia of Materials defines glulam as an "*engineered stress-rated product produced by face bonding individual lumber laminations, [...] to create a member that can resist expected design stresses*". [43]

As Google Ngram shows, as early as the 1920s the term *Ingenieurholzbau* (engineered timber construction) started to appeared in the German technical literature (Diagram 1.1)

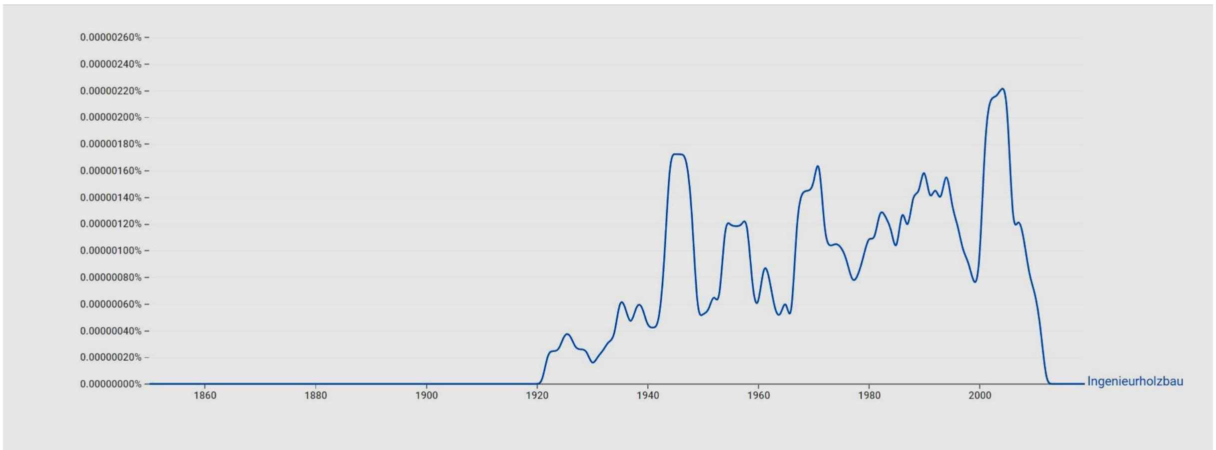

Diagram 1.1 Google Ngram Viewer, diagram of the use of *Ingenieurholzbau* in German literature.

The *Grundlagen des Ingenieurholzbaues* (principles of engineered timber constructions) authored by Hugo Seitz in1925, and the *Holz in Hochbau* (timber in building construction) by engineer Hugo Bronneck published in 1926 serve as examples. In the latter, the author dedicated a chapter to engineered timber structures, however, he did not provide the reader with an explanation of the differences between engineering and carpentry timber structures.[44]

The first attempts for an official demarcation of engineering timber construction from craft ones apparently date back to the 1940s.

Fritz Kress (1884-1962), German master carpenter, technical author, and one of the founders of a series of carpentry schools, a figure whose efforts will be discussed later in this chapter, denied the possibility of a precise delimitation between timber construction by carpenters, from those designed by

[43] Leichti, R. J. "Wood: Lumber and Other Solid Wood Processes" *The Encyclopedia of Materials: Science and Technology,* edited by Buschow, K. H. J, et al., Pergamon Imprint, vol. 10, T-Z, 2001.
[44] Seitz, Hugo. *Grundlagen des Ingenieurholzbaues*. Berlin, Springer, 1925. _ Bronneck, Hugo. *Holz im Hochbau : Ein Neuzeitliches Hilfsbuch für den Entwurf, die Berechnung und Ausführung Zimmermanns- und Ingenieurmässiger Holzwerke im Hochbau*. 1st ed. Vienna, Springer, 1927.

engineers. In the *Holzbau Taschenbuch* (timber construction pocket guide), published in 1948, Kress argued:

> […] the distinguishing feature can be seen in the way the timbers are joined. In carpenter's timber construction, the timbers are joined together in the traditional manner, in engineer's timber construction by nails, dowels, and other special means. Carpentry timber construction is also characterized by the use of traditional timber construction measurements, while engineered timber construction is inconceivable without static calculations of the timbers and their connections. The carpentry timber construction can justifiably point out that its working methods have been tested by centuries of experience and are best adapted to the building material and properties of wood. On the other hand, however, timber engineering has also had a cleansing effect on carpentry in recent decades by eliminating impractical and outdated forms.[45]

As the quotation explains, the question of joint type plays an essential role in the definition of engineered timber structures. The boom of novel timber structures driven by the first world war in Germany got governmental support and shaped the timber propaganda of the early 1920s. In this context, the term "wood engineering", as Mathias Seraphin demonstrates it in his thesis on the origin of timber engineering, generally denoted the commercial application of two joining devices: "timber connectors", and "structural adhesives" distinguishing engineered timber structures from carpentry and joinery structures.[46] In the engineered timber structures, the joints developed eventually in such a way as to form a separate entity from the wooden elements, in comparison to carpentry and joinery where the joint was embedded in the structural member; a construction logic developed within iron and steel structures during the long 19th century, picked up for engineering methods in timber construction. For the efforts of the promoters of mechanical connectors who paid special attention to the type of articulated trusses, metal dowel rings could stand out as the pioneer or an outstanding achievement. Many firms patented variants of dowel rings in Germany,[47] and as well did Terner and Chopard who patented their own variant in 1924 (Fig. 5).

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[45] Kress, Fritz."Zimmermanmässiger Holzbau". *Holzbautaschenbuch*. Berlin, Wilhelm Ernst & Sohn, Berlin, 1948, p. 82. (translated from German by the author).

[46] Seraphin also brings the notion of proto-timber engineering: the early trusses which had combination of steel and timber for different members in tension and compression respectively. "The constructions by Howe and Polonceau in particular clearly identify themselves as engineering constructions based on a number of characteristics: - Clarity of the overall system - Clarity about the stress on the components: pressure, tension or bending, - axial rod connections - systematized knots - articulated nodes, without restraint - Node without cross-section reduction - Members and nodes of a computational - Dimensioning optimization accessible". In this early phase one can therefore speak of a proto-engineering timber construction. (Matthias Seraphin, p. 36. See note 29 above)

[47] Among them the following firms: Carl Tuchscherer in Breslau, Metzke & Greim in Berlin, Dehall in Munchen, Christoph & Unmack in Niesky, Paul Schulz in Berlin. For a wider account of this technology see Matthias Seraphin (see note 45 above), and Geissler, F., et al. *Freitragende Holzbauten*, edited by C. Kersten, Berlin, Springer, 1921. _ Kersten, C. *Freitragende Holzbauten; Ein Lehrbuch Für Schule Und Praxis*. Berlin, Springer, 1926.

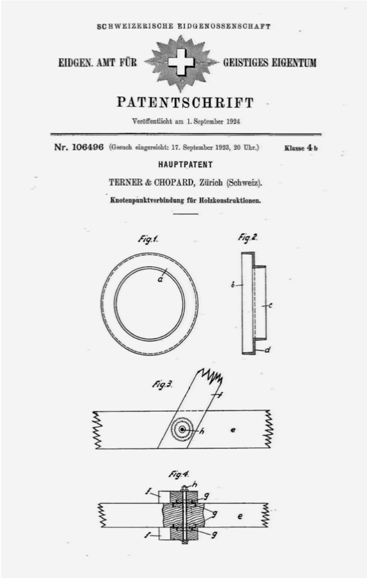
SCHWEIZERISCHE EIDGENOSSENSCHAFT
EIDGEN. AMT FÜR GEISTIGES EIGENTUM
PATENTSCHRIFT
Veröffentlicht am 1. September 1924
Nr. 106496 (Gesuch eingereicht: 17. September 1923, 20 Uhr.) Klasse 4 b
HAUPTPATENT
TERNER & CHOPARD, Zürich (Schweiz).
Knotenpunktverbindung für Holzkonstruktionen.

Fig. 5 Patent granted in 1923 to Terner and Chopard for a step-shaped offset ring dowel.

"Connected" and "glued" structures were extensively used during the second world war building constructions. The use of timber connectors, as Seraphin shows it, declined drastically in the post-war decades and glulam remained until today as the only representative of engineered timber structures.[48]

Among concurrent timber structures, glulam was in fact potentially a suitable candidate to become "the" engineered timber structure. One evident reason is that in glulam structures, by reducing the number of joints to a minimum, in comparison to other novel timber structures, a huge amount of labor during the manufacturing process and assembly was saved, which accelerated the industrialization of the construction process. Another important reason was probably the separation of the joint and the structural member, as we can see in the next chapter, which took place quite early, but also the fact that it brought up the possibility of designing structural elements with longer lengths and formally customized cross-sections. Moreover, all the properties inherent to the natural timber which were considered obstacles to the industrial use of wood discussed earlier in this chapter, were progressively losing their influence on design, since by de-structuring the material, the anisotropy was massively reduced and moreover, the vital flaws could easily be sorted out during the manufacturing process, without any significant waste or vital damage to the raw material.

Having this understanding of glulam as an engineered timber (engineered material that allowed for engineered structures), the question now would be, what novelty in the whole process existed that needed the expertise of the engineers? Could this engineered quality discussed above imply any specific contribution of the engineers to different design and construction processes?

The glulam technology, although having a momentous contribution to the building industry, has been indeed a basic one. It hardly introduced any novelty from a technical point of view. Halls and bridge

[48] Today, large engineered structures, such as industrial halls, sport halls, etc are built almost exclusively from glulam or laminated veneer lumber. Peter, Mandy, and Stefan Winter. *Holzbau-Taschenbuch: Grundlagen.* Newark, Wilhelm Ernst & Sohn Verlag fur Architektur und Technische, 2021, p. 8.

arches and beams composed of layers of timber have been built for hundreds of years (by different means such as interlocking, bolting, and screwing), such as the mechanically laminated timber arches of the French royal architect, Philibert de l'Orme (1515-1570).[49] Laminated arch timber bridges have a long history also in Switzerland. The famous bridge over the Limmat river in Wettingen built in 1766, with a free span of 61 m, stands out as exemplary within the projects of Hans Ulrich Grubenmanns.

However, what is considered the forerunners of the glue-laminated timber industry – where relatively thin timber lamellas were bent into position before gluing – were the efforts done at the beginning of the 19th century, especially the works of the German water engineer and architect Carl Friedrich von Wiebeking (1762-1842) and the French military engineer, colonel Amand-Rose Emy (1771-1851).[50] Gluing lamellas of timber together, in principle and in practice was then nothing new. The juxtaposition of glue and wood dates back to the Egyptian Empire.[51] There is even a recipe of Theophilus Presbyter, a German monk who lived at the end of the 11th century, which described the production of glue out of cheese, very similar to the casein glue described in Hetzer's patent, claimed as a self-made, and overestimated as water-proof. Limiting our study to only the structural use of glue and skipping its use in furniture building,[52] it can be demonstrated that even the process of glue-laminating has been although not a current, but a known practice, like the Wiebeking bridge built in 1809 near Altenmarkt, with a span of 43 meters where the lamellas have been laminated with animal glue (bone glue), through a warm gluing process.[53] Moreover, in the British context, the studies of Geoffrey Booth, Paul Bell, and Nicholas Bill, shaping the main body of knowledge about laminated structures in England and Scotland, bring forward evidence of the practice of glue-laminating in the 19th century. A railway bridge constructed in 1850 and some roof structures in the 1860s are among the known examples of early glue-laminated structures in England.[54] From the wood processing point of view, it is known that machine planning of boards has been possible as early as 1776. Suitable storage types for lamellas have been in practice for air drying, long before Hetzer's patent. What was

[49] For the example of this construction method in Switzerland see: Pflug, Léopold. "Une charpente rarissime aux portes de Lausanne". *Ingénieurs et architectes suisses,* vol. 125, no. 1-2, 199, pp. 2-5.
[50] There is abundant literature on this subject. For primary source, see: De L'Orme, Philibert. *Nouvelles inventions pour bien bastir et apetits fraiz*, Paris, 1561. _ Émy, Amand-Rose. *Traité de l'art de la charpenterie*. Paris, Carilian-Gœry und Anselin, 1837–41. Von Wiebeking, Carl Friedrich. *Traité contenant une partie essentielle de la science de construire les ponts, avec une déscription de la nouvelle méthode économique, de construire des ponts à arches de charpente*, Munich, 1810.
[51] The history of glue used in the carpentry is briefly addressed in chapter five.
[52] For the use of glue in furniture making see: Rinke, Mario. "The Form as an Imprint of an Idea". *Formful Wood. Explorative Furniture,* edited by Mario Rinke and Florian Hauswirth. Berlin, Jovis, 2019, pp. 175-185. _ Wilk, Christopher, and Elizabeth Bisley. *Plywood: a Material Story*. London, Thames & Hudson, 2017.
[53] Carl Friedrich Von Wiebeking (see note 50 above).
[54] See: Booth, L. G. "Henry Fuller's Glued Laminated Timber Roof for Rusholme Road Congregational Sunday School and Other Early Timber Roofs." *Construction History*, vol. 10, 1994, pp. 29–45. _ Booth, L. G. "Development of laminated timber arch structures in Bavaria, France, and England in the early nineteenth century", *The development of timber as a structural material*, edited by David Yeomans Abingdon, Oxon, Routledge, 1971, pp, 291-304. _ Bill, Nicholas A. "Laminated-Timber-Arch Bridges of Joseph Locke (1805-60) and His Assistants." *Construction History*, vol. 29, no. 2, 2014, pp. 39–62.

claimed then to be an invention, was basically “a reshuffling of existing, familiar knowledge and practice”.[55]

So, contrary to its recognition as a breakthrough invention, the genesis of early glulam, at least as introduced in the patent – which needed much less sophisticated knowledge about wood and expertise in craftsmanship – did not go beyond a known and familiar craft. This situation provided a good opportunity for the engineers to construct with timber, those who normally dealt with it only occasionally.

Glulam, however, was by no means the first timber construction system that involved engineers in the design process. In parallel to glulam, different non-patented and more conventional timber truss structures for large-span roofs and halls have been calculated and dimensioned by the engineers. With a span of 40 meters, the main hall of the Swiss Federal shooting festival of 1910 in Bern, could serve as an example. The lack of shapeability of normal timber usually resulted in overlapping patterns of truss elements structured geometrically in a way to distribute the loads on the structural elements. When the architect or the client aimed for a certain form of internal space, then the pattern of structural elements would vary from the known determinate structures and would result, similar to the example of the building of the shooting festival, in indeterminate structures. Engineers, in charge of the static calculations, assumed considerable simplifications, in order to be able to find one possible solution. However, involving a variety of carpentry joints, as we can see in figure 6, with different behaviour under compressive and tensile forces, as well as the “Due to the impossibility to determine the safety of the construction perfectly by calculation”,[56] the designers were often encouraged, not as a common practice though, to bring a model of the structure under the loading test (Fig. 7). The engineer defined also the behaviour of the joints, and based on this, the carpenter (possibly with the collaboration of the engineer), designed the joints.

[55] Rupert Hall (see note 33 above), particularly p. 337: “Indeed, it is difficult to imagine how, without new sources of energy or new materials, there could be any very rapid change in engineering-even if more complete and reliable scientific theorization had been accessible. As it was, technical invention could consist of little more than a re-shuffling of existing, familiar knowledge and practice”.

[56] As the project has been explained in the Schweizerische Baizeitung : “Wegen der Unmöglichkeit, die Sicherheit der Konstruktion auf rechnerischem Wege einwandfrei zu ermitteln, […]”. “Die Bauten für das Eidgen. Schützenfest in Bern 1910.”, Schweizerische Bauzeitung, vol. 55/56, no. 4, pp. 43-47.

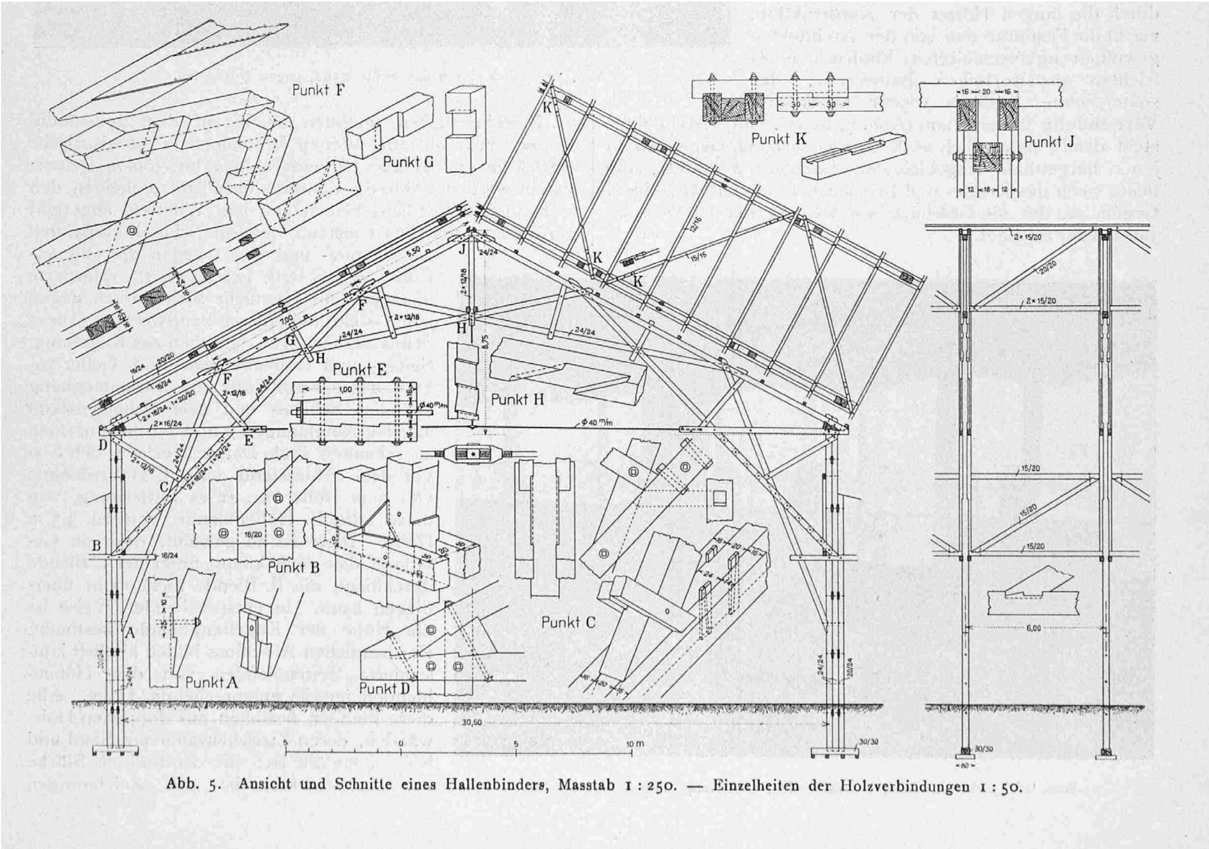

Fig. 6 Project for the hall of Shooting Festival in Bern, 1910.

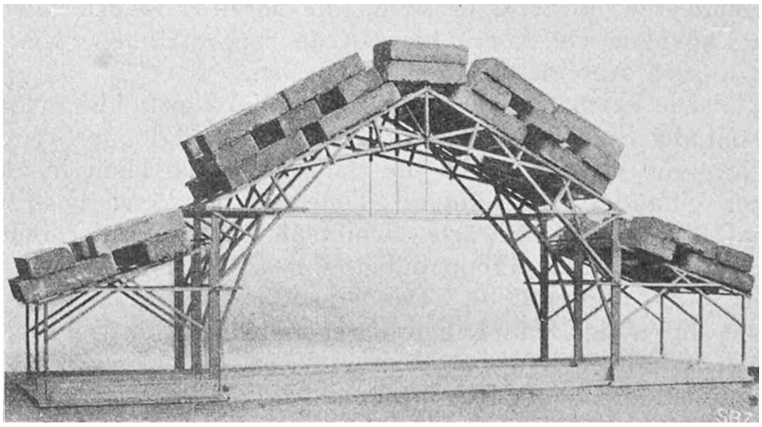

Fig. 7 Loading test performed on a scaled model of the festival hall

The design of timber joints was dependent on their loading condition (compression or tension), so it was crucial to accurately predict the type of forces in the structure. However, technical reports from that time indicate that the actual behaviour of the timber joints did not always match the calculated results. For example, the loading test conducted during the construction of the main hall of the 1901 Swiss Federal shooting festival in Lucerne revealed that the actual force distribution in the model was not consistent with the initial calculations (Fig. 8). For example, one main strut was under tension instead of compression, which was corrected by adjusting a connection.[57]

[57] Griot, Gustav. "Modell und Modellbelastung". *Schweizerische Bauzeitung*, vol. 35/36, no. 15, pp. 141-142.

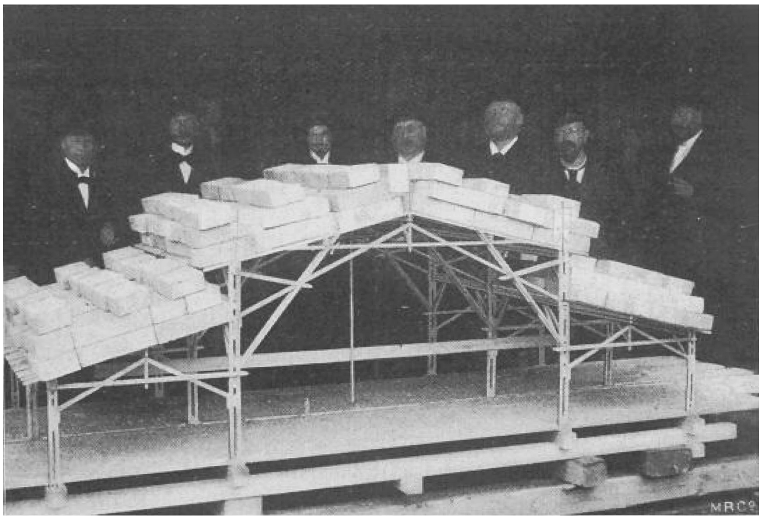

Fig. 8 Loading test on the model of the main hall of the Swiss federal shooting festival in Lucerne, 1901.

These few examples highlight the importance of new timber construction systems such as glulam that minimized the number and type of joints, and their significance for long-span timber structures with unconventional forms. These new solutions were well received by both the structural engineers and the carpenters.

5. Guilds and power structures

In an interesting article entitled “Timber Construction and Engineer”*,* published in 1936 by Jacob Seger, master carpenter and then the president of Lignum (association promoting the Swiss timber industry founded in 1931),[58] the decline and resurgence of structural timber around the turn of the 20th century was discussed and it sought to understand the reasons behind its decline and promotion, not from the perspective of the material itself but from the social, economic, and political factors that influenced its status.

According to the author, the strict statutes of the guilds played a crucial role in advancing carpentry and timber construction. With the collapse of the guilds, as noted by Seger, the craft stood at the height of its achievements. The article implies that the novelties in craft and its continuous development in a structured way within an institution that planned and organized all different aspects of technical development, preserved and promoted the interest in structural timber during the centuries. Seger then looked at the path of structural timber in other institutions substituting the guilds, namely in the engineering colleges (besides the carpentry workshops that continued to operate), where structural timber was either rarely taught as a building material or removed from the curriculum as being outdated. The few traces of timber as a structural material demonstrated that it has been treated in a subordinate manner, which resulted in a “severely disadvantageous” situation of structural timber.

[58] Title of the article in German: *Holzbau und Ingenieur.* Seger, Jakob. “Holzbau und Ingenieur”. *Zur Entwicklung des Holzbaues in der Schweiz or on the development of timber construction in Switzerland.* Zurich, Buchdruckerei a.d. Sihl A.G., 1936.

The author suggested that private research and development programs and systematic tests carried out by the EMPA helped to bring back timber as a state-of-the-art material for structural purposes. The increased use of modern timber construction systems, such as glulam, finally received the recognition it deserved from educational institutions, which had previously focused on steel and reinforced concrete.

Seger thus described the process of the reorganization of the network of the professionals of timber, giving a common base to research, education, and practice, which occurred simultaneously with the deinstitutionalization and re-institutionalization of it, as the rise and fall, or decline and promotion period of this material, and the transition from craft to engineering. Glulam was developed within the institutions that defined indeed the profile of the engineer and was hence understood as an engineered structural material.

Considering glulam, in this context, as an engineered product, the next question could be whether this re-institutionalization of structural timber can justify or explain the historical pioneering role of Germany and consequently Switzerland in timber engineering. The next section should be understood as an attempt – and maybe not a direct answer to this question – to develop a framework and an approach toward understanding the historical dimensions of this question. Some hypotheses will eventually be developed that could help to understand the particularity of the German and Swiss context in institutionalizing timber engineering.

6. Timber engineering, "a German affaire"?

Hetzer registered his patent in France and England almost at the same time that the registered his patent in Switzerland. However, the success that glulam experienced in Germany and in Switzerland is by no means comparable to its journey in those two other countries, where it hardly ever got locally marketed until the 1940s.[59] One of the main reasons why glulam (and the engineered timber structures in a larger context) developed very early and almost simultaneously in Germany and Switzerland, by a considerable time gap of some decades ahead of France and England, can be explained in historical background, considering the social context and the models of the political economy of these countries.[60]

The first evident reason for the fact that timber engineering appeared and then permanently developed in Germany and immediately as well in Switzerland is the availability of the raw material. Throughout the 19th century timber, in Germany and Switzerland was obtained mainly from local resources. This

[59] For France see note 23 above. The large-scale marketing of glulam in England, according to James Sutherland, started in 1937, by the introduction of the synthetic resin in Britain by the aircraft engineer and industrialist: Sutherland, James. "Revival of Structural Timber in Britain after 1945." *Construction History*, vol. 25, 2010, pp. 101–113.

[60] The reason that this part of the research is centred on these countries is that here a combination of knowledge (mainly related to the technical school) and power as well as an existing longstanding tradition in timber construction were the main criteria.

was not the case for France and particularly for England.[61] Elie Halevy believed that "the fact that the English [were] obliged to use [iron] instead of timber they [did] not possess, has led them to invent cheap processes for its manufacture, and to put the metal to a larger number of uses".[62] Although the availability of the raw material might be correctly considered as a necessary condition for the development of a related technology, it can however not be considered a sufficient one.

One of the fundamental reasons behind the death or survival of timber as engineering material at the turn of the 20th century in different countries, was the survival of socio-economic features of the Old Regime beyond the French Revolution in the transition to modernity, particularly the absence or partial persistence of guild-like mechanisms.[63] To this, it should be added that in the wake of the industrial revolution and the abolition of the guilds, national vocational education and training systems diverged widely according to the social characteristics of each country, which influenced the survival of the tradition of construction with structural timber.[64]

Although the abolition of the guilds has not been an abrupt decision that resulted only from the French Revolution, the spread of this idea in the larger European context is widely understood as a result of the French Revolution and its political upheavals.[65] Guilds as multifunctional institutions were responsible, from the High Middle Ages to the early 19th century, to regulate the social and political economy of European countries.[66] Beyond the historical view towards the guilds explaining them as rent-seeking institutions, guilds have been the subject of studies understanding their functions as providing adequate skills training through formal apprenticeships,[67] controlling the quality of the products, the joint purchase of raw materials, the dignity of the production processes and also the production quantity and the prices in corporative autonomy, as Andreas Würgler explains it.[68]

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61 Saveney, Edgar. *Rapports des délégations ouvrières à l'exposition de Paris en 1867, l'opinion des ouvriers sur l'industrie et sur eux-mêmes.* Revue des Deux Mondes (1829-1971), vol. 77, no. 3, Paris,1868. pp. 586-621. In this report, the dependency of carpentry to the timber imported from l'Esclavonie, de Croatie, des frontières de la Hongrie et de la Transylvanie is discussed. England was also dependent to the colonial timber, as well as Canadian, Russian and Baltic timber, among others. See Potter, J. "The British Timber Duties, 1815-60". *Economica*, vol. *22*, no. 86, 1955, pp. 122–136.

62 Halévy, Elie. *A history of the English people 1830-1841.* Vol. 3, London, Unwin, 1927. As cited in Potter J. (see note 60 above), p. 124.

63 My account of survival of structural timber and its relation to the survival of guild mechanisms has been influenced by: Hoogenboom, M., et al. "Guilds in the Transition to Modernity: The Cases of Germany, United Kingdom, and the Netherlands." *Theory and Society*, vol. 47, no. 3, 2018, pp. 255–291.

64 Wollschläger, Norbert, and Eric Fries Guggenheim. "Zur Geschichte der beruflichen Bildung in Europa, Von der Divergenz zur konvergenz [Dossier]" *Europäische Zeitschrift für Berufsbildung (CEDEFOP)*, no. 32, 2004, pp. 1–112.

65 Friedrichs, Christopher R. *The Early Modern City 1450-1750.* London; New York, Longmans, 1995, p. 56, explains for example the Charles V's abolition of the guilds' political privileges in 27 German free imperial cities, as a political decision, between 1548 and 1552.

66 It does not mean that other countries did not have guild system, it only means that this study is limited to the European guilds. The perspective adopted to the function of the guilds is mainly influenced by one of the most important contributors to the recent debate about guilds, S. R. Epstein (see note 69 below).

67 "Overall, except for craft guilds, institutions that organized occupational training in pre-industrial Europe remained the exceptions. In some countries institutions were established for relatively large groups of girls […]". *Learning on the Shop Floor: Historical Perspectives on Apprenticeship*, edited by Bert De Munck et al., New York, Berghahn Books, 2007.

68 Würgler, Andreas. "Zünftige Politiker. Korporative Regulierung Des Zugangs Zu Politischen Ämtern in Der Eidgenossenschaft (16.-18.Jahrhundert)." *Regulierte Märkte: Zünfte Und Kartelle = Marchés Régulés: Corporations et Cartels*, edited by Margrit Müller et al., Zurich, Chronos, 2011, p. 151.

Different studies of S. R. Epstein which had a fundamental contribution to our today's understating of the guild mechanisms, show that the craft guilds were formal associations of specialized artisans, mainly the master craftsmen, "whose authority was backed by superior political sanction. Apprentices and journeymen came under guild jurisdiction as well, but lacked membership rights".[69] The guilds had normally political power through their connection to the local councils.[70] The abolition of the guilds in this context, as we will see later in this section, entailed therefore important social, political, and economic consequences, influencing the organization of the trades, including the building trade.

The following part presents a proposal and a brief sketch of a comparative investigation of the abolition of guilds systems, the development of reorganization of the vocational training specific to each context, different patterns of relations between the political body, the governing entity, and the artisans and craftsmen, resulting in the promotion or decline of iron and timber in France, England, Germany, and Switzerland.[71] (Inter)National differences in time and degree are very difficult to measure, and the following impressions - it needs to be stressed – therefore remain rather preliminary and proposed partly as a hypothesis and could be the subject of a further and deeper study. The study here starts with the abolition of the guilds in France, followed by England, and then it will be compared with the situation in Germany and in Switzerland.

6.1. France

In France, guilds had been theoretically abolished on the night of 4 August 1789, in the course of the French Revolution which proclaimed all men equal in rights, abolishing privileges of every sort.[72] Fearful of aggravating unrest and violation in the nation, it took 18 months, until the National Assembly in Paris announced the guilds as explicitly and definitively abolished in 1791.[73] However, already in this period, the consequences appeared in different cities in France. For example, in 1790, the "master joiners took action against journeymen who had begun to practice their trade freely".[74]

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[69] Epstein, S. R. "Craft Guilds, Apprenticeship, and Technological Change in Preindustrial Europe." *The Journal of Economic History*, vol. 58, no. 3, Sept. 1998, pp. 684–713.

[70] Andread Würgler (see note 68 above, p. 161) concludes that the job market for politicians in the early modern period was to a degree, corporately regulated: as far as council positions are concerned: seats on the Great and Small Councils were allocated to the guilds in the city republics of the old Confederation according to a fixed key. For a Switzerland-wide overview see: Bauer, Hans. *Von der Zunftverfassung zur Gewerbefreiheit in der Schweiz, 1798-1874: ein Beitrag zur schweizerischen Wirtschaftsgeschichte.* Basel, Buchdruckerei der National-Zeitung A.-G., 1929.

[71] I was alerted to several important sources regarding the abolition of the guilds in Germany and Switzerland, by Rauhut, Christoph. *Die Praxis der Baustelle Um 1900: Das Zürcher Stadthaus Fraumünsteramtnstern*. PhD dissertation, ETH Zürich, 2003.

[72] However, before the revolution, there were attempts to abolish the guild systems: for the suppression of guilds and their re-establishment, in January and August of 1776, see: Husson, François, *Artisans français : étude historique. Les charpentiers,* Paris, 1903, pp. 189-193.

[73] Sauvage, P.-C.-M. *Le travail et l'industrie de la construction*. Paris, A. Morel et Cie., 1875. However, this does not mean that there were no attemps to reestablish the guild system. In 1805-1810, Napoleon considered the revival of guild system, and the Napoleonic officials advocated it. See Fitzsimmons, Michael P. "The Debate on Guilds under Napoleon". *The Western Society for French History*, vol. 36, 2008. This was under influence of the ifforts of the master carpenters to revive the guild system. See Sauvage, P.-C.-M. *Le travail et l'industrie de la construction*. Paris, A. Morel et Cie., 1875, pp. 134-137.

[74] Fitzsimmons, Michael P. "The National Assembly and the abolition of guilds in France." *The Historical Journal*, vol. 39, no. 1, 1996, pp. 133-154. Particularly p. 140.

These manifestations as well as letters of objection sent by the master craftsmen to the newly established, over-centralized political body in Paris which downgraded the regional authorities, were taking place only sporadically. Historians describe the activities of craftsmen as "purely individual efforts, […] freed from the bonds of any corporative structure", where "no solidarity br[ought] together, […] the spontaneous manifestation of activity and of energies".[75] It can be argued that the artisans and craftsmen's attempt in order to negotiate their lost advantages had hardly any result and guilds member eventually lost their social, economic, and sometimes political power. Quite rapidly and within less than two years, craftsmen's professional activities got deinstitutionalized. By this, they also lost their power to negotiate with the central government, to lobby and voice their opposition, in order to find a solution to build up a guild-like organism organizing the activity of the body of the craft. One reason could be that the revolution not being limited to the guild system, resulted as well in the renewal of the structure of politics, where the local authorities, which were products of the *Old Régime*, now had to assume office through elections based on the new ideals of the nation. This situation could have possibly resulted, as the master craftsmen claimed, in the decline of many trades, and the decline in the quality of the works of the craftsmen, which could work without having the necessary training assigned previously within the framework of the contracts between the master and the apprentices.[76] The possible deterioration in quality and also the worker unrest that followed the dissolution of guilds was not in favour of timber construction in particular and accelerated its substitution with iron. Historical data shows that the number of carpenters in Paris and its suburbs, in around 15 years from 1845, has been reduced to less than half, shrinking from 7'500 carpenters to only 3000 ones, and this was mainly due to the use of iron and cast iron, that constantly restricted the use of wood.[77]

A particular event has evidently accelerated the diffusion of the metal in the construction sector: the strike of Parisian carpenters which lasted for many months in 1845, and is considered to be the most important strike of the carpenters of this country.[78] Deprived of wood, the contractors then had recourse to iron to be able to complete the constructions begun, thus contributing to popularizing what

[75] For a detailed acount see, Martin Saint-Léon, Étienne, *Histoire des corporations de métiers depuis leurs origines jusqu'à leur suppression en 1791*, Paris, 1922. Citation in pages 620-621. In his brilliant study "La quéstion ouvrière", Du Maroussem shows how this strong influence of the over-centralization of the power, and its influence on the labour movement in France, studying the case of workers of carpentry, and opposing this attitude towards the government, with the German attitude and their strong champagne of worker movements. Du Maroussem, Pierre. *Les charpentries de Pris : compagnong et indöpendents, La quéstion ouvrière,* vol 1, Paris, Librairie nouvelle de droit et de jurisuprudence, 1891.
[76] Fitzsimmons, Michael P. "The National Assembly and the abolition of guilds in France." *The Historical Journal*, vol. 39, no. 1, 1996, pp. 133-154. Particularly p. 140. However, it cannot be affirmed completely, because this is what the masters claimed, and the claim can be stated in order to push their objections to the government against the abolition of the guilds.
[77] Le Play, Frédéric, and P.U. Focillon. "Charpentier de Paris de la corporation des Compagnons du Devoir". *Les Ouvriers des deux mondes : études sur les travaux, la vie domestique et la condition morale des populations ouvrières des diverses contrées et sur les rapports qui les unissent aux autres classes*, Paris, Société Internationale, 1857.
[78] Le Play, Frédéric, and P.U. Focillon. "Charpentier de Paris de la corporation des Compagnons du Devoir". *Les Ouvriers des deux mondes : études sur les travaux, la vie domestique et la condition morale des populations ouvrières des diverses contrées et sur les rapports qui les unissent aux autres classes*, Paris, Société Internationale, 1857.

was until then a somewhat exceptional material.[79] This three-month strike would have accelerated the use of iron in construction, since wood specialists were lacking, and gave this idea to the contractors, to use iron more frequently.[80] In 1867 on the occasion of the World Fair, the carpentry workers ask the government to accelerate the import of wood and to reduce its transport cost from eastern Europe, in order to increase the amount of carpentry work and reduce the share of iron in construction.[81] This also shows that since construction timber was not a local material, and its import was regulated by the government, the power of the carpenters for negotiation to raise the share of timber has been considerably lower than in Germany and Switzerland, which will be discussed later in this chapter. Moreover, the influence of the over-centralized system should be noticed, where the inclination of the government for a particular material and new taste in architecture, meant the reform in the industry of the whole country. From the first months of the Second Empire (1852-1870), Napoleon III personally took sides in favor of iron architecture, thus giving a decisive impetus to the extraordinary development that it was to experience.

Furthermore, what should also be explained here, is that by the abolition of the guilds, following the French Revolution, one of the most important functions of these institutions remained not solved: the vocational training, for which the guilds have been responsible for centuries. By the decree of the abolition, the problem of training qualified workers remained unsolved for a long time.[82] However, it is well known that France took the leading role in the natural sciences in the 18th century, with its tradition in technical schools such as *Ecole des Ponts et des Chaussées* founded in 1746, and the *École Polytechnique* of Paris in 1795. What was thought in these technical universities, was considered theoretically sophisticated but hard to apply to practical questions, with, according to Kurrer and Ekkehard, "the geometry and algebra skills [that] could not be used directly for solving specific tasks"[83].This was also the case for timber structures taught at these schools. For example, from the carpentry manuals that we have from that time, we can mention *Art du trait pratique de charpente par Émile Delataille* [84], published around 1870. The last edition in 1893, is packed with complicated geometrical projections of structural elements that made this *triaté pratique* almost unpractical for a

[79] I was alerted to the sources related to this strike, by Vandenabeele, Louis, *Roofs with Roots. The historical developments of timber roof structures in 19th- and early 20th-century Belgium.* PhD dissertation, Vrije Universiteit Brussel, 2018.
[80] Blanc, Julien. *La Grève Des Charpentiers En 1845 Épisode de La Crise Sociale de L'époque*. Paris, Librairie sociétaire, 1845.
[81] Saveney, Edgar. *Rapports des délégations ouvrières à l'exposition de Paris en 1867, l'opinion des ouvriers sur l'industrie et sur eux-mêmes.* Revue des Deux Mondes (1829-1971), vol. 77, no. 3, Paris,1868. pp. 586-621. "*Pour donner un nouvel essor à la charpenterie, il faudrait diminuer les droits d'entrée et de navigation qui pèsent sur les bois. [...] Des associations d'ouvriers pourraient exécuter les travaux à bon marché, en concurrence avec le fer, si les architectes et les capitalistes favorisaient ce genre de sociétés. [...] Les bois ne manquent pas pour la charpenterie. On pourrait en favoriser le transport des forêts de l'Esclavonie, de Croatie, des frontières de la Hongrie et de la Transylvanie. Si on se servait un peu moins de fer et un peu plus de bois, les charpentiers auraient tous des travaux; c'est la première chose à desirer".*
[82] Wollschläger, Norbert, and Eric Fries Guggenheim. "Zur Geschichte der beruflichen Bildung in Europa, Von der Divergenz zur konvergenz [Dossier]" *Europäische Zeitschrift für Berufsbildung (CEDEFOP)*, no. 32, 2004, pp. 1–112.
[83] About the specific culture of early French technical schools see Kurrer, Karl-Eugen, and Ekkehard Ramm. *The History of the Theory of Structures: From Arch Analysis to Computational Mechanics.* Berlin, Wilhelm Ernst & Sohn, 2008. pp. 51-54.
[84] Delataille, Emile. *Art du trait pratique de charpente*. Tours, C. Guilland, 1887.

practicing carpenter or even an engineer.[85] Those puzzling drawings can also be found in the *Traité théorique et pratique de charpente Mazerolle,*[86] of Louis Mazerolle (1842-1899), one of the most important French carpentry handbooks, published for the first time in the 19th century. The drawings and their explanations are provided in 2 different volumes. Associating the theoretical part with the, as claimed, practical part was the work of an engineer with an advanced level of geometry, a feature that made this book almost impractical for a practicing carpenter.[87] Sometimes the tendency can be observed in order to ignore the achievements of German carpentry in the French manuals. For example, one of the last timber handbooks appearing in the opening decades of the 20th century was J. Denfer's *Charpente en Bois et Menuiserie* [88], published from 1892 until around 1910. In the 1910's edition, Stephan and Hetzer's systems, which has been leading the renewal of structural timber in the 20th century, were totally overlooked, and the handbook remained at the end, as a review of the existing conventional timber construction systems, staying mainly descriptive and hardly useable for a practical carpenter. A situation that is understandable, considering the post-Franco-Prussian war atmosphere.

This brief sketch of the situation shows that although the education of the craftsmen remains unsolved, the concentration of education of technical branches in the technical schools, mainly located in Paris, brings the carpentry structures of more challenging spans, to the domain of the work of the engineers, and consequently iron (steel). The manuals of carpentry filled with sophisticated and mainly unpractical drawings and explanations of the fabrication and assembly of structural elements, mirror the situation of structural timber, suffering from a lack of novelty and practical solutions.

6.2. England

The fate of structural timber in England was quite similar to its trajectory in France, although British history has been marked by quite different events than the French one.

Being "virtually dead" by 1900, as described by James Sutherland, the structural timber was "replaced by iron, then steel and reinforced concrete." The carpentry, following the craft principles, was "confined to little more than the floors and roofs of small houses, doors, windows, and cladding".[89]

It can be argued that in England, the French Revolution coincided with the Industrial Revolution, known as the *dual revolution*, to use the term coined by Eric Hobsbawm, had profound consequences on the social and politico-economic system, which accelerated the substitution of structural timber

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[85] I was alerted to these books, and the following German handbooks by Prof. Stephan Holzer at ETH Zürich. I would like to thank him for giving me access to his collection of the original print of these books.
[86] Mazerolle, Louis. *Traité théorique et pratique de charpente*. Paris, C. Juliot. (Different editions in 1900-1920)
[87] There have been attempts in order to simplify these drawings: see e.g., Biston, et al. *Nouveau Manuel Complet Du Charpentier, Ou, Traité Élémentaire et Pratique de Cet Art: Contenant Les Principes de Géométrie, l'Art Du Trait La Structure ...* Paris, L. Mulo, 1903.They eventually remained unpractical.
[88] Denfer, J. *Charpente en bois et menuiserie*. Paris, Gauthier-Villars,1892 and 1910.
[89] Sutherland, James. "Revival of Structural Timber in Britain after 1945." *Construction History*, vol. 25, 2010, pp. 101–113.

with iron. The period 1789-1848, marked by the dual revolution, refers to the political changes of the French Revolution, combined with the technological changes of the industrial revolution, in the case of England.[90]

In the British context, the question of the abolition of the guilds may not be of prominent importance. Although the formal abolition of the guilds happened in 1799, the guild-like structures remained dominant in some sectors of craft. This, however, could not contribute to the survival of timber as a structural material. It was not only the building sector that was considering replacing timber with iron but all the industrial sectors needed iron for making machines. For mechanical engineers especially, "wood was anathema to the ideals of precision, power and production",[91] which defined the profession and clearly distinguished engineers from millwrights and carpenters. Iron's uniformity made it possible for mass production, whereas, in the case of timber, it was always important for the carpenter to know where the timber element was going to be used. [92] Swelling and shrinking with the humidity of the air, made it an unsuitable material for the moving parts of machinery, or those working in high pressure, temperature, and speed conditions. [93] The material culture shaped by the new forms of production, "necessitated the replacement, modification, or adaptation of the materials upon which production depended", requiring principles such as "uniformity, reproducibility, predictability, plasticity, and speed, replaceability, and prefabrication". [94] This new perception of the material facilitated the replacement of wood with iron. As Eric Schatzberg demonstrates, a belief got developed that linked industrialization, economic growth, and the idea of progress, to iron, symbolizing it as a material standing for progress, against timber as backwardness.[95] The fast speed of early industrialization of England, and above all, the very rapid growth of the railway sector which made the biggest demands on the iron industry, all made no doubt that timber would not be a suitable material candidate for the engineering projects of different branches of the industry.[96]

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[90] Although France also had this dual revolution, but the France did not reach the peak of its industrialization until the end of the 19th century. The "oversimplified view" which advocated for the arguments promoting the idea that the industrialization of England served as model for other European countries, has been criticized by the scholars and historians. In his interesting study "A New View of Industrialization", Rondo Cameron argues "Industrialization is not identical either with economic growth or economic development, although it is closely associated with both". He counts then four factors for the process of economic growth: population, resources, technology, and institutions. Cameron, Rondo. "A New View of Industrialization". *The Economic History Review,* vol. 38, no.1., 1985, pp. 1-23. Being aware of these critics, since in this thesis the focus is on the technological part, and not about the whole process of economic growth, the classic model arguing for the supremacy of British model of industrializing, can be used here.

[91] Evans, F. T. "Wood since the Industrial Revolution: A Strategic Retreat?" *History of Technology*, vol. 7, 1982. pp. 37-55.

[92] Evans argue that industrial revolution was not a "swift and wholesale replacement of wood by iron". "wood has been written off as obsolete in the eighteenth century". Evans is looking at different "branches of engineering" for the use of wood: energy, ship building, civil engineering, factories, aviation. He brings many evidences that the increased use of iron, was not depended to any crippling shortage of wood. (Evans, F. T., see note 91 above)

[93] Deane, P.M. *First Industrial Revolution*. Cambridge, Cambridge University Press, 2010, pp. 136-137.

[94] Haines, Ch.M., *The industrialization of wood: the transformation of a material.* PhD Dissertation, University of Delaware, 1990, p. 1.

[95] Schatzberg, Eric. *Wings of Wood, Wings of Metal: Culture and Technical Choice in American Airplane Materials, 1914-1945*.

[96] As Nicholas Bill shows in this study on the early timber railways bridges, "thousands of timber bridges were constructed throughout Great Britain and Ireland between 1840 and 1870." The choice of this material has been based on more short construction deadlines and financial constraints, but also the low capital of early railways companies. Bill, Nicholas A.

The other point that would have played an important role in the transition to iron, was the shift of political power from the craftsmen to the engineers, their rise to prominence, and the "panoply of power and influence" of the new professionals, namely the engineers. As Robert Buchanan explains it, in England:

> […] by 1870, civil and mechanical engineers had both achieved a substantial measure of institutional and professional recognition in Britain. The great boom in industrial development and the construction of transport systems had ensured them places of importance and honour in mid-Victorian society. Several engineers had received knighthoods and become members of parliament. Many had grown rich from the practice of their skills […]. [97]

New places accorded to the engineers in the political power, could have possibly pushed a systematic bias in favour of iron as the engineering material. The engineers for whom building a project out of "iron" has been considered as a more "gratifying" one, than a project in timber.[98]
Moreover, the iron trade in England, being "dominated by men of great capital, usually arrayed in partnerships with a strong dynastic flavour",**[99]** went in hand with the powerful tradition of laissez-faire government, and could have favoured, different political, and economic levels, the preference of iron over timber in the industry, including the building industry.[100] To all that must be added that iron in the very early years of the Industrial Revolution could become, due to the availability and accessibility of its raw material within the local resources of England, a "native material", as PM Deans demonstrates it in his study on the first Industrial Revolution.[101] This aspect of the material had a primordial role in the immediate growth of its domestic market.

Besides, historians have recognized the passive role of the government in planning and providing higher education, either in organizing the vocational training beforehand fully planned and organized

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"Timber Bridge Construction on British and Irish Railways, 1840-1870: The Scale of Construction and Factors Influencing Material Selection." *Construction history: journal of the Construction History Group, vol. 31, no. 1,* 2016, pp. 75–98. He shows that if timber used, in a subordinate manner, they knew that the bridges would be replaced in less than few decades.

[97] Buchanan, Robert Angus, *Science and engineering: a case study in British experience in the mid-nineteenth century*. London, Notes and Records of the Royal Society of London, vol, 32, no. 2, 1978, p.215-223.

[98] See note 95 above.

[99] Buchanan further explains:"Yet behind this new-found panoply of power and influence, the great engineers of nineteenth century Britain remained essentially the same as the diligent artisans, millwrights, surveyors, and craftsmen, from whom the engineering profession had sprung in the previous century. To a man, they had all learnt their craft primarily by practice, with virtually no reliance on higher education and with very little theoretical or 'scientific' content to their training". Buchanan, Robert Angus, *Science and engineering: a case study in British experience in the mid-nineteenth century*. London, Notes and Records of the Royal Society of London, vol, 32, no. 2, 1978, p. 215.

[100] One of the most important contributors to the recent debate about guilds, S. R. Epstein argued that the craft guild guaranteed apprenticeship contracts and functioned as the chief conduit for the transmission of skills during industrialization. Does this mean that industrial development in England grew within rather than outside of traditional guild control or monopolistic restrictions? S.R. Epstein (see note 69 above). This perspective to the guilds, however, did not go unchallenged. See: Ogilvie, Sheilagh. "The economics of guilds". *Journal of Economic Perspectives*, vol. 28, no. 4, 2014, pp. 169–92, particularly p. 188.

[101] It was one of Britain's special advantages as a location for the first industrial revolution that her iron and coal resources co-existed in the same regions, often within the same mines. The ore that was used at this time was almost entirely from beds within the coal measures: indeed in 1850 it was estimated that 95 per cent of the iron ore used was coal measures' ore". "In addition to iron ore the industry used large quantities of British limestone and British coal. The iron industry was the most important single factor in the rising demand for coal in the first half of the nineteenth century, and through its demand for both coal and ore it created an associated demand for transport facilities". Deane, P.M. *First Industrial Revolution*. Cambridge, Cambridge University Press, 2010.

by the guilds, or in setting up technical universities for the engineers. The powerful tradition of laissez-faire and the absence of state responsibility for education entrenched aristocratic fear of popular schooling, as explained in the study "artisan education in science in 19th century England".[102] To this, it should be added the public inertia toward technological education, where according to Eric Ashby, "any formal training in college was regarded with suspicion, as likely to lead to the disclosure of "know-how" and trade secrets […]".[103] The technical education in England, still the richest country in the world around 1870, was described as "quite remarkably little. Of that little, much was inadequate in quality". This is how Margaret Gowing compared education, including technical education, in England with the European context, particularly with Germany and Switzerland, described as the "star performers".[104]

In the turbulent century marked by the dual revolution, timber eventually fell down from the status of structural material and lost the chance to be re-institutionalized. By the evident lack of interest in a systematically organized technical education, timber missed any little chance that it could possibly have to enter the circle of science-based technics. However, in other developed Western European nations, such as Germany and Switzerland, the state exhibited a more assertive role in the educational spheres, and these countries moved earlier than England to establish school systems for practical technical education.

6.3. Germany & Switzerland

In this context, the main difference between France-England and Germany-Switzerland, is the quality of the transition of vocational training after the abolition of the guilds, and the decentralized governing mechanisms of the latter countries. The situation of these two countries will be studied in parallel in this section.

In many of the German states, guilds were formally abolished during the period of French occupation (1794–1815). However, they were not abolished as thoroughly as in France, where everything "guildish" was radically eliminated. In most German states the authorities were following a zigzag course in the nineteenth century, alternating between different attempts to stimulate economic development, either by lifting all sorts of protective regulations or by reinstalling guilds and guild-like regulations, particularly in times of social upheaval.[105] This continuation of corporative traditions,

[102] Wrigley, Julia. "The Division between Mental and Manual Labor: Artisan Education in Science in Nineteenth-Century Britain". *American Journal of Sociology*, vol. 88: Supplement: Marxist Inquiries: Studies of Labor, Class, and States, 1982, pp. S31-S51.
[103] Ashby, Eric. *Technology and the academics: an essay on universities and the scientific revolution.* London, New-York, MacMillan St Martin's Press, 1958, pp. 56-57.
[104] Gowing, Margaret. "Science, Technology and Education: England in 1870". *Oxford Review of Education*, vol. 4, no. 1, 1978, pp. 3–17.
[105] 1815-1867 (German confederation, Prussia) "freedom of trades" removes compulsory guild membership, and many guilds persist. 1845: freedom of trades reaffirmed but also strengthening control of guilds over apprenticeship. In other States up until 1860, many guilds were still effective, and during 1860s, many states (Saxony and Bavaria) removed compulsory guild

overlapped by liberalist principles, “led to the formation of specific zones of entanglement between the spheres of action of "state" and "society" in the form of intermediary self-governing bodies under public law.[106] Therefore, in Germany there were relatively strong intermediary forces that could provide "an effective mediation between citizen and state", concept brilliantly explained by Jürgen Schriewer,[107] and made the introduction of a thoroughly structured apprenticeship training possible in so many companies. [108]

In this regard, the situation in Switzerland was not much different. Having a non-centralized governing system, the regional authorities played a powerful role in the politic, (in contrast with the centralized governing systems of France and England) and this gave the opportunity to the craftsmen to negotiate with the local and regional governing bodies in order to re-introduce the guild system or establish a guild-like mechanism with the aim of raising the social and economic status of these craftsmen. Abundant literature and studies on this subject describe the decades of negotiations of the leaders of the trades with the cantonal authorities. In Switzerland, the abolition of guilds did not follow the same pattern and speed in all regions. For example, in western Switzerland (French-speaking part), the guilds were already in 1798 abolished.[109] In the German-speaking part, this took some decades longer until the final abolition.

Here the situation in Zurich will be studied as an example[110]: after early attempts to abolish the guild system, from 1804 to the 1830s, supervision of handicrafts in Zurich was once again assigned to the guilds. One of the reasons was regulating the anarchistic state of the apprentice and journeyman system. The journeymen and apprentices were to be made to obey their masters again.[111] In 1837 the last traces of the guild system in Zurich were lost. Two years later in 1839, a *Schreinerigesellschaft* (society of carpenters) was formed, where the affiliation was described as voluntary. The carpentry

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membership. Hoogenboom, M., et al. “Guilds in the Transition to Modernity: The Cases of Germany, United Kingdom, and the Netherlands.” *Theory and Society*, vol. 47, no. 3, 2018, pp. 255–291.

[106] “Zur Geschichte der beruflichen Bildung in Europa: Von der Divergenz zur Konvergenz” Berufsbildung (Europänsche Zeitschrift), no. 32, August 2004, pp. 1–112.

[107] Schriewer, Jürgen. “Intermediäre Instanzen, Selbstverwaltung und berufliche Ausbildungsstrukturen im historischen Vergleich”. *Zeitschrift für Pädagogik,* vol. 32, no. 1, 1986, pp. 69-90.

[108] Wollschläger, Norbert, and Eric Fries Guggenheim. “Zur Geschichte der beruflichen Bildung in Europa, Von der Divergenz zur konvergenz [Dossier]” *Europäische Zeitschrift für Berufsbildung (CEDEFOP)*, no. 32, 2004, pp. 1–112.

[109]Vuattolo, August. *Geschichte Des Schweizerischen Bau- Und Holzarbeiterverbandes 1873 - 1953*. Zurich, Genossenschaftsdruckerei, 1953, p.106.

[110] 1336 – 1837: Zunft zur Zimmerleuten in Zurich is officially established and worked for almost 500 years. (Meyer, Helmut. *Zimmerleuten – Eine kleine Zunftgeschichte.* Zürich, Hans Rohr, 1991). For the case of Bern: 1373 - 1807: earlier than 1373, the Gesellschaft zu Zimmerleuten in Bern was established. They used the name Gesellschaft instead of Guild. “Mit der Aufhebung des zunftzwangs durch den grossen Stadtrat 1805 trennte sich die Schreinermeisterschaft, wie die übrigen Meisterschaften auch, von der Muttergesellschaft zu den Zimmerleuten ab”. (Zesiger, Alfred. *Die Gesellschaft zu den Zimmerleuten : Festschrift auf die Einweihung des neuen Gesellschafthauses am 15. Oktober 1909*. Bern, Stämpfli, 1909. p. 63.)

[111] “The petitions of the craftsmen of Zurich and Winterthur as well as the pleas of individual craftsmen to the city and country for the abolition of the freedom of trade and commerce and the restoration of a healthy crafts policy, together with the insight of the authorities, led in 1804 to a "General Police Ordinance for Trades and Crafts". The legislator started from the realization that through the reorganization of the craft sector, ways and means should be found to remedy the very oppressive evil of abuse in traffic and craft matters, to revive industry and to help the craft sector again. The supervision and promotion of the crafts should again be granted to the guilds or crafts societies as in the past”. Strobel, Ernst. *Die Handwerkerpolitik Zürichs von der Helvetik bis zur liberalen Aera*, Basel, Hänggi, 1926, pp. 22-30.

society of Zurich provided the impetus and served as the basis for the establishment of the carpenters' association in 1871.[112] Freedom of trade was finally manifested by the revision of the Federal Constitution of 1874, which contained far-reaching provisions on freedom of trade.[113]

In Germany, the reform in the educational system after the guild structures coincided with the policies of the newly founded Wilhelmine Prussian state and the connection between the design reform initiated and led by this State and its economic development policies. John Maciuika demonstrated in his remarkable contributions, the funding role of the policies of that State in the modern German design culture.[114] These policies were applied through different arts, crafts, and trade schools. In these schools, following a dual vocational training model, where shop-floor learning occurs parallel to learning at school, those apprentices in the craft could benefit from school-based learning with a work-based practice, and this could very early tie the education of the craftsmen to the higher education system.

Regarding the schools specifically dealing with the education of the carpentry apprentices, the *Baugewerkschule* (Building Trades Schools) can be mentioned, and some other schools founded by the master carpenters as private schools (however, the government had an overview of the activities of these schools), whose success reached beyond the German borders, and recruited apprentices from neighboring countries, including Switzerland.

As an example of the Building Trade Schools, the Prussian State Building Trade Schools of Holzminden founded in 1831 can be mentioned, where during the winter, when most construction works were suspended, the trainees were taught about the building materials and histories of building constructions and styles, but also trained in drawing and construction techniques related to their specific trade. More examples are the Royal Building Trade School, founded in 1823, followed in many other German regions, e.g. schools of Nienburg/Weser in 1853, Höxter in 1864, Regensburg in 1846, and Luebeck in 1896.

However, this vocational training was not limited to the efforts of the state. Privately founded in 1906 (the same year when Hetzer patented glulam in Germany), the carpentry school of Fritz Kress stands out as an example. Fritz Kreß (1884-1962), a German master carpenter, published several handbooks for the carpentry trade and founded and ran a privately founded technical school. His handbook published initially in 1907, reached its 11th edition in 1959, and provided the apprentices with a body of totally practical knowledge about the carpentry rules. In his school, the apprentices were sitting in rows, similar to the layout of normal schools' classrooms, with a workshop table in front of each

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112 Vuattolo, August. *Geschichte Des Schweizerischen Bau- Und Holzarbeiterverbandes 1873 - 1953*. Zurich, Genossenschaftsdruckerei, 1953, p.106.
113 Regarding the relation of power between the guild of the carpenters, the body of politic in Switzerland see: Meyer, Helmut. *Zimmerleuten – Eine kleine Zunftgeschichte.* Zürich, Hans Rohr, 1991.
114 Maciuika, John V. "Art in the Age of Government Intervention: Hermann Muthesius, Sachlichkeit, and the State, 1897-1907." *German Studies Review*, vol. 21, no. 2, 1998, pp. 285–308.

apprentice, practicing the carpentry operations explained in the handbook of their master, or imaginably constructing roof structures following the scaled models hanged from the ceiling of the workshop (Fig. 9).

Fig. 95 Fritz Kress carpentry school in Tübingen, Lustnau.

Although this school does not represent a standard situation and a common practice for the vocational training of craftsmen, it demonstrates however the efforts of the master carpenters in order to reorganize the training in a way, that the practical part plays its principal role in training.

Fritz Kress' school was one of the leading private schools in training master carpenters at the beginning of the 20th century. The State had however an overview of this school by having a representative on the board of directors. Following its international success, another 4 to 5 carpentry schools based on the model of Kress were set up in Germany.[115]

These examples demonstrate, how the public and private spheres, how the master craftsmen and the engineers, and how the theory and practice were given a chance to grow up in parallel and to shape an exceptional vocational training system, called the dual system.

Switzerland, following closely the achievements of the German system in training and schooling, did not show a fundamental difference in its vocational training system in comparison to its northern neighbor, especially the southern part of it, which had close relations with Switzerland. The *Gewerbeschule* (Trades School) in Zurich founded in 1873, was one of the early attempts here to organize vocational training, and in order that "the path [be] equally open to everyone to train himself to become a competent craftsman or tradesman […]".[116] Reports on several travels of its directing

[115] The information about this school are derived from the online encyclopaedia of Tübingen, called "*Tüpedia*". The main references for this article have been *Der Deutsche Zimmermeister, Der Zimmermann*. I did not have access to these journals.
[116] Original text in German: " […] denn jedem steht der Weg gleich offen, sich zu einem tüchtigen Handwerker oder Gewerbsmann auszubilden und so sich ein anständiges Auskommen zu sichern; es besteht kein anderes Vorrecht als dasjenige der Intelligenz und der Beharrlichkeit". Vergl. Bericht d. Direktion d. Innern a. d. Regierungsrat über die Petition d. Handwerks- und Gewerbevereins d. Kt. Zürich v. 28. Sept. 1856. As cited in Strobel, Ernst. *Die Handwerkerpolitik Zürichs von der Helvetik bis zur liberalen Aera*. Basel, Hänggi, 1926, p. 131.

board to Stuttgart, helping them to stay informed about the latest German achievements in structuring vocational training, demonstrate the links between the German and the Swiss vocational training system in this specific field. [117] In the Trades School of Zurich, the teaching material consisted of, among others, drawings for the carpenters and joiners, taught by the master carpenters. These courses were provided mainly to accompany the shop floor training in the carpentry workshops and to, more importantly, re-institutionalize the trade, and raise the social and economic status of the people involved in this craft. This, as we can see later in the case of Switzerland, helped to keep a body of carpenters who had a voice in the politic, up to the turn of the 20th century. The fact that this body existed in the early years of the 20th century, helped to organize and re-institutionalize the glulam technology in Switzerland.

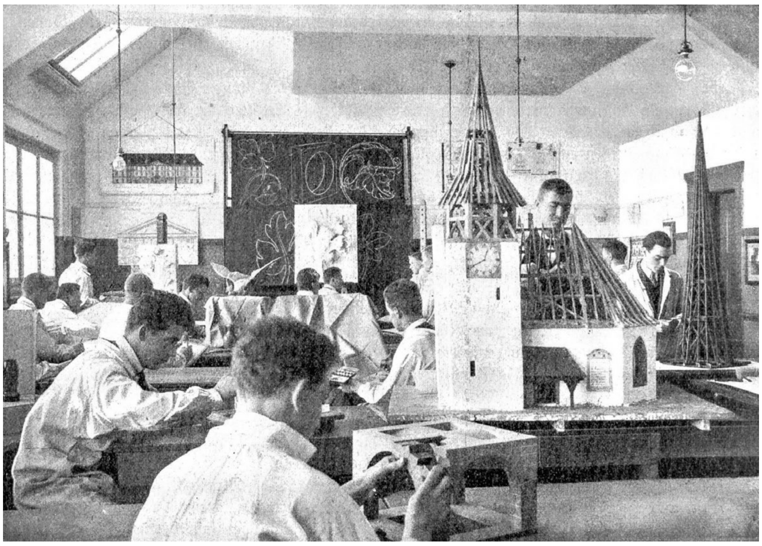

Fig. 10 *Das Technikum Burgdorf.* Drawing and modelling, (Department of Structural Engineering), photo is taken before 1917.[118]

Among the advantages of the decentralized education and training system in Germany, as Eric Ashby explains it, is the particular communication and collaboration that existed between different schools or universities. Ashby compares it with the situation of the *Geselle* (journeymen), who travelled and spread knowledge and technique from one city to another one. He compares this situation with the French and the British context, where in France higher education was mainly centered in Paris, and in England, different financing systems of schools for higher education, among other reasons, entailed a lack of collaboration among them. According to Ashby:

> The German universities, founded and sustained by independent states, constituted an intellectual fellowship without parallel in Europe. Their teachers and students were constantly migrating from one university to another and continually interchanging ideas. Between one university and another, there

[117] In 1875, on behalf of and with the financial support of Schweiz. Gemeinnützigen Gesellschaft, two members of the supervisory board and a teacher from the trade school made a trip to southern Germany to get to know the related schools there, especially the one in Stuttgart. "Die Gewerbeschule Zurich". *Pädagogischer Beobachter: Wochenblatt für Erziehung und Unterricht*, no. 2, 1876, pp. 201-202.

[118] "Das Technikum Burgdorf". *Die Berner Woche in Wort und Bild: ein Blatt für heimatliche Art und Kunst*, vol. 7, no. 19, 1917.

> was a healthy rivalry. Of course, liberalism did not prevail everywhere, but if one university was suffering through the illiberal interference or bigotry of some patron, there was always another university in the fellowship where persecuted professors might expect to be received and sheltered.[119]

For example, Gustav Adolf Breymann's (1807-1859) handbook on timber structures, who was Government building officer and professor at the Polytechnical School of Stuttgart, was reworked and completed in 1870 by professor Gustav Lang at the technical school of Karlsruhe, became afterwards professor at the polytechnical school of Riga, and then in technical school of Hannover. The book is once again reworked and extended in 1900 by professor Otto Warth, teaching at the technical school of Karlsruhe. To this list, we can add Fritz Kress, who traveled to different states and taught in different technical schools connecting the timber knowledge of Berlin to that of Leipzig, Stuttgart, and Neustrelitz, by giving lectures in these cities. He became later a leading figure in the organized campaign to promote German timber engineering in the 1920s, which brought all the dispersed efforts of the carpenters and engineers of different regions under one umbrella and in a converged network aiming at promoting structural timber in the building industry.

Here it could be seen that in Germany and Switzerland, thanks to a non-centralized governing system, the change from the guild structure to freedom of trade, was not at all an abrupt change and a linear transition process, but a gradual one cycling back and forth between those two forms, including many intermediate stages, stretching over the whole 19th century. This process gave the craftsmen the opportunity to negotiate with the regional governments (with whom they had close political relationships as we can see later in the case of early Swiss carpenters licensed for glulam), to lobby, to voice their opposition, and to plan for the re-institutionalization of timber. Moreover, the dual-corporatist model in Germany (where shop-floor learning occurs parallel to learning at school), and also in Switzerland, gave the carpenters the opportunity to systematically pursue their role in training the generations to come, and by this to keep alive and update the supporting network of technologies related to this material.[120]

Glulam, a technology that hardly offered anything genuinely innovative technically speaking, got promoted through the genuine efforts of a part of the society that had been struggling for survival for many decades. Keeping timber an institutionalized structural material in Germany and in Switzerland, had a fundamental role in the emergence and development of engineered timber structures at the turn of the century.

Against the background developed in this chapter, the notion of engineered timber can be understood beyond the concerns related to timber, joint, glue, static calculation, and so on. The role of the

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[119] Ashby, Eric. *Technology and the academics: an essay on universities and the scientific revolution.* London, New-York, MacMillan St Martin's Press, 1958, pp. 220-222.

[120] In his study, Friedrich Lenger explored the dichotomy between the survival and abolition of corporative traditions in Anglo-American and continental European countries. He found many similarities between the French and German patterns and compared them to those in England and the USA. However, taking a different perspective may reveal more differences between these countries. Lenger, Friedrich. "Beyond Exceptionalism: Notes on the Artisanal Phase of the Labour Movement in France, England, Germany and the United States." *International Review of Social History*, vol. 36, no. 1, 1991, pp. 1–23

engineers, as well, can be portrayed, far beyond their apparent contribution of investing in the glulam patent and dimensioning the structural elements. A rich historical context, as we saw earlier, brought many factors together, from the availability or scarcity of the raw materials to the organization of the political system, the perspective of this system toward the role of the government, the perspective of government toward education, toward the concepts of mass and elite, toward the economy, toward social oppositions, towards the relations with neighbouring countries, accompanied with historical events, like the wars and revolutions. In this context, some people could keep significance using a material that was strongly devaluated, and glulam was that technology, which depicted the best this significance.

This historical vision could help us to understand why glulam had such a momentous contribution to the building industry, although being quite a simple one. This explains as well, how deep the hopes, ambitions, and efforts for technological changes and their implementation concern the reasons and accounts that are indeed almost totally dissociated from the technology itself.

Timber was transformed into glulam for several reasons. It was transformed to make long curved structural elements to construct big halls and factories. It was transformed by people's hopes, ambitions and insights, disbelieves and prejudices, collaborations or conflicts and tensions, whose social, economic, and political status was strongly related to this material. One category of these actors who, historically, were not much associated with structural timber, however, had a major contribution to the re-institutionalization of it, includes the engineers. Glulam as an engineered product should be understood through their contribution, in the continuity of one-century-long efforts of the carpenters, to the re-institutionalization of a material, known as an outdated, unprecise, and unpredictable.

Chapter two

Swiss entrepreneurship

the patent-licensing cartel

In the previous chapter, it was demonstrated that while both eighteenth-century England and France had already existed as nation-states for a long time, Germany and Switzerland only became nation-states towards the end of the 19th century. These young nation-states biased for a decentralized governance, which, along with other reasons, resulted in quasi-persistence of the guilds regulations and traditions for over a century. This difference could serve to explain why timber engineering was mainly a German, and subsequently a Swiss affair. However, as we will see in the present chapter, the early market structure of this technology met fundamental difference in these two countries. Understanding the reasons of this difference is a major step to explain the particularities of the Swiss market and the reasons for the exceptional early development of Swiss glulam.

Although it was in Germany that a considerable amount of innovative and engineered timber structures was developed in the turn of the 20th century, it was in Switzerland that the revival of structural timber pushed the early institutionalization of it, leading to the first European timber code of standard practice in 1925. This pioneering role of Switzerland was largely due to the particular organization of the early network of glulam, both in the technological and the economic level.

As discussed in the previous chapter, glulam patented in 1906, was by no means an invention. However, the fact that it was very early taken up by the timber industry, was due to both historical decisions and historical events. It was at the intersection of choices and chances that the practice of glulam went beyond technological possibilities and developed into an economically profitable and socially acceptable concept.[1] A process, to which, Schumpeter, the great economic historian refers as "entrepreneurial innovation". It happens when a technical change is followed by the act of entrepreneurship, explained by Schumpeter as the root of economic growth.[2] What concerns us here, is not glulam as an invention, but as an innovation, or the successful exploitation of the technology in the market. This approach to technology, which allows a comparatively wide-scope to the play of economic motives, plays a key role in understanding the particularities of the early Swiss contribution to the development of glulam.

The promotion of early glulam technology was a deliberate economic activity and profit-oriented entrepreneurship in both German and Swiss contexts, but followed different patterns and established the market differently in each. The question arises as to why these differences existed and what impact the unique Swiss approach to entrepreneurship had on the early development of glulam.

[1] For the space of technical change see: Perez, Carlota. "Technological revolutions and techno-economic paradigms". *Cambridge Journal of Economics,* 2010, vol. 34, no.1, pp. 185–202.

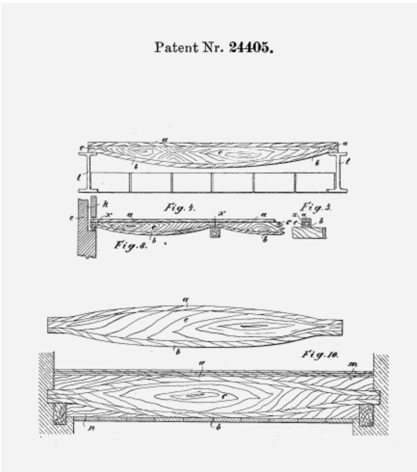
[2] Schumpeter, Joseph A. *Theory of Economic Development*. London, Routledge, 2021(initially published in 1911). Questioning the drivers of technological changes have been the subject of abundant studies. The relation between the economy and the technical change, explained first by Schumpeter, was later subject of more critical studies. Among the most relevant to our subject here could be the Dosi & Giovanni's, "Technological paradigms and technological trajectories: a suggested interpretation of the determinants and directions of technical change" *Research Policy*, vol. 11, no. 3, 1982, pp. 147-162. These scholars explain the concept of "technological paradigm", mediating between the two approaches of "demand pull", and "technology push", that interpret the technical changes.

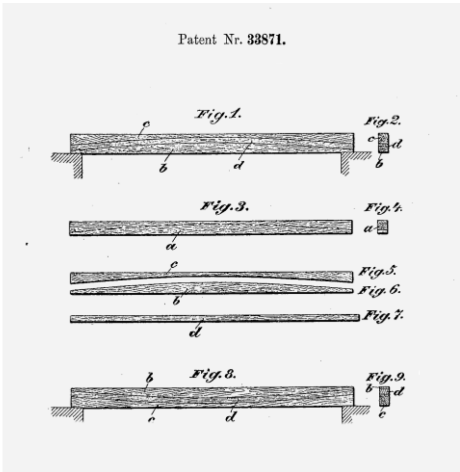
1. One patented technology, two different markets

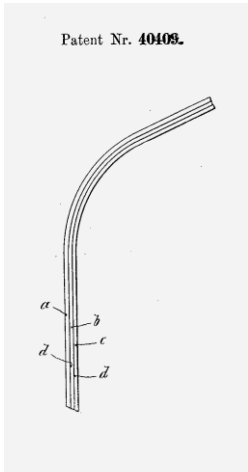
Glulam was patented in 1906 after successive efforts of Otto Hetzer, German master carpenter to produce more economic timber alternatives by combining and gluing smaller pieces of wood. Table 2.1 shows some of his most recent patents:[3]

Table 2.1 The most recent patents registered by Hetzer prior to glulam.

Patent registered in Switzerland in	Patent no.	Subject of the patent
1901	24405	Composite wooden beam
1905	33871	Wooden beams
1907	40409	Curved wooden building component







Figs 1-3: Illustration of patents registered respectively in 1901, 1905, and in 1907.

In 1872 Hetzer founded his firm as a steam sawmill combined with a wood processing and carpentry workshop, right after returning as a soldier from the Franco-Prussian war. He had about 300 employees at its peak and was therefore an important employer and taxpayer for the city of Weimar.[4] Germany, emerging victorious from the war, experienced a veritable economic boom in the following years. The company of Hetzer was one like many others, which shaped the Franco-Prussian postwar episode of the economic growth of Germany.

Hetzer's company was converted into a joint-stock for further expansion. Hetzer *Holzpflege und Holzbearbeitung Aktiengesellschaft* (Woodcare & Woodworking) was registered in 1901 as a joint-stock company. Studies on the Berlin stock exchange in the period 1892-1913 reveal the role of the successive registered patents in transforming the company into a joint-stock one, and to sell its shares

[3] The title of the patents in German are respectively: 1. Zusammengesetzter Holzbalken, 2. Holzbalken, 3. Gebogener Holz-Baukonstruktionsteil. Hetzer had registered previous patents prior to the ones mentioned above, such as a new system for the installation of parquets: Arndt, C., et al. *Das Buch der Erfindungen Gewerbe und Industrien : Gesamtdarstellung aller Gebiete der gewerblichen und industriellen Arbeit sowie von Weltverkehr und Weltwirtschaft,* Leipzig, Verlag und Druck von Otto Spamer, 1896, p. 407.
[4] Wirth, Hermann. Speech at the dedication of a memorial plaque on October 21, 2004. Bauhaus-Universität Weimar, 2004. (https://web.archive.org/web/20110313030549/http:/www.otto-hetzer.ch/Texte/Laudatio.pdf _ visited online on 12.4.2018)

in the stock-exchange. The number of the patents was usually used as a leverage for the trade of the shares, to increase the initial public offering or stock launch, while transferring the firm into a public company, with the aim of financing and promoting further the innovative activities of the company.[5] These innovative firms were therefore dependent on the number of their patents as assets, and as a source of financing further the future projects. These successive patents registered by Hetzer should therefore be understood in the context of entrepreneurial strategic development, rather than technical novelties.[6]

Thus, in the favorable economic circumstances of the Wilhelmine Age, the economic benefit of the joint-stock company, pushes Hetzer to develop more patents for its wooden products, while initially one concept more or less stays fixed: to expand the use of the German red beech wood.

The core idea of Hetzer's successive patents was the material economy, as well as extending the use of German red beech wood.[7] Hetzer's company for parqueting started with the production of its beech floorboards (Buchenholz Fussböden), which were cut from the trunk in such a way that the core remained as a beam of square cross-section. These woods, as described by the technical journal of the time, the best part of the trunk and of special strength, were not suitable for floorboards and due to their small dimensions could not be used as construction timber. Hetzer laid these parts on top of each other several times and joined them together with an adhesive under high pressure to form beams.[8] Moreover, the approval of beech as a railway sleeper wood by the Royal Prussian Railway Minister in 1900 represents a major expansion in the use of beech, and also in the diversification of the projects of the Hetzer's company. It was well known that the wood of the German beech forests was not used in a way that could correspond to its properties and was mostly sold as firewood.[9] Hetzer proposed then an appropriate care for the beech wood, a process specific to the company, for removing the protein substances from the wood. This treatment thus opened up a totally new and large branch of business to Hetzer's company.[10]

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[5] Lehmann-Hasemeyer, Sibylle, and Jochen Streb. "The Berlin Stock Exchange in Imperial Germany: A Market for New Technology?" *The American Economic Review*, vol. 106, no. 11, 2016, pp. 3558–76. In which the authors analyze 474 cases of firms going public in the German capital between 1892 and 1913. However, it is not sure if Hetzer's company's share were listed in the Berlin stock or not, since at the beginning of the 19th century, there were 23 stock exchanges in operation in Germany. See: Burhop, Carsten, and Sibylle Lehmann-Hasemeyer. "The Berlin Stock Exchange and the Geography of German Stock Markets in 1913." *European Review of Economic History*, vol. 20, no. 4, 2016, pp. 429–51.

[6] Patent itself, as we know them today, is a production of the *Deutsches Kaiserreich* (1871-1918). This law codified for Germany for the first time the practice of privileging inventions by means of letters of protection (inventor privilege). See: Däbritz, Erich. *Patente: Wie versteht man sie? Wie bekommt man sie? Wie geht man mit ihnen um*? Munich, C. H. Beck, 2009.

[7] Techow, H. „Fussböden aus Rothbuchenholz". *Zentralblatt der Bauverwaltung*, no. 7, 1894, p. 69. Koch, Hugo."Baustoffe und Baukonstruktionen". *Berlin und seine Bauten*. Berlin, Ernst, 1896, p. 424

[8] However, soon the use of beech wood for this purpose was completely put aside, and spruce was mainly used which "is the easiest to bend and has the cleanest knots". Adams. "Neuere Holzbauweisen". *Zentralblatt der Bauverwaltung*, no. 21, 1907, pp. 147-148.

[9] H. Techow, Prussian government building officer in Berlin. *Zentralblatt der Bauverwaltung*, no. 7, 1894, p. 69.

[10] *Otto Hetzers Holzpflege- und Parkett-Fabrik in Weimar*, Hof-Buchdruckerei, Weiamr, 1900, pp. 1-9.

1.1. Germany: State intervention

In view of the importance that the utilization of beech wood had for the national forestry industry of Germany, a renewed reference to the appropriate method of production of these floors was noticeably supported by the Prussian state, to the extent that the early patents of Hetzer concerning flooring, resulted in the new brand of a parqueting system, promoted and celebrated as the *Deutscher Fußböden* (German floor).[11] Promoting Hetzer's product by labeling and defining it with the descriptive "German", was within the efforts of branding commodities as national products, started at the end of the 19th century. Hetzer's parquet was promoted then as a national trademark, and the government becomes a major client of the products of the company, for its many public buildings that were under construction at the turn of the 20th century.[12] It was even assumed that the State Forestry Administration, would move on to planting beech, on land unsuitable for coniferous wood.[13] Besides, the journals of the time reported on a trade war, where the USA closed off their market to German trade, and subsequently Hetzer, in line with the policies of the Wilhelmine State, was increasingly trying to promote his products on both the domestic and the foreign market of the German beech wood, and particularly for the use in the German building industry.[14] Hetzer's company, by increasing the variety of products (parquet, railway slippers, carpentry elements, composite beam, reinforced beam, glulam, etc.) while using the same set of resources (concentrating on the German beech wood), aimed at increasing the use of this wood, benefiting hence from "economies of scope", where the efficiencies are formed by variety, and not by the volume of the output. The economies of scope shaped the model of his business and pushed the relatively short-term performance of the company, until 1926, when the whole business went bankrupt. [15]

Hetzer, from 1891 on, was honored with the title *Großherzoglicher Hofzimmermeister* (the grand-ducal master carpenter), and his innovative concepts were then repeatedly reported in the high-profile journals and promoted in professional circles, supported by the Prussian Ministry of Public Works. He was recognized and highly respected in the business world, by high state authorities and in wide circles of Prussian building administration.[16] This achievement should be also understood in the context of Wilhelmine Prussian state propaganda for design and increasing the reputation of German

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[11] Techow, H. „Fussböden aus Rothbuchenholz". *Zentralblatt der Bauverwaltung*, no. 7, 1894, p. 69

[12] In an advertisement of the company of Hetzer, it is claimed that "Whole barracks, schools, post office and public buildings are covered with floors from our system and with wood that has been cared for using our process." Handbuch des Bauwesens, 1907, No title page found, P. 482.

[13] Stated by H. Techow, Prussian government building officer in Berlin. *Zentralblatt der Bauverwaltung*, no. 7, 1894, p. 69.

[14] "Fussböden aus Rothbuchenholz von Otto Hetzer in Weimar". *Deutsche Bauzeitung*, vol. 26, no. 100, 1982, pp. 609-10. Historians mention several reasons for the progress of anti-German sentiment in the United States in 1870s-1914. Herbert Sirois explains it as a consequence of interest conflict, or establishing and expanding their hegemony in their sphere- namely Europe and Latin America. Sirois, Herbert. *Zwischen Illusion Und Krieg. Deutschland Und Die USA 1933 - 1941*. Munich, Schöningh, pp. 15-17. See also: Schieber, Clara Eve. *The Transformation of American Sentiment toward Germany, 1870-1914*. Boston, Cornhill Pub. Co, 1923.

[15] In 1926, the Hetzer company disappeared from the market and had to file for bankruptcy, probably due to the migration of qualified carpentry personnel abroad (economic development in Germany was characterized by inflation).

[16] *Rede bei der Begräbnisfeier von Herrn Hofzimmermeister otto Hetzer*, 1911, as cited in Müller, Christian. Die Entwicklung des Holzleimbaues unter besonder Berücksichtigung der Erfindungen Otto Hetzer- ein Beitrag zu Geschichte der Bautechnik. PhD dissertation, Bauhaus-Universität Weimar, 1998.

products for the export,[17] to boost the country's competitive position in international markets, and in the context of this State's goal for qualitatively superior "German Style" in the global commerce. A State that became a true sponsor of modernist design principals through its economic development policies,[18] and through a centralized economic development model, as different publications of John Maciuika demonstrate the interrelation between propaganda, design, education, economy, and politics of the Wilhelmine State.[19] The government-supported export also included structural timber for building purposes, to almost all continents.[20]

By shifting the focus towards the southern alpine neighbor, it can be observed that the relation between the then young federal government and the business elites reveals major differences with the German context.

The Swiss timber industry, at the end of the 20th century, had lost almost entirely all its export capacities, and the timber trade was reduced to the domestic market. In a petition sent by the *Schweiz. Holzindustrie-Verein* (Swiss Wood Industry Association) to the Federal authorities in 1886,[21]this association outlined the frustrating situation of the export of timbre. Being just founded during the same year, this institution counted different reasons as responsible for this situation: among other reasons, this fact was mentioned that Switzerland is locked among the neighbouring countries. So, the lack of access to the trans-boundary waters, presents the railways transport as the only available choice as the export means. However, since the railways companies at that time, were not yet unified as a Federal institution, they remained a collection of different private companies, a situation which was mentioned to be as one of the main reasons for setting the transport prices relatively high and responsible for the dramatic state of timber export in general. The central government could not establish rules and regulations, for the private and in some case foreign companies, in favour of the transport of wood. According to the petition, France remains as the only export destination,[22] which was not counted as a considerable market. The petition alarmed that "the complete ruin of the Swiss timber export industry would have to be stated as a fact in a very short space of time".[23] The situation

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[17] In 1907, Germany exported barracks, country houses, and furniture to various European countries and also to countries such as Argentina, Mexico, Western India, Egypt, and South Africa. *Handbuch des Bauwesens*, 1907, No title page found, P. 483.

[18] Maciuika, John V. *Before the Bauhaus: Architecture, Politics and the German State, 1890-1920*. Cambridge, Cambridge University Press, 2005, and Maciuika, John V. "Art in the Age of Government Intervention: Hermann Muthesius, Sachlichkeit, and the State, 1897-1907." *German studies review,* vol. 21, no.2, 1998, pp.285–308.

[19] Maciuika, John V. "Werkbundpolitik and Weltpolitik: The German State's Interest in Global Commerce and 'Good Design,' 1912-1914." *German politics and society,* vol. 23, vol. 1, 2005, pp.102–127.

[20] See note 16 above.

[21] Eingabe Schweizer. Holzindustrie-Vereins an den Hohen Bundesrath zu geehrten Handen der Tit. Bundesversammlung (Petition of the Swiss. Wood Industry Association to the Federal Council), 1886. Basel, Schweizerisches Wirtschaftsarchiv (Swiss Economic Archives), B. Verb./Bc 619.

[22] According to the petition, the export was only possible to France, since the import of wood in Germany and in Italy, was mainly done through the borders to Austria, where, considering the taxes and the transport prices, this was more advantageous rather than Switzerland. See note 21 above)

[23] Eingabe Schweizer. Holzindustrie-Vereins an den Hohen Bundesrath zu geehrten Handen der Tit. Bundesversammlung (Petition of the Swiss. Wood Industry Association to the Federal Council), 1886. Basel, Schweizerisches Wirtschaftsarchiv (Swiss Economic Archives), B. Verb./Bc 619, p. 2. Original text in German: „bei solchem Forschreiten des Ausfalls der

shows that, unlike in Germany where a strong policy-making system supported the timber trade for the purpose of pushing the export, in Switzerland, the export of the structural timber, in the lack of direct support of the young Federal state shrank to minimum and resulted in the convergence of the efforts towards a domestic market, which is normally more subject to restrictive practices and policies.

In order to understand different marketing of glulam in Switzerland and in Germany, we should moreover consider the fact that, at the turn of the 20th century, the German market was highly dynamic by different patented timber structures, such as Carl Tuchscherer in Breslau, Metzke & Greim in Berlin, Dehall in Munchen, Christoph & Unmack in Niesky, Paul Schulz in Berlin, Hetzer in Weimar, to name a few. This animated scene of novelties in structural timber, generated a chaotic situation for the local carpenters. As previously explained, these patents should be indeed considered as tools helping the carpentry firms to expand their business.[24] This elevated the dynamic of the carpentry trade, at the expense of the smaller firms whose share of the trade was shrinking day by day. The decrease of interest in timber as structural material in the 19th century reduced the number of clients and projects, and those business that survived this complicated situation were then facing a new market condition: those who were not owner of patents, had to be satisfied with the small-scale local project or being sub-contracted by the larger companies.[25]

As Mathias Seraphin explains in his doctoral thesis, those bigger companies tried to allay these fears by giving lectures in the professional circles, clarifying the situation of the market loaded with patent. In 1910, according to Seraphin, the journal *Deutscher Zimmermeister* (German Master Carpenter) reported on a lecture given by father and son Hetzer to the regional association of Thuringian master-carpenters. According to this speech, the company of Hetzer was in the majority of projects, entrusted with the delivery of the patented parts, were the assembly, the delivery and carpentry of other non-patented timber elements were contracted out to the local master-carpenters. [26]

Hetzer's licensing model aimed at, according to himself, enhancing the cooperation between the nation-wide companies and the local carpenters:

> In all cases, we are prepared to offer Hetzer constructions at favorable prices to members of the Association of German Master Carpenters in competition with stone, concrete and iron, or to hand over licenses for self-fabrication at moderate rates. We might also be prepared to issue licenses for entire

vollständige Ruin der Schweizer. Holzexportindustrie in kürzester Frist als geschehene Thatsache konstatiert warden müsste."

[24] "The company Stephan Düsseldorf traded as a limited liability company on its patent applications between 1904 [DRP 176759] and 1921 [DRP 391534]. Hetzer, Tuchscherer, Christoph&Unmack, Adolf Sommerfeld as well as Karl Kübler trade as AGs". (as cited in Müller, Christian. Die Entwicklung des Holzleimbaues unter besonder Berücksichtigung der Erfindungen Otto Hetzer- ein Beitrag zu Geschichte der Bautechnik. PhD dissertation, Bauhaus-Universität Weimar, 1998, p. 165)

[25] From 1816 to 1861the number of master carpenters in Germany reduced from 9464 to 4633, shrinking to less than half. See Bringmann, August. *Geschichte der Deutschen Zimmererbewegung.* Hamburg, 1909, p.117.

[26] Seraphin, Mathias. *Zur Entstehung des Ingenieurholzbaus - eine Entwicklungsgeschichte*, PhD dissertation, Technical University of Munich, 2003, p. 165. Original citation in N.N.; Bezirksverband Thüringischer Zimmermeister -Versammlung 06.02.1910; in Deutscher Zimmermeister 8/1910.

districts not to individual gentlemen, but to the associations, so that there would then be a central office for production from which all members living in the vicinity could obtain license.[27]

The situation in Switzerland was however quite different. The market for the innovative uses of structural timber was much less dynamic and the licensing system of Hetzer's glulam was fundamentally different from what was described by Hetzer as the licensing model in Germany. Moreover, the almost total absence of the direct support of the Swiss Federal government as a driver of the market of this technology can be clearly recognized.

In the Swiss context, the network of early glulam developed over a single-output scenario, the structural glulam, and set up protectionist policies, in order to promote this single product. This is what the economists call the "economies of scale" (in contrast to the "economies of scope" adopted by Hetzer), which is more prone to monopolistic approaches and protectionist policies.

1.2. Early Swiss glulam network

In 1909 Terner and Chopard established their office in Zurich and during the same year they received the exclusive right to exploit the 3 patents of Hetzer in Switzerland (Table 2.1). The first 3 years, Hetzer remained as one of the holders of patent in Switzerland alongside with Terner and Chopard. The patents expired each after 15 years, respectively in 1916, 1920 and glulam in 1922.

Terner and Chopard, in close collaboration with the contractors of their early projects, set up an early network of regional competence centres. These well-established contractors – mainly carpenters – with various locations in Switzerland were granted the licence for the production of glulam. Each of them was responsible for several cantons.

The following were the glulam licensees in 1910:[28]

- Fietz & Leuthard, in Zurich, responsible for Zurich, St Gallen, Schwyz;
- Albert Blau's widow, in Burgdorf, responsible for Bern, Aargau (northern part), Fribourg, and Lucerne.[29]
- Riesterer-Asmus, in Basel, responsible for Basel Land, Basel Stadt, Solothurn, Aargau (southern part) and Schaffhausen;
- A.-G. Baugeschäft Chur, in Chur, responsible for Graubünden and Ticino,
- Bugnion, in Lausanne, responsible for Vaud, Neuchâtel, Valais, Geneva.

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[27] *Ibid.* Original text in German:„Wir sind in allen Fällen bereit, im Konkurrenzkampf in Stein, Beton und Eisen den Mitgliedern des Bundes Deutscher Zimmermeister die Hetzer-Konstruktionen zu günstigen Preisen anzustellen bzw. zu mäßigen Sätzen die Lizenzen für Selbstfabrikation abzugeben. Evtl. wären wir auch bereit, für ganze Distrikte die Lizenz nicht an einzelne Herren, sondern an den Verband abzugeben, sodass dann eine Zentralstelle für die Fabrikation existiert, von der alle Mitglieder, die in der Nähe derselben wohnen, beziehen können.“ (Translated by the author)

[28] According to Hübner, four carpentry companies were involved, while Helmut Kühne believed there were 6 of them. Hübner, Fritz. "Versuche mit Holzbalken nach Bauweise Hetzer". *Schweizerische Bauzeitung*, vol 83/84, no. 6, 1924, pp. 51-65. The list presented here is taken from the official advertisement of the Terner & Chopard engineering office, in *Schweizerische Bauzeitung*, vol.55/56, no. 17, 1910.

[29] The first contractor for the Bern area was Veuve Albert Blau. The company was founded in 1890 by the Baumeister Ludwig Albert Blau. In 1903, after the death of Albert Blau, his wife took over the company, which was resolved in 1911. Afterwards Gribi became the licensed partner for the Bern region. The status of the licensed contractors will be discussed in chapter three.

At the end of 1912, the patent holders (Terner & Chopard) transferred the patents of Hetzer to a newly established consortium, in order to coordinate all glulam activities, the Schweizierische A. -G. für Hetzer'sche Holzbauweisen Zürich (Swiss Corporation for the Hetzer Timber Construction System). Starting officially in 1913, the consortium got slightly extended by engaging more licensees: Locher & Cie in Zurich, and Zöllig in Arbon joined the consortium and Gribi & Cie, replaced Albin Blau's widow's company which was dissolved in 1911, following the death of owner.

- Fietz & Leuthold, in Zurich, responsible for Zurich, St Gallen, Schwyz, Aargau & Uri;
- Locher & Cie. in Zurich,
- Zöllig, in Arbon, responsible for Thurgau, Lucerne & Glarus;
- Gribi & Co, in Burgdorf, responsible for Bern;
- Riesterer-Asmus, in Basel, responsible for Basel Land, Basel Stadt, Solothurn and Schaffhausen;
- A.-G. Baugeschäft Chur, in Chur, responsible for Graubünden and Ticino,
- Bugnion, in Lausanne, responsible for Vaud, Neuchâtel, Valais, Geneva and Fribourg.

To this list, should be added the company Nielson-Bohny in Basel which apparently later joined the consortium.

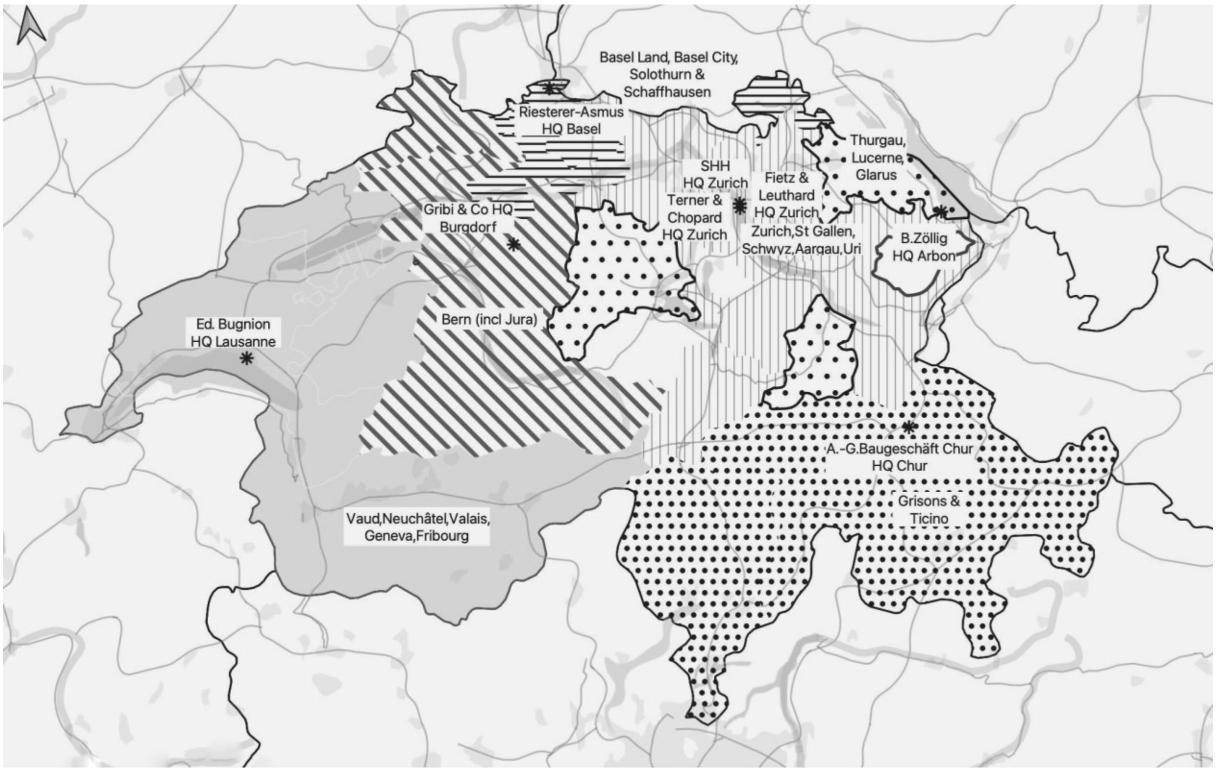

Fig. 4 The areas of responsibility of the glulam licensees as of 1917.

Figure 4 shows the areas of responsibility of the licensees as of 1917. Some areas were not covered by the network for which the reason is not known. The role and the responsibilities of the licensees will be discussed in-depth in the next chapter.

The nature of the business of different licensees, their role within the consortium, their effort to promote glulam, and their involvement in development of glulam from technological point of view have not been the same. What we can observe is that, first of all, the network has been nation-wide quite homogeneous in the structure: the engineers in the head of the consortium (although in the board of directors, usually one contractor is involved, but the representative figures of the consortium always remained the engineers Terner and Chopard), with a limited number of contractors as the licensees, organized in a restrictive way. In the directing board we see other figures from the business world: the board of directors always included Terner or Chopard, usually one of the licensed contractors and usually a figure from the Swiss business or financial world. This way, the company merged economic and technical expertise. First president of the board of directors was Jean Baer who was joined by Charles Chopard and also Georges d'Eplattonier, who held commercial power of attorney. Jean Baer was the director of the upcoming Swiss company Eternit which manufactured fibre-reinforced cement-products, patented also only a few years back in 1903. Two years later, they were replaced by a new board, consisting of the new director Emil Burkhard, a Swiss engineer based in Milan – who was the license holder of glulam for Italy as well –, vice director Eduard Bugnion, one of the licensed contractors based in Lausanne, and Bernhard Terner. Since this complete constitution, the company resided at Stampfenbachstrasse 15, a commercial building near Zurich's main railway station. Terner and Chopard were not only closely linked when it came to company policy, but also spatially. One year after the consortium was founded, they moved into the same building with their engineering office.

Regarding the role of government, it should be noted that although in Germany, a strong policy of the Wilhelmine period, set the scene for the economic development of the country through the direct influence of the government, in Switzerland, with "the constrained policy capacity of the central state", as André Mach and Christine Trampusch refer to it, the government with a restricted involvement had a background role in the economic growth. These scholars consider this as the first factor playing a crucial role in shaping the organization of the Swiss political economy, which is followed by "the strong tradition of self-regulation by economic associations" as the second decisive character of the Helvetic political economy. [30]

The organization of the Swiss political economy should be understood as the project of the business elites. Many factors that progressively emerged during the 19th century and shaped the political economy, such as governance models and decision-making processes, industrial relations and market regulations, vocational training systems, distribution of the means of production, as well as limiting or promoting competition in the product market, can only be understood by the central role of business elites in the organization of the Swiss political economy, played in the "shadow of politics", without the direct involvement of the politicians.[31] As Mach and Trampusch explain, it was in the context of

[30] Mach. André, and Christine Trampusch. "The Swiss Political Economy in Comparative Perspective". *Switzerland in Europe: Continuity and Change in the Swiss Political Economy,* edited by Christine Trampusch and André Mach. London, Routledge, 2011, pp.11–26; citation in page 15.
[31] *Ibid.*

“quiet politics and informal institutions” that the business elites including the employers and the trades associations, could largely self-regulate major socioeconomic issues (like labor market regulations that will be discussed in the next chapter).[32] In this context, the early development of glulam and the particular way of the organization of its early network should be understood in the context of the coordinated market economy of the country, “characterized by dense interfirm networks and the strong role of business associations”.[33] In the Varieties of Capitalism, Hall & Soskice define the coordinated market economies, as a context in which,

> [the] firms depend more heavily on non-market relationships to coordinate their endeavors with other actors and to construct their core competencies. These non-market modes of coordination generally entail more extensive relational or incomplete contracting, network monitoring based on the exchange of private information inside networks, and more reliance on collaborative, as opposed to competitive, relationships to build the competencies of the firm.[34]

This characteristic, as we will see later in this chapter, largely influenced the spread and the adoption of glulam as a technological innovation during the turmoil and upheavals that shaped the first half of the 20th century.

The main question that arises here is why the early actors privileged a restrictive network in Switzerland, and how this organization influenced the early development, spread and adoption of the technology in this country?

1.3. Why a consortium?

In the last section it was demonstrated that the early glulam was developed within two different markets in Switzerland and in Germany. The Swiss organization was more in favour of protectionist approaches in form of a consortium, while in Germany, the alternative of a more liberal model was privileged. This consortium shaped a clear barrier to entry by limiting the number of contractors practicing early glulam and by assigning geographically to each licensee a target territory of the market. This eliminated to a high degree the competition among all the possible contractors of the consortium.

One of the main purposes of restrictive practices and protecting devices at the time of the introduction of new things, like new technologies, as explained by Schumpeter in Capitalism, socialism, and democracy, is to help “steady the ship” and “alleviate temporary difficulties” at the early time of the introduction of these novelties:

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[32] Mach, André, et al. “From Quiet to Noisy Politics: Transformations of Swiss Business Elites’ Power.” *Politics & Society*, vol. 49, no. 1, Mar. 2021, pp. 17–41

[33] *Ibid.*

[34] *Varieties of Capitalism: The Institutional Foundations of Comparative Advantage*. Edited by Peter A Hall and David Soskice, Oxford, Oxford University Press, 2013. Introduction, pp. 1-68. Citation in page 8.

> Long-range investing under rapidly changing conditions, especially under conditions that change or may change at any moment under the impact of new commodities and technologies, is like shooting at a target that is not only indistinct but moving—and moving jerkily at that.[35]

By this explanation, Schumpeter considers the "monopolistic practices" – which are generally regarded as suspicious – as normal elements of rational management, similar to the "patenting system, temporary secrecy of the process, and in some cases, long-period contracts".[36]

One category of these monopolistic practices is the case of cartels. Largely considered a market failure, the cartels once were blamed and widely criticized by the literature on price theory accusing them of pushing up prices. This accusation was later rejected as empirically unsound, and scholars have studied as well, as we will see below, the constructive aspects of restrictive and monopolistic practices. In the following section, it will be argued that a similar approach at the early phase of the development of glulam influenced and pushed its early success.

1.4. Cartelistic character of the Swiss glulam consortium

Terner and Chopard, in collaboration with the contractors, organized via the glulam consortium (as a temporary setting for effective exploitation of the patented technology and the benefits of the temporary monopoly), a quite particular network, in which the production, the research and development sector, the quality control body and the market organization overlapped. The market structure is normally defined as any one of the possible configurations of sellers of which perfect competition and monopoly are the polar cases.[37]

The way of organizing the network of professionals of the technological aspects and the market, in a consortium, was based on cooperation, which did not exclude competition but restricted it to limited areas.

The study of the early glulam network, particularly the cooperation or the consortium set up in 1913, from several perspectives reveals its cartelistic character, although what constitutes a cartel is by no means an easy question. Debate still rages about why they existed and about the economic impact they exerted.

In a research on cartels commissioned by the *Département fédéral de l'économie publique* (Federal Department for Public Economy) published under the title *Les cartels et la concurrence en Suisse* (Cartels and Competition in Switzerland), published in 1957, the following definition for cartel in Switzerland is proposed:

> Agreements concluded between entrepreneurs or companies of the same branch or of similar branches which, while preserving in principle their independence, seek to maintain or improve

[35] Schumpeter, Joseph A. *Capitalism, Socialism and Democracy*. London and New York, Taylor and Francis e-library, pp. 87-106. Citation p. 88.
[36] *Ibid.*
[37] Kamien, Morton I., and Nancy l. Schwartz. *Market Structure and Innovation*. Cambridge: London, Cambridge University Press, 1982., p. 2.

> their income or even to attenuate the decline in it by means of a collective limitation of the competition.[38]

In the organization of the Swiss market, article 31 of the revised Federal constitution of 1874 on the "Freedom of Trade and Industry" played an important role, where the "freedom of trade and industry was guaranteed throughout the territory of the Confederation". This included as well the freedom of limiting and restricting the market. In Switzerland, cartels flourished from 1880 in various forms, especially in the sectors of construction, cement, iron, aluminium, coal, glass, potash, the chemical industry, but also paper, cheese, textiles, cables, beer, chocolate, shoes, and books. Other cartels were formed and then dissolved several times, or only managed to consolidate in the context of the war and the crisis of the 1930s.[39,40]

The cartelistic character of the early glulam consortium should be understood in its historical context of craft organizations and in the continuity of the guildish charters, a topic that is addressed in the previous chapter. The craft guilds were not disappeared due to misfunctioning or through adaptive failure, but because national states abolished them by decree.[41] The abolition of the guilds, as was demonstrated previously, did not immediately give an end to the conservative market in Germany and in Switzerland. Throughout a whole century, several solutions were proposed which were interspersed with elements of protectionist dispositive. One of the most well-known is the cartelization movement. It is not coincidental that Germany, where the guild system prevailed into the 19th century, was known as the "land of cartels", and in a bigger context, the German speaking area as "the most heavily cartelized sphere of the world"[42], while Switzerland where the guilds were functioning until the establishment of the modern federal state, was labelled as "the unmatched world champion[43] of cartels".[44]

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[38] *Les cartels et la concurrence en Suisse*. Published by le Département Fédéral de l'Economie Publique, Bern, Feuille officielle suisse du commerce, 1957, p. 21. Original text in French: "Les accords conclus entre entrepreneurs ou entreprises d'une même branche ou de branches similaires qui, tant en conservant en principe leur indépendance, cherchent à maintenir ou à améliorer leur revenu ou encore a en atténuer le fléchissement au moyen d'une limitation collective de la concurrence". (translated by the author)

[39] Tissot, Laurent, and Peter Moser. "Économie intérieure, tourisme et agriculture". *Histoire économique de la Suisse au XXe siècle*, edited by Patrick Halbeisen et al. Neuchatel, Livero-Alphil, 2021, p. 556.

[40] *Ibid*, pp. 557-558.

[41] Epstein, S. R. Larry. "Craft Guilds, Apprenticeship, and Technological Change in Preindustrial Europe". *The Journal of Economic History*. Cambridge University Press (on behalf of the Economic History Association), vol. 58, no. 3, 1998, pp. 684-713.

[42] First citation from Leonhardt, Holm A. *Kartelltheorie und internationale Beziehungen : theoriegeschichtliche Studien*. Hildesheim, Georg Olms Verlag, 2013, p. 84. Second citation from Leonhardt, Holm A. *The Development of Cartel+ Theory between 1883 and the 1930s – from International Diversity to Convergence,* Hildesheim, Universitätsverlag Hildesheim, 2018, p. 28.

[43] Citation from the preface of *Regulating Competition: Cartel Registers in the Twentieth-Century World*, edited by Martin Shanahan and Susanna Fellman, Taylor & Francis, 2016. For the history of the cartels in Switzerland see also: Cortat, Alain. *Contribution à une histoire des cartels en Suisse*. Neuchâtel, Ed. Alphil, 2010.

[44] *Big Business and the Wealth of Nations,* edited by Alfred D. Chandler et al., Cambridge [etc.], Cambridge, 1997(2010), p. 201.

1.5. Glulam cartelized in Switzerland and not in Germany

Here this question might be asked that why the cartelization of glulam did not happen in Germany. One of the main arguments to explain this situation might be the fact that Germany, as we saw previously, developed very early a highly competitive market of engineered timber structures and products. It is also known that "the creation of cartels requires certain conditions, in particular the homogeneity of the product and a limited number of operators".[45] This very condition, was satisfied in Switzerland by converging almost all the forces on only one system of timber engineering, glulam. Although systems like Stephan found an early success in Switzerland like in Germany, however its use was limited to hall roofing projects with very few specific geometrical forms, whereas glulam contributed as well to the bridge building and scaffolding projects, and was used in form of beams and also columns for theoretically every structural element in buildings of any function, the fields where the other patented system, could hardy find a share of the market.

It should, moreover, be noticed that the production chain of early glulam, the line connecting the raw inputs (here lumber) to final output (erected glulam structure) was particularly short. Moreover, glulam being prefabricated, the majority of the work on lumber to transform it into glulam was done inside the carpentry shop. So, this very short chain of production, and the concentration of the dependence of many features of glulam on only few actors, gave the carpenter contractors more power to negotiate with the other actors, to shape and to feed the market. This "limited number of operators", as we saw earlier, is considered to be one of the principal conditions of shaping a cartel. As it will be demonstrated in the following chapter, those contractors who were the most active in this consortium and had the highest contribution to the early development of glulam, were those who expanded their business on the whole organization of the trade, by different roles that they adopted: being politically active in the city and cantonal levels, presiding the associations for the organization of all the trades related to timber, from tree cutting, its transport, sawing, impregnation, to all other activities related directly to glulam production. So, the main operations of the chain were mainly concentrated in single workshops. This short chain of production was a reason that kept this industry to a high degree a domestic economy and was suitable for a cartelized organization.

Generalizing about cartels is however quite difficult since they come in such a variety of forms, objectives, and effectiveness. Cartels adopted many functions, however, in the post-war period, under the influence of the antitrust ideas spread across the world, the interpretation was narrowed down to their protectionist aspect, as rent-seeking institutions. They were therefore perceived as a problem, and understanding them as a "conspiracy against the public" become the prevailing interpretation.[46] Later

[45] Tissot, Laurent, and Peter Moser. "Économie intérieure, tourisme et agriculture". *Histoire économique de la Suisse au XXe siècle*, edited by Patrick Halbeisen et al. Neuchatel, Livero-Alphil, 2021, p. 558.
[46] For more about this perspective toward the cartels see: Tanner, Jakob. "Kartelle und Marktmacht im 20. Jahrhundert". *Die offene Moderne – Gesellschaften im 20. Jahrhundert*, edited by Marx Christian and Reitmayer Morten. Göttingen, Vandenhoeck & Ruprecht, 2020, pp228-247. Citation in p.229.

on, business historians showed the varied effects and services provided by cartels (quality standards, technology transfers, or risk management) that extend beyond the conspiratorial motivation to raise prices, and studied cartels in their multifaceted functions.[47] The perspective adopted in this research towards cartels, which helps the most to explain the function and the influence of the cartelistic character of the early glulam consortium on its development, is best clarified in the book *les cartels et la concurrence en Suisse* (Cartels and the Competition in Switzerland), published in 1957. The authors favour the use of the word "benefit" over "profit", by emphasizing that the constitution of cartels, at least in Switzerland, has been a "general phenomenon" and not only a "capitalist operation".[48] It is in this perspective, that the beneficial aspects of this consortium will be analysed. Studying its profits, not being in the scope of this research, will be discarded here.

1.6. Why leaning toward cartelization?

It can be stated that among a multitude of functions of different cartels with different goals and mechanisms, this consortium can be understood first of all, as a patent-licensing cartel, a network where a shared knowledge about a technology is protected within the members, while the information from individuals outside of the network is strongly limited. Moreover, this consortium could be understood as a territorial cartel, which distributed districts of the market to individual (maximum 2 for the regions of Zurich and Basel) participants, acting as monopolists. This characteristic could be explained by, among other reasons, the regional dimensions and the particular Federal structure of the country.[49] In this context, it is important to know that when Terner and Chopard acquired the patent for glulam in late 1908, Hetzer remained the co-owner of it. The Swiss engineers and Hetzer then had equal shares. Only when Terner and Chopard transferred the patent right to the glulam consortium in 1913, Hetzer dropped his share, and the consortium was then presented as a "Swiss" association.

The very diverse cultural and political entities, the geography, and the topography of the territory pushed the early builders of glulam to pool their resources and to organize the early network of this technology as a cooperation-based national consortium and to arrange corporative capitalism, in which Switzerland has a strong tradition. In this national wide cartel, the early contractors could keep or build plants of optimum size. The distribution system and their market size could therefore stay almost the same as before. This would have made them less fragile in the hard times of the first half of the 20th century like war, post-war recession, prosperity, depression, again war, etc, which was not the case for example for Hetzer company which went bankrupt in 1926.

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[47] For an overview of the arguments in this regard, but also of the relevant studies see: Schröter, Harm G. "Cartels Revisited: An Overview on Fresh Questions, New Methods, and Surprising Results". *Revue économique,* vol. 64, no. 6, pp. 989-1010.
[48] *Les cartels et la concurrence en Suisse*. Published by le Département Fédéral de l'Economie Publique, Bern, Feuille officielle suisse du commerce, 1957, p. 19.
[49] Tissot, Laurent, and Peter Moser. "Économie intérieure, tourisme et agriculture". *Histoire économique de la Suisse au XXe siècle*, edited by Patrick Halbeisen et al. Neuchatel, Livero-Alphil, 2021, pp. 551-553. For a discussion in the broader European context see Schröter, Harm G. "Small European nations : Cooperative capitalism in the twentieth century". *Big business and the wealth of nations*, edited by Alfred D. Chandler et al., Cambridge [etc.], Cambridge, 1997(2010), pp. 176-206.

Moreover, it should be noticed that the carpenters, at the time of the introduction of the glulam patent, were already in a vulnerable situation, the reasons for which were addressed in the first chapter. They needed to invest in new patents and mobilize their different resources in this direction. Although it is hard to assess to what degree, launching the production line of glulam technology was a capital-intensive one, the archival records, mention that one of the early glulam contractors in 1909 had to go through a considerable extra cost for the "the introduction of electric power as a result of the acquisition of new machines, and the introduction of a patented timber construction method" (arguably glulam). The original text in German reads *"Anlernung einer Patentholzbauweise"*. The word *Anlernung*, in broader sense could be interpreted as the introduction of the technology to the workshop, including both the required capital stock and building up the human expertise.[50]

A comparison of the annual expenses of the company Trippel in Chur – which was in this research the only available and archived reports on annual costs of the early glulam contractors – demonstrates a considerable increase in the expenses related to machinery in the years 1909-1911(diagram below). However, it should be noted the analyse of other costs, such as movable assets/furnishing (?) and the fleet vehicles, demonstrates a general increase in the cost of the company. This could possibly be justified by a general increase in the capital of the company with the aim of expanding the business, for which the introduction of electricity would have been a necessary step. For these reasons, and considering the fact that the available archived material in this regard are very limited, it would not be easily possible to determine the share of glulam in the escalation of the costs of the years 1909-1911. It can simply be observed that the investment in tools and in machinery in 1911, when the company built its first glulam project, increased respectively 91% and 52 % in comparison to 1909, when the company got licenced for the production of glulam. Unfortunately, no record of the license fee could be found.

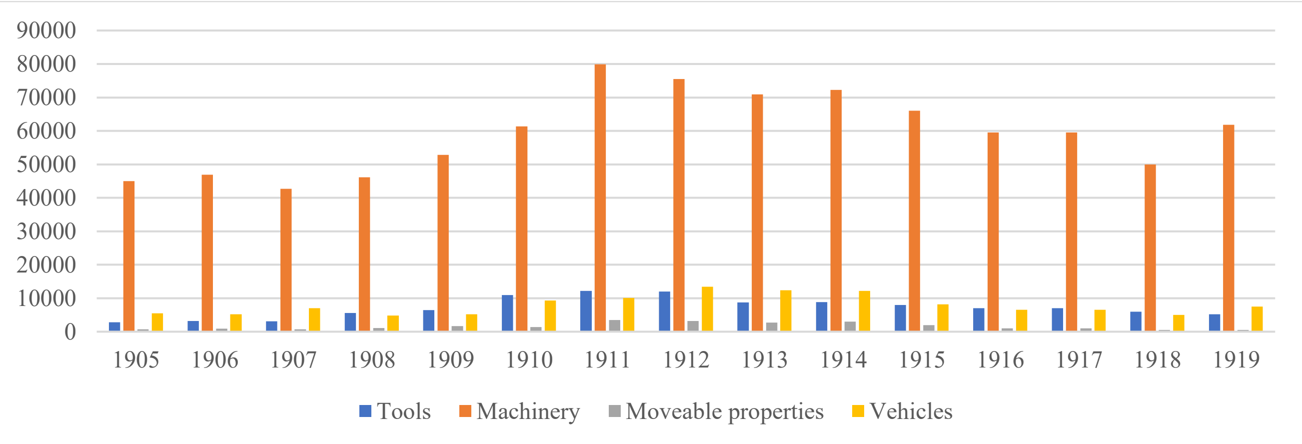

Diagram 2.2 Comparison of 4 categories of expenses of the company Trippel AG over the period 1905-1919

[50] Original text in German: "*Spesen infolge kapitalerhöhung, einführung elektrischer Kraft infolge Anschaffung neuer Maschinen, Anlernung einer Patentholzbauweise*". Trippel AG, Geschäftsbericht, Betriebsjahr 1909. Basel, Schweizerisches Wirtschaftsarchiv (Swiss Economic Archives), Erw. G. H. u. I/Bc 619.

In the same report, the company explains its main intention to invest in the license of glulam as "to be more evenly occupied throughout the year and to have a little less competition".[51] So the restrictive access to the technology and increasing the market power has obviously encouraged the contractors to invest in it.

Considering the fact that the building industry is one of the most vulnerable regarding the economic hazards, in addition to the fragile situation of structural timber in the building industry, it seems that investing in this new technology could be seen as risky. Against this context, those early contractors (mainly carpenters) decided to secure the investment by reducing the competition and the uncertainty associated with the implementation of innovations, but also by favouring the cooperation over competition and consequently facilitating the provision of the resources needed for promoting the glulam "innovation", in the sense of the word used by Schumpeter.[52]

Moreover, it should not be neglected that the influence of other industries which were heavily cartelized, such as cement and steel, the main materials for steel and concrete structures and the rivals of timber, could have arguably pushed the timber industry to organize itself via a similar system. The cartels generated in fact a social capital of shared norms and common information in a technological level, but also facilitated mutual sanctions and collective political action, which was needed in order to be able to compete with those other cartelized structural materials.

In this context of "alpine capitalism", term coined by Michel Albert in his Capitalism against Capitalism, and through the glulam consortium, the members could protect and close the Swiss market against the northern neighbor's products.[53] It should be considered here that the Germany's economy at this period was extremely strong, leading figure within the European borders, standing only behind the USA in an international scale. Besides, it is known that that at this time, Hetzer's glulam girders have been exported as far as south America.[54] This cartelistic organization of the domestic market could be considered as a strategy to ensure that the investment in the new technology would be worthwhile.

One important point that would additionally justify such a cartelistic organization of the early glulam network, is related to the social context of the turn of the 20th century, the industrial relations, and the strong waves of labour unrest. As it will be shown in the next section, this period until the end of the 1910s witnessed strong waves of discontent of the workers. The workers who constitute the majority of the actors who were practically performing the process of manufacturing and assembly of glulam, started to protest for their rights, and voicing their discontent from the working conditions via strikes.

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[51] Original text in German: "*Um das ganze Jahr hindurch gleichmässiger beschäftigt zu sein und etwas weniger in konkurrenz treten zu müssen, haben wir eine Lizenze für eine neue Holzbauweise erworben*".
[52] Schumpeter, Joseph A. *Capitalism, Socialism and Democracy*. London and New York, Taylor and Francis e-library, pp. 87-106.
[53] Albert, Michael. *Capitalism against Capitalism*. London, Whurr Publishers Ltd., 1993, 85.
[54] Denkschrift über Hetzer's neue Holzbauweisen, Verfasst im Auftrage des «Schutzverbandes für neue Holzbauweisen» von K. A. Urban, Grossherzoglicher Bauart in Weimar, 1913.

It was considered as a familiar practice at that time, that when a master-carpenter's project was halted by the strike of the workers, other contractors would have assisted the master in order to conclude the construction work. This situation would have very possibly imposed a form of the cooperation of the contractors, rather than the competition among them, especially in the case of dealing with a new technology, where not necessarily highly skilled, but surely a trained work force was needed to perform the tasks.

Last but not least, we should consider the role of standardization of the cartels, at the time that even normal timber structures did not have a building code of practice, let alone glulam. The process of standardization needed a limited network of well-stablished carpenters who could systematically evaluate the design and construction development of glulam, could have an overview on the damages, defects, failures, and all the problems occurring at different phases of the glulam building, who were involved in the process of decision making and could compare the result of different solutions proposed by different contractors for similar problems. This limited network based on cooperation, working as quality assurance bodies, had a crucial role on implementing common homogenized process of fabrication among all members and regulating the practice at the time that the official standard practice for glulam was not yet established.

1.7. Concluding remarks

To conclude, it can be stated that this study, besides contributing to the history of cartelization in Switzerland, in which the share of structural timber has been largely neglected, could demonstrate how the particular form of organizing the early network of glulam as a national consortium with cartelization tendencies substantially influenced the early domestic market and consequently the early development of the new technology. This study contributes as well to our knowledge and understanding of the technology diffusion and the entrepreneurship of innovative ideas via restrictive practices. Although the prevailing narratives accuse largely the monopolistic approaches by focusing only on their price-fixing and rent-seeking tendencies, a broader perspective on these practices could demonstrate other capacities of these approaches and served to explain why the early glulam particularly in Switzerland experienced rapid and steady development.

Despite the current theories that praise the perfect competition market conditions as the main driver of technological development, the case of early glulam provides evidence that the opposite scenario could also be in some cases defended. It is in fact remarkable to observe that the essential early stages of the diffusion of glulam in Switzerland, coincided with the historical moment of the transition from the guild structures to cartel agreements, both of the mechanisms renowned for being founded on collusive arrangements. Moreover, the study of the different focuses on Economies of Scope and Scale, adopted respectively in Germany by Hetzer and in Switzerland by the Swiss glulam consortium, as well as the different relation between the government and the business elites (this concept will be studied further in the following section) in these two contexts helped to explain why the Swiss context was more prone to monopolistic approaches.

Discussing in the first chapter, the concept of guildish mechanisms and their influence on the emergence of engineered timber structures, followed by clarifying the impact of cartel arrangements on the development of early glulam in the present chapter, provided us with a framework to understand the transfer of technology in a wider political economy context, where both the similarities and differences of this context in Germany, Switzerland, England and France, played substantial roles in explaining why this technology was developed very early in one place and not elsewhere.

The concept of guilds and their reputation for technical conservatism, hindering and opposing technological developments have been loosely used in many studies.[55] As a relevant example, we could cite the claim that the mechanically laminated arches of Philibert de l'Orme, mentioned in the previous chapter, has been taken up by the building industry, as a result, and following the abolition of the guilds in France.[56] The development of glulam in Switzerland could possibly be explained by the same argument since it coincides with the abolition of the guilds in this country. This study however demonstrated on the contrary that the development and institutionalization of glulam took place in a truly restricted practice network: a combination of patent-licensing model and cartel arrangements, very similar to the guild charters.

It should however be noted that the adverse impacts and undesirable effects of the cartel arrangements, demonstrated extensively by economic history scholars, could be observed in the case of glulam as well. Eliminating competition, cartels are considered as the incentives to produce as efficiently as possible or at the lowest cost and thus also with the latest technologies.[57] This is clearly the situation that William A. Chugg observed in 1961-62 during his inspection of glulam structures in Switzerland and the behaviour of their glue lines. In his report on the visit of the Gribi & Co. company in Burgdorf he confirms:

> The methods and equipment used in this factory did not compare with those used in the much larger North Americans plants and they would only be used in the smaller British glulam factories. […] One had the feeling after visiting this factory that the Swiss glulam industry had changed little since 1936, when Wilson visited European laminating factories and described the methods and equipment used, and it was possible that the original Hetzer techniques were still being used.[58]

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[55] In the last decades, mainly from 1980s on, a body of literature grow questioning the accuracy and the credibility of these claims: Heusinger, Sabine von, "Mobilität und Dynamik statt Monopol und Zunftzwang: Die mittelalterlichen Zünfte in Zürich". *Regulierte Märkte: Zünfte und Kartelle,* edited by Margrit Müller et al, Zürich, Chronos, 2011, pp. 39-53. See also Schumpeter (see note 35 above), and Epstein (see note 60 below).
[56] Orsel, E. D. "Philibert De l'Orme roof constructions in Leiden and The Netherlands, innovation versus tradition between 1800 and 1900". *History of Construction Cultures. Proceedings of the Seventh International Congress on Construction History, Lisbon, Portugal, 12–16 July 2021,* edited by Joao Mascarenhas-Mateus and Ana Paula Pires, Taylor & Francis, 2021, p. 232.
[57] *Regulierte Märkte: Zünfte und Kartelle = Marchés régulés: corporations et cartels*, edited by Margrit Müller et al, Zürich, Chronos, 2011. p. 13.
[58] Chugg, W.A. *Report on a visit to Switzerland to inspect glued laminated timber structures over ten years old.* Timber Research and Development Association, High Wycombe, Information Bulletin E/IB/7, 1962, pp. 12-13. (can be found in the ETH Zurich University Archives, Hs 1198:50)

Moreover, as it could be shown here, the particular organization of the early consortium, was shaped according to not only the relation between the contractors and the capital, but also the relation between the contractors (mainly craftsmen) and the workers. Although in the pre-industrial age, the craftsmen favoured the technologies that were skill-enhancing and capital-saving,[59] with the dawn of the industrial era this interest was shifted over labor-saving innovations, where it was no more the owners of skill who had the control over the production process, but the owners of capital.

This new relationship between the master craftsman and the journeymen, as briefly mentioned in this section, was among the main reasons that pushed the contractors to privilege collective action over the competition. This argument brings forward the role of other actors involved in the early stages of the development of glulam, namely the workers, who were intimately and sometimes violently affected by the production system put forward by glulam. Although their role in the technical aspects is not easily traceable, since they were not actively involved in the decision-making steps, however, their role in shaping the early network is decisive.

In the following section, the focus from the national-scale economy will be shifted over the micro-economy of a carpentry workshop unit, in order to understand how the fundamental transformation of the relationship between the master craftsman and the journeymen to employer and employee, pushed the early development of glulam, and how glulam, in turn, helped unsettling this relationship.

2. Contractors and journeymen: Glulam & unsettled relations

According to the study commissioned by the Federal Department for Public Economy in 1957 on the nature of the Swiss cartels, one similar pattern could be detected in the creation of all the cartel cases analysed for this study: the cartelization happened when the producers saw themselves threatened with being eliminated from the economic process:

> We will put it more simply that the creation of cartels often only takes place once a part of the remaining competitors feels to have water up to the throat.[60]

Besides, it is essential to understand that indeed many protectionist countermoves were setup and initiated by the freedom of the trade, and the case of cartels, as explained by the historian Jakob Tanner in *Kartelle und Marktmacht im 20. Jahrhundert* (Cartels and Market Power in the 20th Century), was only one of those many protectionist approaches. The latter were, it should be emphasized, not only in favour of the strong, but also the weaker. Tanner supports this argument by a citation from the social democrat Adolf Braun (1862–1929), who explains this protectionist

[59] Epstein, S. R. "Craft Guilds, Apprenticeship, and Technological Change in Preindustrial Europe." *The Journal of Economic History*, vol. 58, no. 3, Sept. 1998, pp. 684–713.

[60] Original text in French: "Nous dirons plus simplement que la création des cartels n'a souvent lieu qu'one fois qu'une partie des concurrents restants sentent l'eau arriver à la gorge". *Les cartels et la concurrence en Suisse*. Published by le Département Fédéral de l'Economie Publique, Bern, Feuille officielle suisse du commerce, 1957, p. 20.

countermoves in 1892 in the larger context of the trade, including different actors, and not only those who economically and politically had the market power:[61]

> As fundamentally different as the cartels and the workers' movement may be in their aims, they are almost identical in overcoming the obstacles they face. Both, cartels and workers' movement, come from the same soil, the development of the private capitalist mode of production, which is rushing towards its climax; these two unequal children, who come from the same mother, are developing inexorably.

These two perspectives towards protectionist movements give rise together to the assumption that in the case of early glulam, both parties namely the contractors (mainly craftsmen) and the workers should have felt themselves being in a desperate situation. A detailed study of this situation by understanding the network of the contractors and the worker in an interaction that extents into the political arena, helps us to explain the early development of the Swiss glulam under new perspectives. In this section and laid out in 6 points, it will be explained why the craftsmen and the workers, were in a desperate situation and how glulam helped the craftsmen-contractors to overcome this situation, at the expense of a significant deterioration of the situation of the workers.

2.1 The desperate situation of the master carpenters

2.1.1. Considerable financial investment required for running a modern carpentry.

Becoming a master carpenter in the 19th century, as Ernst Strobel demonstrates in his thesis on "Zurich's artisan politics from the Helvetic period to the liberal area", required one of the costliest trainings in comparison to other crafts, hence it required a considerable investment. This apprenticeship was supposed to offer in turn a promising professional prospect. Becoming a master carpenter involved a 6 times higher investment than other more basic crafts.[62] Master carpenters were highly skilled and were supposed, after training, to enjoy a decent income. However, the introduction of other modern building materials mainly steel and later reinforced concrete, had a critical impact on increasing the insecurity in their professional life, threatening the future existence of these artisans. Moreover, it should be noticed that the generation of glulam contractors were running their workshops not only by tools, but also by machines, and more and more specialized machines were needed for different wood processing tasks. By changing the sources of energy, the carpentry shops were restructured as well. From the mid-1800s, steam became the number one sawmill power source, turning circular and bandsaw blades, and until the mid-1900s, were electricity phased steam power out at most sawmills, there was a transition from the hand-tool technology to machine-tool one, requiring

[61] Tanner, Jakob. "Kartelle und Marktmacht im 20. Jahrhundert". *Die offene Moderne – Gesellschaften im 20. Jahrhundert*, edited by Marx Christian and Reitmayer Morten. Göttingen, Vandenhoeck & Ruprecht, 2020, pp 228-247. Citation in p. 233.

[62] In the Craft Act of 1804, which can give an idea of the relevant cost of becoming master in different crafts in general, the cost for becoming a master in trades like tanner and weaver, was 8 francs, a tinsmith 40 francs and to become a joiner, went up to 50 francs, and it is known that becoming a carpenter has been even more expensive than to become a joiner. This means that quite a considerable investment was required for becoming a carpenter. As explained by Strobel, Ernst.*Die Handwerkerpolitik Zürichs von der Helvetik bis zur liberalen Aera*. Basel, Hänggi, 1926, p. 30.

a considerable capital.[63] As discussed in the previous section, the Company Trippel in 1909 did a considerable investment for the electrification of his carpentry workshop and the acquisition of related machinery.

In the *Industrie-Geschichte des Thurgaus* (Industrial History of Canton of Thurgau), we read that in 1902, Zöllig invested in the steam-powered sawing machine for his workshop.[64] Later on, in 1912, Bugnion, the glulam contractor from Lausanne, advertised his electric sawmill on his company letterhead. Moreover, with the development of the means of transport, as well as the sources of energy, the location of the sawmills and the carpentry shops were less and less limited to the border of rivers and the vicinity of the forests. The craftsmen could thus move their companies inside or around the cities. The period of increasing urbanization in 1890-1914, intensified the urban construction projects, which justified the transfer of the business of the master carpenters to more urban places. A pattern that was followed by Zöllig, when he moved around 1900 his workshop from Berg to Arbon, from the countryside to the city, a project that demanded an extra land investment.

The artisans, therefore, needed important economic capital to establish their own carpentry workshop while facing an unsure future ahead.

2.1.2. Journeymen competing with the master carpenters

As discussed in the first chapter, the freedom of the trade, provided an opportunity for journeymen to become self-employed as building contractors. Consequently, the low-experienced journeymen could start to "establish independent trades without any means, without any proof of their abilities", according to the masters, and compete then with the master-craftsmen.[65] This phenomenon can be noticed by the German statistics of the period 1816-1861: while the total number of workers and businesses increased, the number of building craftsmen with master craftsman qualifications dropped to less than half, from 9646 to 4633.[66] Consequently, the certified craftsmanship that was probably the most important asset for artisans, lost a big part of its value in the new system. The technical knowledge was regarded previously as a commodity, which the owner could capitalize, for example, through an apprenticeship contract. The investment of the master craftsmen to gain this asset, was partially in the hope of gaining revenue generated by the long apprenticeship contracts; an economic model that was officially abolished by the freedom of the trade.

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[63] Christoph Schindler distinguishes three phases: Hand-Werkzeug-Technik, Maschinen-Werkzeug-Technik und Informations-Werkzeug-Technik. In which the author follows the development in timber construction according to development of these tools, by looking at the type of tools created by the relationship between matter, energy and information at each stage of development. Schindler, Christoph. *Ein architektonisches Periodisierungsmodell anhand fertigungstechnischer Kriterien, dargestellt am Beispiel des Holzbaus.* PhD dissertation, ETH Zürich, 2003.

[64] Isler, Egon. *Industrie-Geschichte des Thurgaus: Chronik thurgauischer Firmen.* Zürich, Verlag von Franz Brun, 1945, p. 287.

[65] This is the principal demand noted in a petition in 1844, where the trade association of the district of Zurich drafted a detailed petition and sent to the Grand Council of the Canton of Zurich with numerous signatures. See Ernst. *Die Handwerkerpolitik Zürichs von der Helvetik bis zur liberalen Aera*. Basel, Hänggi, 1926, pp. 114-118.

[66] Bringmann, August. *Geschichte der Deutschen Zimmererbewegung.* Hamburg, 1909, p.117.

2.1.3. Declining interest in structural timber

As extensively discussed in the first chapter, the master carpenters were highly suffering from the declining interest in structural timber and lost many projects to the concurrences, namely steel and reinforced concrete. This fact is one of the major reasons explaining the desperate situation of the master carpenters.

2.1.4. Detechnicization of the carpentry workshops

The first pan-Swiss building construction technicians' organization was the *Gesellschaft Schweizerischer Ingenieure und Architekten* (Society of Swiss Engineers and Architects) [67] founded in 1837. The idea of such an organization was "initiated by 57 master builders and other technicians",[68] at the time that there was still no official training for architects and engineers inside Switzerland (ETH Zurich was founded in 1855). Setting the goal of "raising the reputation of technical professions", the status of the master craftsmen got gradually down-graded, as their absence in the title of the organization demonstrates it. The technical professions were then represented by architects and engineers. At the time that the transition from timber to other so-called modern materials was described as "the reign of the technology",[69] the owners of carpentry businesses naturally did not feel adequately represented in the social decision-making processes, their status being degraded against the new figures graduated from the technical schools.[70]

2.1.5. Master carpenter contractors & general contractors

One of the important consequences of the freedom of the trade was the rise of the general contractors. Previously, construction of buildings usually involved many contracts, one for each trade. The architects then oversaw and coordinated the implicated tradesmen. In 1844, the trade association of the district of Zurich had a detailed petition drafted and sent to the Grand Council of the Canton of Zurich with numerous signatures, demanding protection from the authorities against the abuses of too much freedom in organizing the trades: "some trades had been united either by individuals or by the combination of several businesses and every kind of trade had been permitted".[71] Two types of contractors emerged from this context. Either a contractor established a company, in which, different tradesmen, employed by the contractor, performed their job inside the company. The whole project was therefore concluded within the workforce of the company. This concept gave rise to general contractors. In the alternative case, one craftsman was contracted as the main contractor for the whole project. In this case, he (hardly ever she), usually a master builder or a master carpenter, did almost all

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[67] Actual name, from 1883, is *Schweizerischer Ingenieur- und Architektenverein*.
[68] "57 Baumeister und andere Techniker aus fast allen Kantonen der deutschen Schweiz". *175 Jahre SIA: 1837-2012 = 175 ans de la SIA: 1837-2012 = 175 anni della SIA: 1837-2012*, edited by Thomas Müller et al. Verlags-AG der akademischen technischen Vereine, 2012, p. 3.
[69] As described, by the cantonal architect in Lausanne. Virieux, Edmond. « Les étapes de l'architecture du XIXe siècle en Suisse". *Bulletin technique de la Suisse Romande*, vol. 65, no. 14, 1939, pp. 192-193.
[70] Lüdi, Heidi. "Schweizerischer Ingenieur- und Architekten-Verein (SIA)". *Historisches Lexikon der Schweiz (HLS)*, Version of 30.10.2012. Online: https://hls-dhs-dss.ch/de/articles/017026/2012-10-30/, consultation date: 15.01.2022.
[71] Strobel, Ernst.*Die Handwerkerpolitik Zürichs von der Helvetik bis zur liberalen Aera*. Basel, Hänggi, 1926, pp. 114-118.

the parts of the project related to his own profession, for example the carpentry parts by himself, and then sub-contracted other parts to other trades. Sometimes the first type of contracting, was privileged by the client, especially for the case of public works, which were more complex, and also needed an overall view on the existing technologies in different fields. The second reason for this preference was that those projects required usually a greater capital, since a more considerable amount of the raw material, consequently larger storage places, more workers, etc., were needed for the large-scale projects. Against this background, the general contractors became new strong competitors for the craftsman-contractors. These general contractors also had the privilege or the freedom to choose the material for the construction in such a way as to lower the price offered in the tender, or according to the other conditions of the market, which would increase in some cases their chances to win the tender. The craftsmen contractors did not have this possibility since they could be contracted only within their particular trades which was strongly related to the material. These different models of contracting and contractors, highly influenced the impact and the involvement of different contractors on the early development of glulam, and also the type of projects, in which they used glulam. This part will be extensively discussed in the third chapter.

2.1.6. Masters facing labour unrest and strong waves of strikes

Probably one of the most important reasons for the desperate situation of both craftsmen and the workers, was related to the social context of the turn of the 20th century regarding the industrial relations and the strong waves of labour unrest.

In the period of social upheaval that affected almost all branches of the building industry, the carpentry trade had practically a leading position. To explain this situation, the historian Bernard Degen argues that the members of the associations of woodworkers were generally disciplined, “better structured, better funded and more organized”, while bricklayers and less skilled workers continued to act rather spontaneously until the 1920s. The interesting fact demonstrating the leading position of the carpentry trade is that they achieved their first national wide collective agreement in 1919, while the construction trade did it only in 1938.[72]

Moreover, it should also be considered that the majority of the members of carpentry trade were the local people of Swiss nationality, who were more actively engaged in the social movements. The table 2.3 shows the percentage of foreign employees in the individual professions in the field of construction in 1911. According to this table, the carpentry trade had the least number of foreigners.[73] The vast majority of them were Germans who had always come to Switzerland on a temporary basis and were gladly employed by the masters for the sake of their skills.[74]

[72] Degen, Bernard. “Gewerkschaft Bau und Holz (GBH)”. *Historisches Lexikon der Schweiz (HLS)*, Version of 11.12.2014. Online: https://hls-dhs-dss.ch/de/articles/016491/2014-12-11/, consultation date: 11.03.2022.
[73] Vuattolo August. *Geschichte des Schweizerischen Bau- und Holzarbeiter verbandes,*1873-1953. Zürich, SBHV, P. 79.
[74] Strobel, Ernst. *Die Handwerkerpolitik Zürichs von der Helvetik bis zur liberalen Aera*. Basel, Hänggi, 1926, p. 124.

Railway construction	91 %
Henchmen	53%
Masons	52%
Architecture	33%
Road and bridge construction	33%
Joiner	24%
Sawmill and woodworking plants	11%
Carpentry	11%

Table 2.3 Percentage of foreign employees in the individual professions in the field of construction in 1911 in Switzerland.

Furthermore, it is important to remember that the carpentry workers were more educated than the factory workers. As Strobel explains, the journeymen had “more restless blood” in contrast to the Swiss factory workers. During the travels of the journeymen as part of their job training, they got aware of new ideas which remained hidden from the factory workers.

> This socialist movements were particularly present among the journeymen craftsmen. In contrast to the Swiss factory workers of the time, the journeymen had more restless blood.[75]

Last but not least, it should be mentioned that the strike of the carpentry workers could often bring the entire construction site to a standstill. That’s why when the carpenters went on strike, immediate solutions were always needed.

Carpentry workers, searching for a decent social and economic status, leaded a movement that established regulated working conditions and payments. In the following, the focus for understanding the desperate situation will be then removed from the contractors and placed on the workers, as the main decisive actors in this conflict. This part will therefore will be explained in the following separate part.

2.2 The desperate situation of the workers

The closing decades of the 19th century, followed by the 1910s witnessed strong waves of discontent of the workers, organized in the form of strikes. These strikes strongly affected the construction sites, causing delays and increased project costs for contractors and owners.

[75] Strobel, Ernst. *Die Handwerkerpolitik Zürichs von der Helvetik bis zur liberalen Aera.* Basel, Hänggi, 1926, p. 124

The below diagram shows the intensity of the strike in the period 1860-2015.[76] It meaningfully demonstrates that early development of glulam until the end of the early glulam consortium, coincide with the second strongest wave of labour movements in the history of industrial Switzerland.

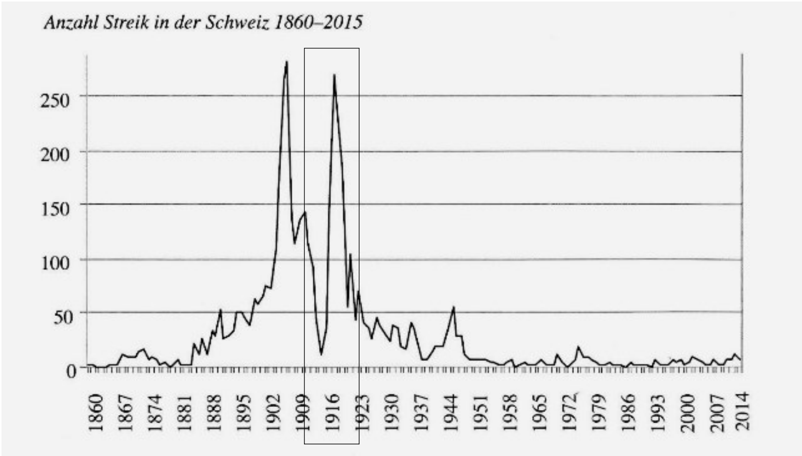

Diagram 2.4 Number of strikes in Switzerland in the period 1860-2015

The collective bargaining over working conditions before the first world war, was not established in the long term, and it was only in 1911, as explains Bernard Degen, that the revision of the law of obligations, laid the foundations for the collective agreement by introducing the exclusively Swiss term Gesamtarbeitsvertrag (collective employment contract) for collective agreements.[77] Glulam was therefore introduced at the time, that the most intense discussion regarding the duties and the rights of the master and the workers were in progress.

In this situation, the building industry was influenced more than other branches of the industry by the labour movement. As Christoph Rauhut demonstrates it,[78] parallel to the enormous economic boom at the end of the 19th century, the volume of construction rose disproportionately to the overall economic development and the employment figures in this sector also grew excessively. In the period 1888 to 1910 the number of people employed in the construction industry doubled, while the population of Switzerland grew by only about thirty percent.[79] Moreover, it should be noted that the mechanization in the building industry, particularly on the construction site progressed with less speed and to a lesser extent in comparison to other branches of the industry. In contrast to the factory organization, where the machines are fixed and the product passes through the machines, in the building industry, the product is fixed and the machines need to be displaced, which, considering the substantially different

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[76] Koller, Christian. "Der Landesstreik im Kontext der Schweizer Streikgeschichte" *Traverse: Zeitschrift für Geschichte = Revue d'histoire*, vol. 25, no. 2, 2018, pp. 91-109. For a broader view on this subject see: Koller, Christian. *Streikkulture; Performanzen und Diskurse des Arbeitskampfes im schweizerisch-österreichischen Vergleich (1860-1950)*, Münster/Wien, LIT-Verlag, 2009.
[77] Degen, Bernard. "travail et capital". *Histoire économique de la Suisse au XXe siècle*, edited by Patrick Halbeisen et al. Neuchatel, Livero-Alphil, 2021, pp. 925-974.
[78] Rauhut, Christoph. *Die Praxis Der Baustelle Um 1900: Das Zürcher Stadthaus Fraumünsteramtnstern*. PhD dissertation, ETH Zürich, 2003, p. 62
[79] Tissot, Laurent, and Peter Moser. "Économie intérieure, tourisme et agriculture". *Histoire économique de la Suisse au XXe siècle*, edited by Patrick Halbeisen et al. Neuchatel, Livero-Alphil, 2021, p. 581.

scale of the product, imposed strong barriers to the mechanization process. The latter could be limited to the scale of single constructional elements, considering as well the limits of transport.

To have a better idea of the working conditions at the time of the introduction of the patented glulam in Switzerland, we will have a look at the "agreement between masters and workers of carpentry in Zurich" published in 22 June 1905.[80] This agreement covered the following issues: working time, work schedule, wage conditions, Sunday work, water and night work, unusual work, out-of-town work, remuneration, and dismissal.

According to the agreement, the working hours for the spring and summer time was set to 10 hours, which had to be reduced to 8 hours during the cold seasons. The salary for a qualified carpenter was fixed at 55 Rappen per hour. Demand for the reduction of the work time to 9 hours and the salary increase, voiced during the strong strike in St. Gallen in 1906 did not lead to any result. It faced stiff resistance from the association of master carpenters, who were against the "exaggerated demands" of the workers.[81]

The Sunday work, according to the agreement had to be remunerated twice as the weekly hours. Moreover, working in water and during the night was supposed to be remunerated 50 percent more than the normal working hours or usual working situation. Out-of-town work was subjected to a salary increase as well. The employment contract could be dismissed from each party without earlier notice, anytime. All these conditions indicate that the possibility of prefabrication, bringing the workload as much as possible to the carpentry workshop, and reducing the site-work, particularly by reducing the construction joints, was clearly in favour of the employer, who could this way considerably avoid the extra salaries.

Looking at different early glulam projects, it can be observed that an important share of them have been erected in conditions that were subjected to an extra payment. Many large-span structures have been, by nature, out-of-town projects, either factories, warehouses, depots, or many festival halls.

The timber construction works of the Swiss National Exhibition in Bern in 1913 fell in that difficult time before the war. The daily reports from the site manager Hagen in Bern to Zöllig in Arbon allow a better understanding of the dynamic of the construction sites. Zöllig was contracted for the construction of the *Halle für Hochbau und Innenarchitektur* (pavilion for the building industry), including its glulam structure (fig. below).

[80] Ritschard, Rudolf. *100 Jahre Zimmermeisterverband Zürich, 1889-1989*. Zürich, Zimmermeisterverband, 1989, p. 25: "Vereinbarung zwischen Meistern und Arbeitern des zimmergewerbes".
[81] "Rapport über den Zimmerleutestreik in St. Gallen und Umgebung vom 9. April bis 29. Juli 1906". *Illustrierte schweizerische Handwerker-Zeitung,* vol. 22, no. 20, 1906, p. 323.

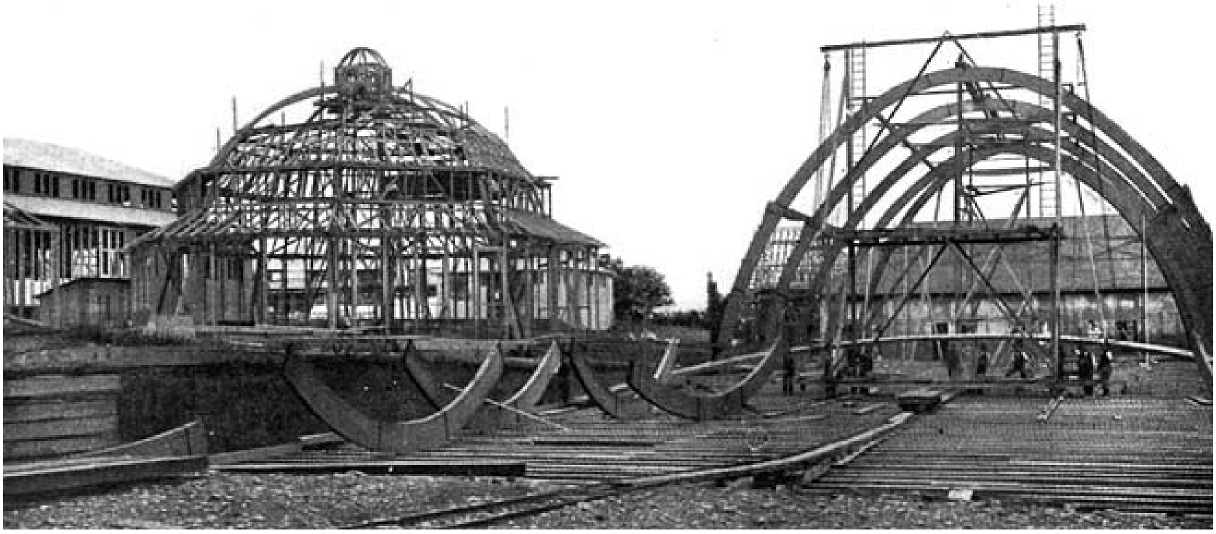
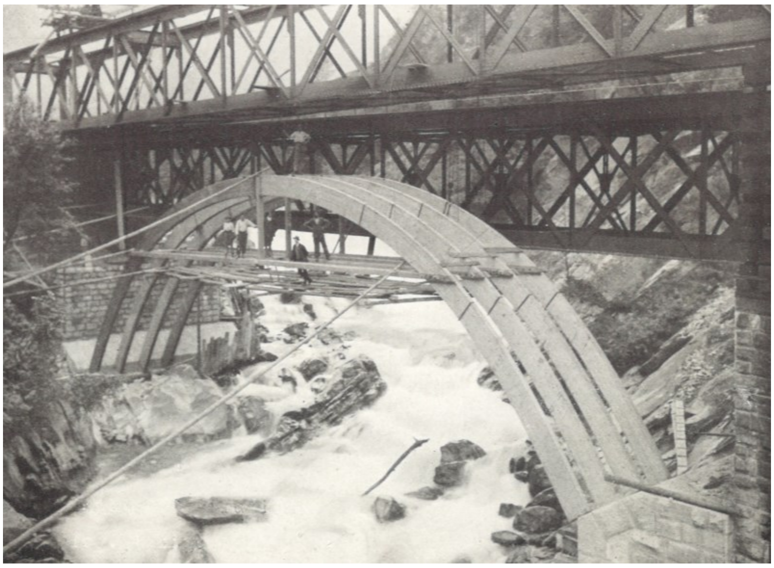


Fig. 5 Construction site of the pavilion for the Building Industry. Bern, 1913.
At left, the glulam structure is getting assembled and erected.

For the entire timber works, Zöllig deployed 11 workers, most of the carpenters from his permanent staff but also a few temporary local carpenters to support the works. Through the detailed descriptions in these reports, we learn that the dissatisfaction with wages was a reoccurring issue that Zöllig and his workers had to resolve over and over again. Often the workers needed were not available: “The number of workers is 11, and perhaps a few more carpenters will join them in the next few days, if they can be found.” And they were constantly negotiating their wages: “Bollfremd wants the carpenter's wage starting last Saturday morning. The other carpenters want to be paid 75 centimes per hour for the time in Bern. Last time I paid out 73 and 72 centimes respectively.”[82] According to the reports, some of the carpenters left the construction site at their own request after only 2-3 weeks. At the time that many timber pavilions were simultaneously under construction and therefore the workers had more opportunities to negotiate with the masters, finding the local carpenters who agreed to work for the indecent wages imposed by the employers was a tough job. The prefabrication of the structure, via glulam, came to the contractors’ aid in these situations.

Moreover, some structures were erected in working situations considered as non-standard. The normal bridges, either the bridge itself or its formwork, required in most cases, working in water, as images 6-8 demonstrate it.

[82] Zöllig, Burkhard. “Rapport über den Fortgang der Arbeiten”, 7 & 13.8.1913. Thurgau State Archives, 8’409-1-2.1.



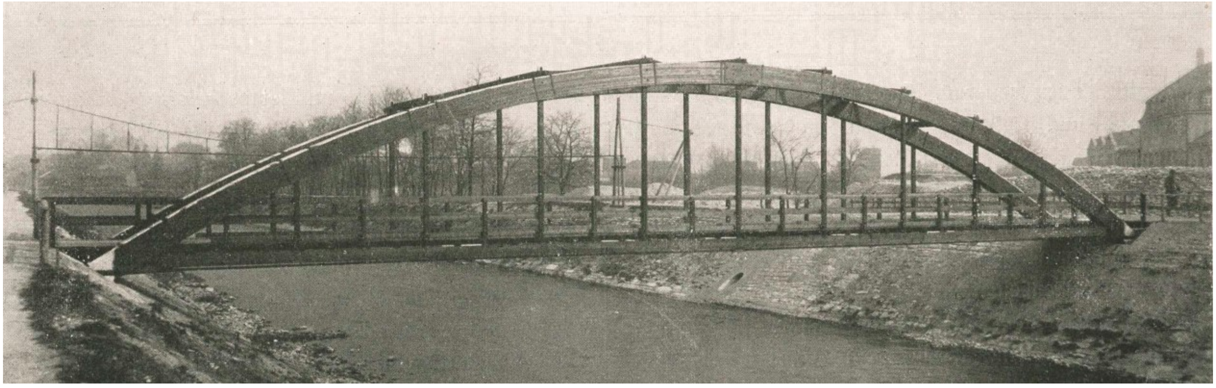
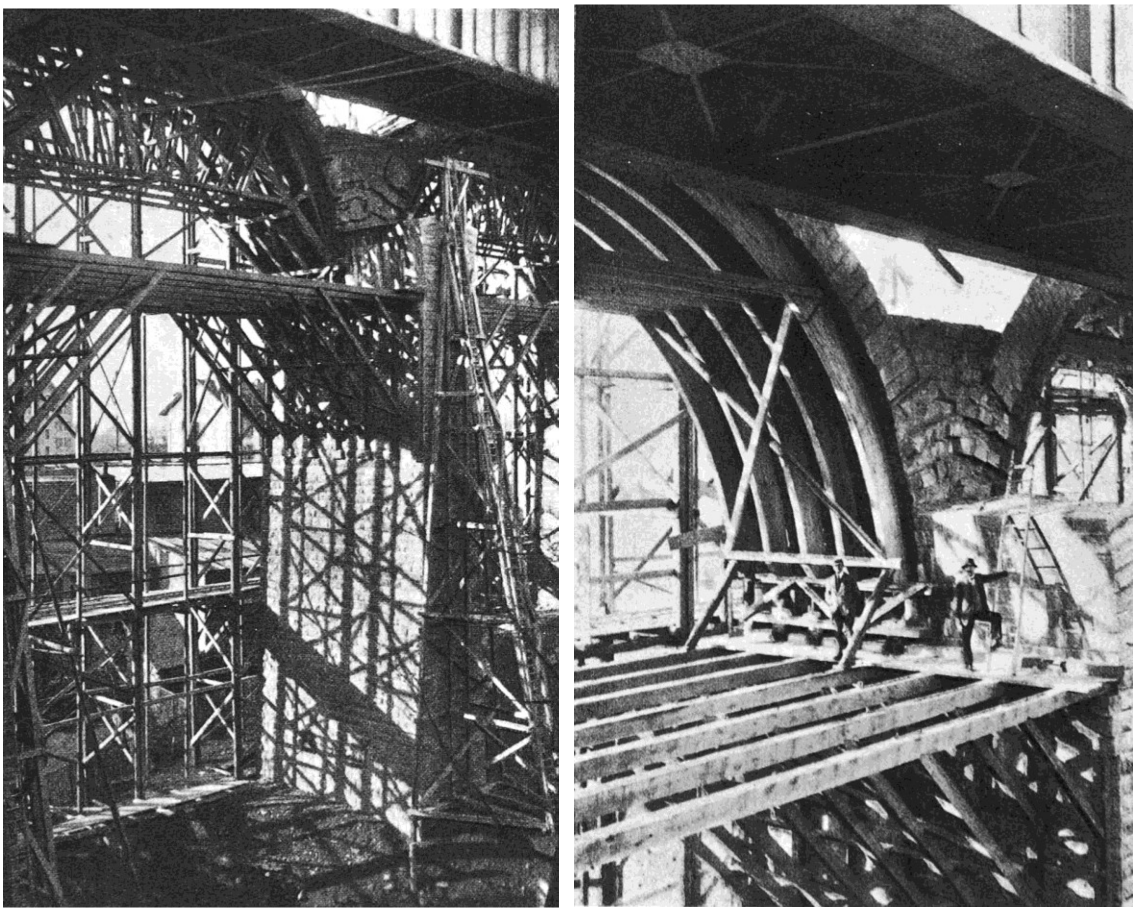


Fig. 6 Glulam formwork for a masonry bridge of Gotthard Railway, near Rodi-Fiesso, Tichino.
Fig. 7 Glulam formwork for a masonry bridge near Göschenen, over the Reuss river.
Fig. 8 Footbridge over Wiese in Basel, 1910.

The formwork of the railway viaducts –infrastructures increasingly expanding in the opening decades of the 20th century – demanded site work in high altitudes and potentially hazardous conditions. In these conditions, the glulam formworks offered the contractors with significant advantages, lower costs, facilitated dismantling process and the possibility of reuse either as a formwork or as roof structure for halls (see Appendix 2.1). Figures 9 & 10 compare the regular timber and glulam formworks used for different spans of the viaduct Paudex (Canton Vaud), constructed in 1921.



Figs 9-10 Regular timber and glulam formworks for the spans of the viaduct Paudex, 1921.

The case of few bridges and formworks discussed here demonstrate how glulam could, for various reasons, appear advantageous to the contractors, at the time that the workers were intensely protesting for safety at the workshop and construction site, higher salary for the non-standard working conditions, insurance for accidents, etc. The carpentry workers' newspapers of the time, reported on daily basis on the workshops and construction sites' accident cases. Working with heavy beams was not without its dangers back then. Even pushing up rafters without a crane could result in fatal accident.[83] The incapacitated workers were simply dismissed, and their families, as well as those of the killed workers, were partially supported by the workers' unions, in the lack of any insurance from the employer's side.

2.2.1. Strikes pushing glulam production

Three contractors of the early network of glulam in Switzerland, namely Zöllig, Bugnion, and Fietz & Leuthold were located in Arbon, Lausanne and Zurich. These cities experienced the most intense general strikes in the period of 1880-1914 (the peak was from 1905 until 1907, the year when the patent of glulam was registered in Switzerland).[84] Knowing that these contractors were the most

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[83] It appeared in the Schweizerische Holzarbeiter-Zeitung.
[84] Degen, Bernard. "travail et capital". *Histoire économique de la Suisse au XXe siècle*, edited by Patrick Halbeisen et al. Neuchatel, Livero-Alphil, 2021, pp. 925-974.

determined and engaged ones in the very early development of glulam, the question may arise whether the particular social context of the cities of Arbon, Lausanne and Zurich, played a role in the fact that this technology was more rapidly taken up by the industry there, considering that these contractors were quite different in the nature and the scope of their activities.

In the following, it will be discussed how these cities, influenced in different ways by socialist ideas, pushed the labour movements, and how consequently the affected contractors, reacted via political measures and novel technologies (glulam) to these movements.

Lausanne

Lausanne at the turn of the 20th century was under the influence of the International and early French and Swiss anarchism. The groundwork for the labour movement there was laid mainly by the exiled revolutionary socialists and anarchists coming from across the continent hosted by Switzerland. The first congress of the International Workingmen's Association (IWA) hosted by Geneva, was mainly dominated by the French anarchists,[85] whereas in the second conference, held in Lausanne in 1867, the local Swiss labour movement consisted the majority of the delegates.[86] It was during this second congress that the international took on a more explicitly socialist program, and housed the first Swiss movement of the International. Lausanne hence became formally and politically the centre of organization of labour movements. It is indeed in Lausanne, in 1905 that several local workers' associations come together and established the *Fédération des unions ouvrières de la Suisse romande* (Federation of Labour Unions of French-speaking Switzerland).[87] In this context, it is therefore not surprising to see that the representative licensee of glulam for the whole French-speaking part of Switzerland (Edouard Bugnion), as a countermove to the concentrated labour movement in this city, was based in Lausanne, as well.

Being an elected politician, Bugnion could benefit from the overlap of the political circles with the business sectors, not only for promoting glulam in the public projects, as we will see in the next chapter, but also for taking position as a politician and not only a contractor, against workers' demands. An example to illustrate the situation could be the role of Bugnion in contesting the allocation of credit by the government, in favour of the workers. In 1914, the city of Lausanne decided to vote for credits regarding the construction of working-class housing, considering some conditions already in practice in Zurich and Basel, like the "respect of trade union agreements and tariffs and the use of stable labour, i.e. workers - without distinction of nationality - who had been domiciled for a certain period of time on the territory of the Commune". According to the local journals, this subject

[85] Yuri Mikhailovich, Steklov. "6. The Geneva Congress of The International". *History of the First International*. Translated by Eden Paul, and Cedar Paul. New York, International Publishers, 1928, p. 79.
[86] Yuri Mikhailovich, Steklov. "8. The Lausanne Congress of The International". *History of the First International*. Translated by Eden Paul, and Cedar Paul. New York, International Publishers, 1928, p. 99.
[87] Vuilleumier, Marc. "Le syndicalisme révolutionnaire en Suisse romande". *Histoires et combats. Mouvement ouvrier et socialisme en Suisse 1864-1960*, Lausanne et Genève, Édition d'en bas & Collège du travail, 2012, pp. 379-409.

faced “very strong opposition” on behalf of Bugnion, the master carpenter. The proposal was then rejected by the authorities.[88]

In some other articles, it can however be seen that Bugnion, acted in few cases in favour of the workers. In an article published by the official journal of the Swiss Socialist Party “Le Grutléen”, the workers were set to express their gratitude towards Bugnion as the only master who acted generously in favour of the workers, by allowing them two extra centimes salary per hour (more than what was agreed by other master carpenters as a general salary increase). [89] The praise of Bugnion’s action, and “thanking and congratulating” him in the workers’ journal happened at the time that this master carpenter sanctioned the government’s projects in favour of the worker’s living and working conditions, and was in the directing board of several associations who acted collectively against the workers’ demands, while it is well known that the individual decisions in these associations for supporting the workers’ demands were strictly forbidden. Therefore, although by reading this article, at first sight it might appear that this decision was at the aim of helping the workers with their difficult situation, this understanding of the article should be relativized and put into perspective considering other decisions of Bugnion as a politician and employers’ associations board member: it is known that a minimum increase of the workers’ salary, was then a common practice to avoid the real legal reform by the workers.

Arbon

The strong waves of socialist movements in Arbon have their roots firstly in the history of the rapid and intense industrialization of the city. Moreover, the German influences exercised partly via German workers pushed the workers in Arbon to voice their discontent with working conditions. In the carpentry trade, the majority of the foreigners, as we saw previously, were Germans. The early protests were largely organized and supported by them as well. It is sufficient to notice that the presidents of the Swiss Federation of Trade Unions (SGB) founded in 1873,[90] until 1888, namely for 15 years were only Germans, and It’s only from 1890 onwards that the SGB was presided by Swiss people.[91] Besides, the *Wanderjahre* (journeyman years) fastened the connection between the Swiss and the German workers, who shared the same language.

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[88] “Au Conseil Communal de Lausanne”. *Le Grutléen, Organe central du parti socialiste suisse*,13 mars 1914, p. 2.

[89] Original text in French: “Chez les Charpentiers, il nous paraît opportune de mentionner la réponse favorable faite par les patrons charpentiers aux revendications présentées par les ouvriers de cette corporation. A fin juillet, une demande d’allocation fut formulée et une augmentation de 3 à 5 centimes à l’heure fut accordée. Dans le chantier de la Sallaz, le patron accorda, au mois de novembre ; une seconde augmentation de 2 centimes de l’heure à tout son personnel, sans aucune demande de la part de celui-ci. Nous ne pouvons que remercier et féliciter M. Bugnon. *Le Grutléen, Organe central du parti socialiste suisse*,22 des 1916.

[90] “Founded in 1873 at the first general Swiss workers' congress in Olten as a nationwide umbrella organization for workers, called "Alter" or "Erster" Arbeiterbund, was the most important of Swiss employee associations. The last congress in Olten 1880 founding of Swiss Federation of Trade Unions (SGB) and suggested a Social Democratic Party (SP) as a political successor organization, officially founded in 1888”. Bürgi, Markus. “Ein früher Präsident des SGB: Johann Kappes”. *Vom Wert der Arbeit : Schweizer Gewerkschaften - Geschichte und Geschichten*, edited by Bernard Degen et al. Zürich, Rotpunktverlag, p. 104.

[91] *Ibid*, p. 104.

The particular industrial character of the city of Arbon can be traced back to the mid-19th century. The number of inhabitants, which had already doubled between 1850 and 1880, exploded under the influence of the industrial development that preceded the First World War, focusing mainly on the embroidery and metal and machinery industry. The factories of Arnold Baruch Heine and Saurer in Arbon, to mention only a few, the largest in the canton of Thurgau, were in 1905 among the twenty largest employers in Switzerland and made Arbon a classic working-class city.[92] The carpentry workshop and timber trade of Burkhard Zöllig with 81 employees in 1911 was among the major employers of the city of Arbon.[93] In the particular context of intensely industrialized Arbon, the labour movement of the artisans was supported by and intensified under the influence of the factory proletariat of the region. The fusion of the ideas of these two groups gave rise to a working-class consciousness that made the *Rote Arbon* (the Red Arbon) as one of the centres of labour unrest and social upheavals of not only the eastern part of Switzerland, but the whole country.[94]

The archival records shed light on the situation at the carpentry workshop of the master carpenter Burkhard Zöllig in Arbon at the time of the introduction of the patented glulam in Switzerland. As the journal *Schweizerische Holzarbeiter-Zeitung* (Swiss Woodworkers' Newspaper), the organ of the Swiss Woodworkers Association reports, the construction activity in the region of Arbon in February 1909 has been completely at a standstill, as the consequence of "the bad working condition and the brutality of the masters". Particularly mentioning the name of the master carpenter Zöllig as one of the carpentry workshops with the worst working conditions, the workers compared this workshop by the stable of the horses of Zöllig which was heated during the cold winter day, whereas any protest for heating the workshop remained without response: "such a horse costs money if one dies, and there are enough journeymen carpenters without having to pay 1000-2000 Fr.", the workers protested.[95] In this situation, the workers pushed the solidarity among themselves and strictly banned the other colleagues from looking around for jobs.[96] The workers, in their regular meetings, reviewed the conditions of the workshops' environments in order to have an overview of the existing working conditions and to make the workers aware of their rights.[97]

In the process of industrialization of the carpentry trade, particularly in the case of glulam, the old craft skills, and consequently the long-term contracts with the journeymen, were made obsolete. The skilled workers then lost out. In another report, the workers talk about a master carpenter (the context of the

92 Which had in 1911, respectively 2200 and 1500 employees. Other companies were involved in this boom: the embroidery companies Stauder & Cie (120 employees in 1911), Jean Hardegger (200) and Jakob Müller-Schär (66), the embroidery machine factory Karl Bleidorn (75), the appliance factory Heinrich Vogt-Gut (83), the first Swiss bicycle factory Gustav Adolf Saurer (23). Buenzli, Kurt, et al. "Arbon. *Historisches Lexikon der Schweiz (HLS)*, Version of 20.10.2010. Online: https://hls-dhs-dss.ch/de/articles/001852/2010-10-20/, Consultation date: 15.02.2022.
93 *Ibid.*
94 Keller, Stefan. *Die Zeit der Fabriken : von Arbeitern und einer roten Stadt*. Zürich, Rotpunktverlag, 2001.
95 *Schweizerische Holzarbeiter-Zeitung: Organ des Sch. Holzarbeiterverbandes*, Zürich, Schweizerischer Holzarbeiterverband, 1906 -1922. 6 Februar 1909, no. 5.
96 *Ibid.*, 23 January 1909, no. 3.
97 *Ibid.*, 6 February 1909, no. 5.

report suggests Zöllig) who "cleaned up with his old journeymen carpenters", since they became "disagreeable", and suggested the others "to do the same way".[98]

In the case of glulam, a part of the process of fabrication and assembly like gluing and laminating could even be done by workers from other fields. The deskilling process of timber craftsmanship via glulam, arguably contributed to the adoption and early promotion and development of this technology by the contractors, who wanted to get rid of the skilled labour, described as old disagreeable journeymen.

Zurich

The labour movement was intense in Zurich. The city's "*Grosse Bauperiode*" of the last decades of the 19th century, led to an increasing number of civil engineering projects, as well as to the general contractors, among them, Fietz & Leuthold, one of the early glulam contractors.

Multiple construction sites set up in and around the city resulted in a high concentration of construction site workers in Zurich. The contractors were facing critical situations of intense strikes. In this context, the use of strike-breakers was a common solution. In the case of the carpentry trade, the engagement of the strike-breakers, coming mainly from Germany, was highly supported by the authorities. In 1909, 28 Berliner strike-breakers, as published in the Berlin newspaper *Vorwärts*, and the *Schweizerische Holzarbeiter-Zeitung*, were accompanied by 200 policemen, on their way from the railways Stadelhofen to the factory Wolff & Aschbacher, a prominent furniture factory. This latter being one of the earliest clients of glulam, had contracted Fietz & Leuthold for a storage shed for his company in the city of Zurich, for which the contractor had planned for a glulam structure.

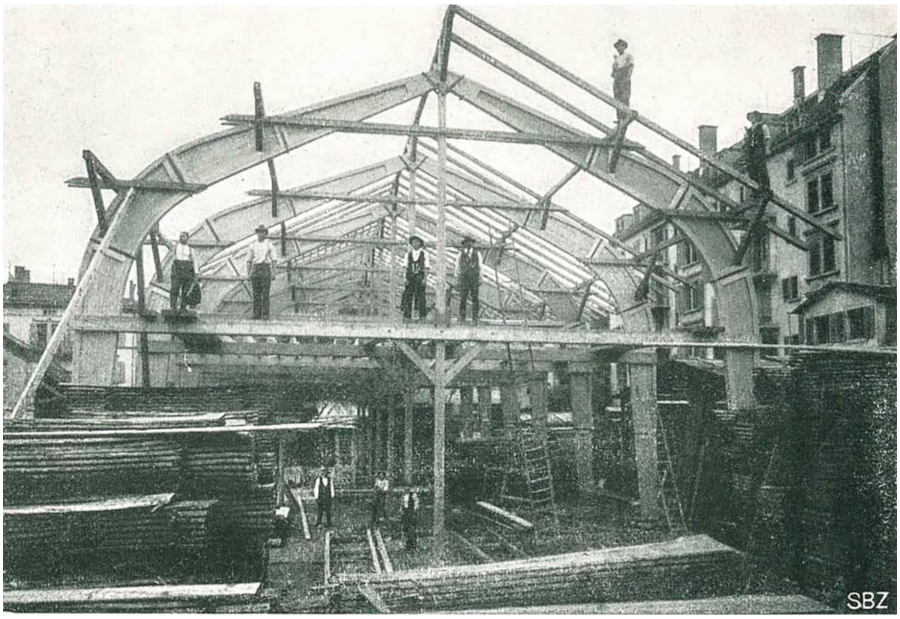

Fig. 11 Assembly process of the wood storage shed of the Aschbacher factory, March 1910.

98 *Ibid.*, 27 March 1909, no. 12.

The report of the workers describes a prison-like situation in the factory of Aschbacher, the strike-breakers constantly being guarded by agents.[99] Employing the strike-breakers for the construction site works was practically not possible, since their confrontation with the workers on strike, could lead to violent conflicts between the two groups. Therefore, prefabrication and the transfer of the construction tasks from the construction site to the workshops was much in favour of the masters who could benefit from the work of the strike-breakers inside the prison-like workshops. Although the archival records do not clearly mention whether Fietz & Leuthold benefited from the strike-breakers for the production of the glulam structure of the Wolff & Aschbacher storage shed, we know however that both Zurich-based companies Fietz & Leuthold and Locher & Cie. were among the minority of the contractors who repeatedly disagreed the working conditions that were discussed by the labour unions and the employers' associations.[100] These two firms regularly appeared on the blacklist of workers, for refusing any negotiation with them.[101]

2.2.2. Glulam and estranged labour

Among different novelties in the timber engineering structures developed in Germany at the turn of the 20th century, glulam, was arguably one of the most fitting candidates that could help the contractors to push degrading the workers professionally and politically. A comparison of the relation between a worker and his work in case of glulam and in case of another structural system would help to elaborate on this statement.

As the example of ring-dowel connections, other popular timber engineering system of the time demonstrate (figures below), there is mainly a one-to-one relation between the worker and the task: operating the drilling machine, inserting the dowels, fitting it into place to fulfil the conditions for a working joint, controlling if the dowel matches the coupling beam, etc. The structural members are principally not interchangeable, and the workers have an overview of the location of the structural elements. Single workers become responsible for the result of the final project.

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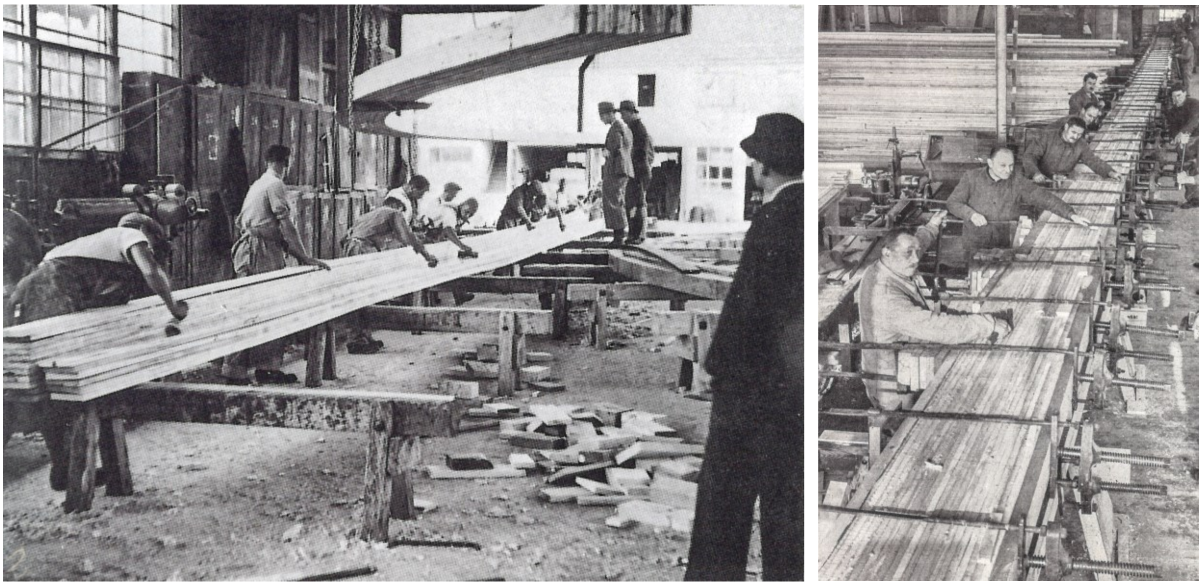
[99] *Ibid.,* 6 March 1909, no. 9.
[100] *Ibid.,*19 June 1909, no. 24.
[101] *Ibid.,* 3 July 1909, no. 26.

Figs 12-14   Processes of drilling, inserting the dowel and making the joint. There is a one to one relationship between the worker and the task.



Figs 15-16 Processes of gluing and laminating. The workers, due to the nature of the work, need to perform all the same task, at the same time and with the same speed.

On the other side, it can easily be demonstrated that glulam, via the agencies of the material itself, necessitated and generated a factory production line. A process of fabrication in which “a series of workers”, had to perform simultaneously the same task, namely gluing and clamping, with the same precision, and the same speed, since glue-coated pieces had to be laid together as soon as the glue was spread. For instance, the hardening time of the applied glue and the balanced clamping pressure needed for the lamination were both important criteria organizing the work process and adjusting the speed of the performance of the workers according to other workers. There was then no more a one-to-one relation between the worker and the product, but a worker to another worker. A working model highly in favour of capitalist production system.

Another factor that essentially transfromed the relation between the workers and the product, was the ever-increasing dimensions of the glulam girders. Formerly, the workers alone, to a certain degree could handle, move, locate, and fix the standard timber structural elements on the construction site. However, the size of these large structural elements also exceeded the manual handling capacities of the carpenters, and the competences of the worker on the construction site became more and more limited.

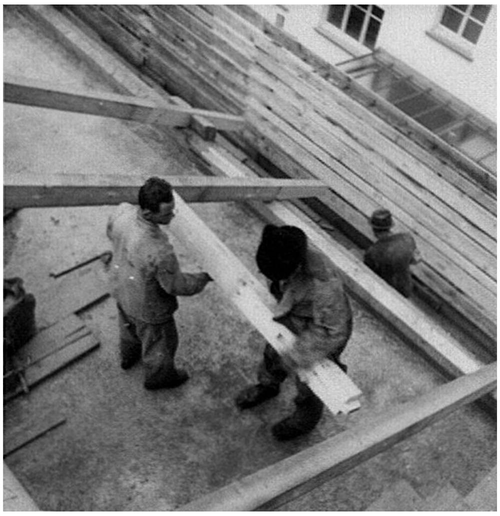
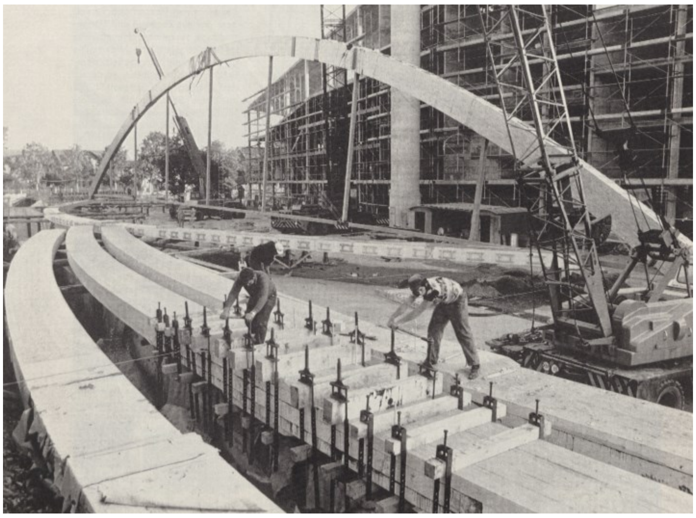
 

Fig. 17 Workers lifting up, and locating a timber beam to construct a regular timber truss roof.
Fig. 18 Workers glue-laminating a glulam girder on the construction site. The size of these large structural elements exceeds the manual handling capacities of the carpenters.

These show that glulam, in comparison to other timber structural systems, reduced and limited to a great degree the capacity of the workers. Therefore, it was easier for the contractors, to professionally and consequently socially excluding them from being decisive factors. Glulam, among other alternatives, appeared then to be the choice of the contractor, struggling to survive a desperate situation. The contractors who had the most considerable involvement in the development and promotion of early glulam, were those who had the highest resistance against the labour demands and organized politically this resistance; either by adopting political roles in the city or canton parliaments, or by presiding the business interest associations and lobbying. This topic will be studied in detail in the following chapter.

Appendix 2.1

The formwork of the railway viaducts –infrastructures increasingly expanding in the opening decades of the 20th century – demanded site work in high altitudes and potentially hazardous conditions. In these conditions, the glulam formworks offered the contractors significant advantages.

First, the contractors were considerably reducing their costs, by transferring considerably the workload to their workshops, and by reducing substantially the amount of site joints.

Secondly, the glulam formwork did "greatly facilitate" the work of the client, as stated by the regional director of the Swiss Federal Railways at the ceremony of the dismantling of the formwork of the Galicien Viaduct near Renens in the Canton of Vaud in 1922. The processes related to the formwork were simplified by glulam. This feature of glulam, among other reasons, made the SBB as one of the most influential clients of early glulam, contributing to the early development of the technology, a subject that will be studied in the third chapter. The formwork could easily be dismantled once a span was constructed, to be relocated to the following span:

> This operation [dismantling] is now greatly facilitated by the Hetzer system, which consists, for the Galician viaduct, of five girders, each formed of twenty-two boards glued with casein and secured by tie rods […]. Each of the two girder's bases is fixed on a wide board which itself rests on a sand box. The cylindrical sand boxes carry the load of the glulam girders and the vault. To detach the glulam arches [from the vault], it is sufficient to empty the sand boxes simultaneously, by removing the plugs that close these boxes: the sand flows and the formwork lowers itself. The operation was successful. The two devices intended to record the sagging up to about ten millimetres, did not show any sagging. The removed arch will be reassembled for the construction of the fifth span of the bridge.[102]

The similar glulam structures were used for a project of the reconstruction of the Paudex viaduct. The archival documents dated 1921 show that the general contractor Emmanuel Bellorini (1863-1939), one of the most important general contractors of public works in Lausanne, had a tight deadline to conclude the project. Therefore, he subcontracted the formwork of four spans out of eight to the glulam contractor Bugnion in Lausanne. Glulam, in comparison with the normal timber formwork, was a "favourable offer" (Figs 9-10).[103]

The third advantage of the glulam formworks had to do with the possibility of their reuse in the future projects of different functions. The noticeable secondary glulam market, as we will see in the next chapter, generated considerable revenue for the contractors.

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[102] *La tribune de Lausanne*, 14 July 1922, no. 194, p. 2. The original text in French: "Cette opération est actuellement grandement facilité grâce au système Hetzer, qui consiste, pour le pont du Galicien, en une série de cinq fermes, formées chacune de vingt-deux planches collées à la caséine et renforcées par un double tirant (moise) où repose un poinçon par ferme, muni de traverses obliques faisant un tout rigide et solide. Chacune des deux bases des fermes repose sur une large planche reposante elle-même sur une boîte à sable. C'est sur les boîtes à sable, cylindrique, que se porte la charge du cintrage boisé et de la voûte. Pour détacher le cintre boisé, il suffit de vider simultanément les boîtes à sable, en enlevant les bouchons qui fermes ces boîtes ; le sable coule et le cintrage s'abaisse de lui-même. L'opération a bien réussi. Les deux appareils destinés à enregistrer les affaissements jusqu'à une dizaine de millimètre, n'ont marqué aucun fléchissement. Le cintre enlevé va être remonté pour la construction de la cinquième arche du pont".

[103] Bugnion, Ed. "Viaduct de Paudex", 24 October 1921. Vaud State Archives, PP 499 D 21 (4/5).

Chapter three

Swiss entrepreneurship

the elites' cartel

Table 3.1

Early glulam contractors

	Name of the company	Owner, president	Canton	Foundation	Dissolution	Type of activity
1	Baugeschäft Alb. Blau's Wwe	Albin Blau's Wwe	Bern	1890	1911	Wood trade with a steam saw
2	Riesterer-Asmus	Witwe Magdalena Riesterer-Asmus	Basel	1886	1923	Construction business, carpentry and joinery
3	A.-G. Baugeschäft Chur	Ulrich Trippel Master builder	Graubunden	1876	2010	Carpentry and construction business
4	Hans Nielsen-Bohny	Hans Nielsen-Bohny Master carpenter	Basel	1897	1974	Mechanical carpentry, parquetry and construction business
5	Locher & Cie.	Edouard Locher Structural engineer	Zurich	1830	Active up to now	Industrial construction, reinforced concrete construction as well as hydraulic and timber construction
6	Ed. Bugnion	Edouard-Marc Bugnion Master carpenter	Vaud	1883	1922 (taken over by Dupont & Desarzens) 1973 (dissolution of the successors)	Carpentry and joinery
7	B. Zöllig	Burkhard Zöllig Master builder and master carpenter	Thurgau	1888	1999 (taken over by Häring group) 2004 (transferred to the company Roth AG) Active up to now	Construction business, carpentry
8	Gribi & Cie.	Fritz-Hermann Gribi Master builder (arguably originally a master carpenter)	Bern	1883	1976 (taken over by the company Roth AG) 1994 (taken over by Häring group) Active up to now	Sawmill and construction business with impregnation plant and architectural office
9	Fietz & Leuthold	Jakob Leuthold & Emil Fietz (respectively, architect and Mater builder)	Zurich	1889	1994	Construction business

** all the information is related to the state of the contractors in 1909, or the nearest to this date, in the cases when the precise data of that year was not available.*

*** the second column gives information about the owner or the president of the company, or the involved person of the company in glulam production.*

**** type of activity in the last column provides us with the information published by the company on the letter headings, in the advertisements, Swiss Official Gazette of Commerce, etc.*

***** the foundation year of companies of Bugnion and Gribi, could date back earlier than 1883. The Swiss Official Gazette of Commerce is available only from 1883 on. The state of the companies in the earlier dates are unknown unless being stated by the companies in their archives.*

In the previous chapter, it was demonstrated that the engineers Terner and Chopard and the early licensed contractors of glulam formed a consortium, coordinating all glulam activities. These contractors however had various professional backgrounds and covered a great heterogeneity of business activities. Studying this situation helps to explain why they had quite different interests in and relations to glulam, and therefore developed different contributions to it. In order to understand how and why they integrated this new technology into their business differently, the nature of these businesses should be studied: the scale and the scope of their activities, their juridical status, and the different social and political roles that the owners of these companies adopted.[1]

Here it should be noted that an exact assessment of the contribution of these contractors to the early development of glulam and reciprocally, the evaluation of the impact of this technology on the transformation of these businesses, and consequently the comparison of glulam-relevant activities of these contractors, are difficult if not impossible to make. One of the major obstacles is that, from the early glulam projects inventoried in this research (numbering 261 buildings, see Appendix 3.1), only the contractor of less than half of them have been identified (114 buildings). Considering that the inventory itself is by no means exhaustive and has been compiled based on the data of very different sources (sometimes biased for the projects of a particular contractor), it would be inaccurate to evaluate the glulam activities of these contractors based on the statistics of this inventory. Moreover, it should be noted that important data on the development of these companies over time, their structures, employees, balance sheets, etc. are missing or incomplete. Besides, having quite detailed information about a contractor, and a lack of basic information about the other ones, make the comparison and any conclusion hypothetical, speculative, and probably distorted. Regarding the bigger firms, namely the general contractors, it should be considered that early glulam projects consisted only one minor part of their activities, that's why in the advertisement of their activities in the journals or in the publications on the occasion of jubilees of their firms, the focus has been not on glulam projects, whereas for the smaller firms, mainly carpenter-contractors, early glulam projects were actually the main activity of their workshops; these contractors hence paid much more attention to publicize those projects.

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[1] The research on the building contractors has not been conducted systematically in Switzerland. The work of Adrian Knoepfli is among the most important ones: Knoepfli, Adrian. "Aufsteiger – oder längst im Bürgertum zu Hause? Bauunternehmer und Bauunternehmen in der Schweiz". *Schweiz im Wandel. Studien zur neueren Gesellschaftsgeschichte. Festschrift für Rudolf Braun zum 60 Geburtstag*, edited by Sebastian Brändli, David Gugerli, et al. Basel/Frankfurt (Main), Helbing und Lichtenhahn, 1990, pp. 259–276. This study has been influenced by the following research: for the case of Belgium, and particularly for the methodology: Bertels, Inge. "Building Contractors in Late-Nineteenth-Century Belgium: From Craftsmen to Contractors." *Construction History*, vol. 26, 2011, pp. 1–18. In this article I was alerted to the following source, for the UK: Cooney, E. W. "The Origins of the Victorian Master Builders". *The Economic History Review*, vol. 8, no. 2, pp. 167–176. For Germany see: Kocka, Jürgen. *Unternehmer in der deutschen Industrialisierung*. Göttingen, Vandenhoeck und Ruprecht, 1975. For a case study regarding the British and American context see: Wermiel, Sara E. "Norcross, Fuller, and the Rise of the General Contractor in the United States in the Nineteenth Century". *Proceedings of the Second International Congress on Construction History,* Cambridge: The Construction History Society, pp. 3297-3313.

To this we should add that, the lack of uniformity and the accuracy of the terminology used for describing the field of activity of the contractors at that time,[2] such as the distinction between a master carpenter, master builder, and so on, makes also difficult to develop a hypothesis about their educational and training background in the cases that these are not clearly mentioned.

Considering all these restrictions, the following method for a more homogeneous study of these contractors is adopted: first, the contractors whose contribution to the development of early glulam was less significant (distinguished by a background colour of yellow in table 3.1), will be introduced only briefly and then set aside. The criteria for evaluating the significance of their contribution will be explained there. Second, the remaining contractors (the green part of the table) will be studied more in detail and depth and categorized according to the significance of their contribution. Third, the future of these companies will be briefly studied. It will eventually be discussed how the contractors, with different degrees and the nature of the contribution, influenced the early rapid development of glulam. The last part will shed light on some particular characteristics of the Swiss way of networking with business elites in the first half of the 20th century, and its impact on the early development of glulam. Concentrating on the consolidation effect of this network, the second part of this chapter will demonstrate how other interested parties as well, by accumulating different roles, performed beyond their initial function and contributed significantly to the early acceptance and legitimization of this technology on a national scale. The particular case of the SBB as a federal institution will be studied in this part.

1. Early licensed contractors

1.1. Contractors with less significant contribution

Albin Blau's Wid. It was a familial construction business with a focus on woodworking and timber trade. It was dissolved in 1911, after the death of the owner (namely the widow who was operating the company of her former husband). Afterward, the company Gribi & Co. became the exclusive glulam licensee, exploiting glulam throughout the region of Bern.

Riester-Asmus. It was a familial construction business that was dissolved in 1923. A couple of glulam projects are known to be developed and built by this company, two of which are among the case studies analyzed in the following chapter. Otherwise, their collaboration with the glulam consortium did not develop further over time.

Construction Business Chur AG. Before turning into a joint-stock company in 1905, the company was active under the name Ulrich Trippel carpentry and construction business in Chur. It started, as

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[2] For example, in the memories of the founder of the company Häring in Basel we read: "Father always used the word "construction business" on the old letterheads from around 1920, even though we only made work with wood as a material". (translated by the author). *100 Jahre Starker Wuchs: ersönliche Erinnerungen zur Geschichte der Häring & Co. AG 1879 – 1979*. Visited online: https://www.haring.ch/haering-geschichte/ Consulted on 12.06.2021.

early as 1910, with building glulam structures. Their contribution to the development of glulam did not grow over time, and their only representative early glulam project remained a riding arena in Chur, which will be studied in the next chapter. The company was dissolved in 2010.

Nielson-Bohny & Co. Few glulam projects built by the company Nielson-Bohny, a family-limited partnership, do not represent a steady contribution to the development of early glulam technology. One of their most important projects, the tram depot Dreispitz, built in Basel in 1916, will be discussed in the next chapter. The company turned into a joint-stock company in 1926 and was dissolved definitely in 1974.[3]

Locher & Cie.: The company was founded in Zurich in 1830 by Zurich city councillor, Lieutenant-Colonel Johann Jakob Locher (1806–1861).[4] The company was taken over in 1872 by Colonel Eduard Locher-Freuler (1840-1910). After an apprenticeship of 5 years as a mechanic in a loom fabrication workshop, he supplemented this practice with a diploma in structural engineering at ETH Zurich. He becomes then one of the major three contractors of the Simplon Tunnel (1898-1906).[5] His company has been involved in many infrastructure projects, for which woodworking and carpentry have been an important part (for footbridges, formwork of bridges, halls, etc). Following the death of Eduard Locher-Freuler in 1910, the contribution of the company to the development of glulam, if any, remained marginal. In 1905, the company was handed over to, structural engineers, Eduard Locher-Hürlimann (1872-1931) and Fritz Locher-Lavater (1874-1942). Fritz Locher was a board member of the Swiss Association of the Material Testing of Technology (SVMT: initially involved in the development of synthetic glue).[6] Edouard Locher (a board member of the Swiss Master Builders' Association) along with Charles Chopard were the representatives of the construction industry, in the commission appointed by the S.I.A. on October 19, 1924, for the establishment of building norms for timber constructions. These roles of Fritz and Edouard will be hence discussed in chapters 4 and 5 respectively. It was most likely with the suggestion of Eduard Locher-Freuler that the company invested in the license of glulam. He has been as well one of the founding members of the Zurich branch of the master carpenter's association, founded in 1889, and one of the founding members of the Swiss Master Builders' Association in 1905. This general contractor privileged until the 1930s his own branded timber truss systems, Locher system, for its project with structural timber. It was in the

[3] In the 1970s, it was decided to sell the company, arguing that the performance of the company was not adjustable. However, selling the 8000 square meters of the land of the company in the city of Basel, which seems to interest the owners of this company, having the Rosch company as the client. Although the labour associations and the Labour Party asked the government of Basel, to intervene, but it seems that this subject did not interest them, and they refused to purchase the land. According to the newspapers of the time, the situation was not in favour of the workers. The land was eventually sold to the Rosch company. For almost 20 years this land had been of no use, and then in the 1990s, they built flats there. The "Nilbo affaire" and their deal with the Rosch was already discussed in the 1974, in the newspaper "Vorwärts, Basel" in an article entitled "Nilbo oder gewöhnliche Kapitalismus". All the debates about this affaire can be followed in different left-wing and right-wing newspapers: Basler Zeitung, Abend-Zeitung, Basel, Vorwärts, Basel, National-Zeitung, Basel, Basellandschaftliche Zeitung, Liestal, Basler Volksblatt, Neue Zurcher Zeitung, from 1973 to 1996. These newspapers can be found at: Basel, Schweizerisches Wirtschaftsarchiv, Erw. G. H. u. l. Bc 500.

[4] 1857-1861, Locher was member of the City council of Zurich.

[5] Consulted online on 2022.05.23. https://www.locher-ag.ch/locher-ag-zuerich/

[6] The name of the association in German: *Schweiz. Verband für the Materialprüfungen der Technik.*

1940s that, following the introduction of synthetic glue, more glulam projects were built by this company.[7]

1.2. Contractors with a decisive role in the development of early glulam

1.2.1. Politician-craftsmen

Edouard-Marc Bugnion-Pittet. The 18-year-old Edouard-Marc Bugnion-Pittet (1878-1922), passed the exam of the obligatory professional courses for carpenters, organized by the *Société industrielle et commerciale* of Lausanne (industrial and commercial association) in 1896.[8] Later in 1903, he took over the familial business of the carpentry shop and sawmill of his father. The latter, a prominent master carpenter of the city of Lausanne, constructed in 1892 the roof of the church “Chapelle des Terreaux”, with mechanically laminated timber girders, a project praised in the technical journals of the time.

Edouard Bugnion started quite early to reorganize not only the activities of the workshop of the father but also the timber trade in general, at the municipal and cantonal levels. At the beginning of his professional activity in 1905, he co-founded the Association of the Master Carpenters of Lausanne and the surrounding area,[9] where Bugnion was elected as the president. The goal of the association was described among others as “mediating between the members of the association and different political bodies, and also the workers”. During the same year, in 1905, Bugnion stood as a candidate for the city council election, where he got elected and represented the liberals in Lausanne until 1921.

In 1906, during one of the strongest waves of strikes in the country, he co-founded the Society of Carpentry Contractors, at the cantonal level,[10] where he was appointed as the vice president. During the first couple of years of his work, and beyond his carpentry workshop, Bugnion expanded his network and his influence on different sectors of timber trade, in a national context. In 1907, he became one of the key members of the administrating committee for the purchase and the sale of logs, “Timber Merchants Association”, where Bugnion was responsible for treasury management.[11]

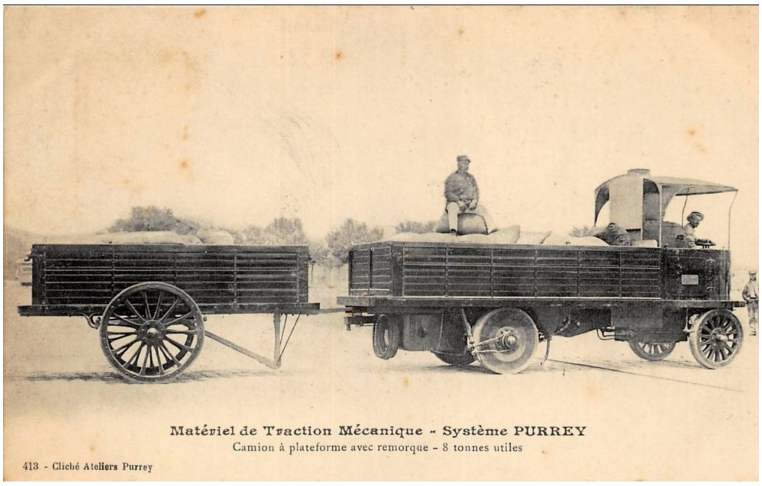
Among different tasks related to the process of timber, one sector of this trade which had not changed over the centuries, despite its extreme importance, was the transport of logs and timber elements. In general, the transportation infrastructure was highly important for the wood industry. Principally the workers had to bring the logs to the mill site. Hauling wood was until then mainly done by horse-drawn sled.[12] Horse-driven transport of wood was usually done on a carriage with rubber wheels.

[7] See *Hundert Jahre Technik, 1830-1930: Die Baufirma Locher und Cie. in Zürich*. Zurich, Berichthaus, 1930.
[8] Feuille d’avis de Lausanne, 15 mai 1896, p. 5. „which, according to the law of the Grand Conseil of Canton Vaud, that admits the obligation for the apprentices to follow the professional courses”. (translation from French by the author)
[9] The name of the association in French: *Association des maîtres charpentiers de Lausanne et des environs*
[10] *Société Vaudoise des Entrepreneurs de charpentes*
[11] *Association des marchands do bois*.
[12] Johann, Elisabeth. "Transportation of Wood Out of the Forest (along Short Distances)". *International Journal of Wood Culture,* vol. 1, no. 1-3, 2021, pp. 80-111.

Although the system of wood transportation, for longer distances, was revolutionized by the railway system, over short distances changed however very little for centuries. Knowledge was traditional and handed down from generation to generation. Until the end of the First World War, this technology, including the construction of forest roads, remained unaffected by changes in other exploitive industries. Trucks then gradually replaced horses in timber transportation.[13] Being aware of the extreme importance of updating the wood transport system, Bugnion invested in a project that enjoyed an early considerable success.

Since in Switzerland, the business elites normally used to find each other in the political circles, Bugnion, following this tradition, teamed up with Edouard Pilet, also a business agent and president of the City Council of Lausanne in 1910, to import to the country the trucks suitable for road transport.[14] Together with Pilet, they established the *Société des transports par camions, système Purrey* (Company of Transport by Trucks, System Purrey). Representing this brand in entire Switzerland, this company was one of the most important importers of buses and trucks at the beginning of the 20th century, aiming at the purchase and the sale of the trucks System Purrey, produced in Bordeaux, France (Fig. 1). Those trucks could be used for the transport of different ranges of goods, including logs (Figs 2-3). Thus, Bugnion's business was expanded over the main parts of the wood value chain - from log-cutting to the on-site assembly of engineered timber components, following his investment in glulam technology in 1909. Besides the timber trade, he invested in the financial intermediary market, including credit unions and insurance, and contributed to several property development projects, mainly as a shareholder and board member of these associations.[15]

[13] *Ibid.*
[14] Who was the father of Marcel Pilet-Golaz, businessman, president of the Lausanne Municipal Council in 1910, and later president of the Confederation.
[15] From 1907 to 1914, he was member of the *Union Vaudois de credit*, and as well member of the management commission of the *Assurance mutuelle Vaudois*. Bugnion has been member of the administration committee of the Société Immobilière du Home des Fontenailles, Société immoblière du Petit Rocher.



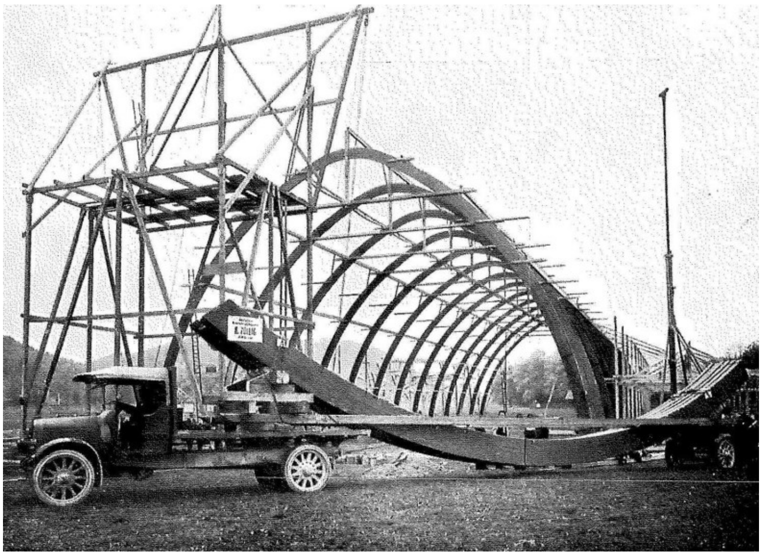


Fig. 1 Purrey trucks, advertisement of the company.
Fig. 2. A truck for transporting logs, ca. 1900-1920.
Fig. 3. A truck of the company B. Zöllig, transporting glulam structures to the festival hall of the Swiss federal shooting fair.

Cumulating different roles in both politics and business, Bugnion used this extended network for promoting glulam: as a member of the city council of the city,[16] he pushed the use of glulam in public projects. As an example, we can mention the aeroplane hangars project of the City of Lausanne. At the

[16] which was for more than 30 years until 1914, almost entirely dominated by the right-wing parties.

beginning of the First World War in 1914, the City of Lausanne decided to build hangars for the aeroplanes in Blécherette near Lausanne (Figs. 4-5).


Fig. 4 hangars for the aeroplanes in Blécherette near Lausanne, constructed in 1914. Contractor: Ed. Bugnion.
Fig. 5 Glulam structure of the hangar, partially destroyed by the fire of 1923.

Bugnion could convince the authorities that the hangar should have a glulam structure, emphasizing that the construction of halls, 44 meters in length and 21 meters in width was too big to allow the construction of normal timber trusses: "in general, this hangar would be built as simply as possible, but with good materials", emphasized Bugnion.[17] The good material was referred to as glulam and implied the prejudice that existed at that time towards timber known as an outdated material. By cumulating different roles, as shown here, Bugnion could benefit from the overlap of the political circles with the business sectors, not only for promoting glulam but also for systematically opposing the workers' demands, as we saw in the previous chapter.

Although diversifying the investments across different service and industry sectors brought early success for Bugnion, the First World War had a devastating effect on the future of these financial projects. The coal restrictions of the war of 1914-1918 put an end to the steam cars. Accordingly, the activity of the company of Purray trucks ceased definitely in 1929. Two of the three members of its administrating committee, including Bugnion, went bankrupt.

Bugnion was an example of the carpenter whose profession was traditionally linked to their carpentry workshops. With the freedom of the trade, these carpenters felt the necessity to expand their craft-based business to new areas of construction in order to survive the situation that threatened their existence for the reasons discussed in the first chapter. Unlike some other construction companies that expanded their activities by transforming into general contractors, Bugnion, considering his background in a family of bankers, expanded his business by mainly investing in financial assets. An investment plan which was strongly affected by the years of economic crisis following the First World War. Following his bankruptcy in 1922, the master carpenter Bugnion committed suicide.[18]

[17] Original text in French : "d'une facon generale, ce hangar serait construit le plus simplement possible, mais avec de bons matériaux. Bulletin officiel des séances du conseil communal de Lausanne, meeting of Tuesday, 24 march 1914.
[18] In 1915, César Cierici, one of the three shareholders and the members of the administrating committee of this association went bankrupt as well.

Burkhard Zöllig. The beginning of his business dates back to 1888 when Zöllig founded in Berg near Arbon a carpentry shop. Later in 1898, Zöllig moved his company to the city of Arbon. His occupation has been described as both a master builder and master carpenter, or a building contractor with carpentry as his domain of expertise.

Similar to Bugnion's situation, the years around 1909 when Zöllig was granted the license of glulam were decisive years for the formation of his professional life and the organization of the carpentry trade in the eastern part of Switzerland.

In 1909, the Swiss Association of Master Builders Section of Arbon & Surroundings[19] was established, where Burkhard Zöllig was elected as the president. In 1914, he was the co-founding member and the president of the Association of the Master Carpenters of Canton of Thurgau.[20] Two years later in 1916, he co-founded as a member of the board of directors (later promoted to president), the Association of Sawmill Owners of Canton of Thurgau,[21] in order to promote the professional interests of the Thurgau sawmill owners and to reduce the competition among the members. This association formed a section of the Trade and Industry Association of Canton of Thurgau[22] and the Swiss Wood Industry Association.[23] He was as well elected as a member of the *Grosser Rat* of the Canton of Thurgau which is the canton's legislative and supreme supervisory authority.

Zöllig managed his company until 1934 when he transferred it to his sons. During these years, glulam construction was the main activity of his carpentry workshop. All the early developments of glulam were therefore done under the supervision and direct involvement of Burkhardt Zöllig.

1.2.2. High-ranked army officers

Fritz-Hermann Gribi. Different large construction companies emerged from varied circumstances.[24] The construction company of Gribi in Bern is an example of the contractors that got developed by the projects generated by the introduction of the railways to the country.

Fritz-Hermann Gribi (1879-1948), was born into a family of high-ranked military officials and building contractors whose main activities flourished with the introduction of the railways in the region. The projects generated by the railways included the construction of buildings directly related to the railway's structures, as well as the consequences of the plans imposed on the urban fabric, streets, existing buildings, etc., following the location of the railway stations.

In the 1880s and within the Gribi family, two companies were founded in this regard. First, in 1883, a construction business, sawmill, timber trade, and impregnation company was founded by master

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[19] *Schweiz. Baumeister-Verband Sektion Arbon & Umgebung.*
[20] *Thurgau Zimmermeister verband.*
[21] *Genossenschaft thurg. Sägereibesitzer.*
[22] *Thurg. Gewerbevereins.*
[23] *Sehweiz. Holzindustrievereins.*
[24] Adrian Knoepfli investigated these circumstances in his study on some major Swiss building contractors. (See note 1 above).

builders Hans & Friedrich Gribi,[25] both involved in the army with the rank of Major.[26] Later in 1888, by the introduction of the railways in the region, Hans & Friedrich established a second company named *Eisenbahnbau-Unternehmung Langenthal-Huttwyl* (a railway construction company) in the Langenthal village, in the same region as Burgdorf. Although these two companies worked separately, the influence of their family business in the development of glulam within the SBB projects is significant. This subject will be discussed in detail in the latter part of this chapter. Moreover, as we will see in the last chapter, Gribi was one of the first contractors that collaborated with Colonel Ulrich Meister, who initiated testing Swiss structural timber in 1893 and encouraged systematic research on timber as a structural material within EMPA.

As soon as 1901, the general partnership of Gribi & Cie., which was developed from the first company founded in 1883 and specialized in the timber trade, involved an architect in the directing board, and an architecture office in their construction business. This way, they not only took over the construction parts but often also planning tasks.

Lieutenant-Colonel Fritz-Hermann Gribi (hereafter only Gribi), the figure of the company who was associated with the development of glulam, joined the company as a partner in 1912.

In 1917, he transformed the company into a joint-stock one, where the managing director remained Gribi himself, with the title master builder (most likely initially a master carpenter). During the same year, as well, he co-founded the Bern section of the Swiss Master Carpenters' Association, where he remained as a board member until 1934. From 1918, he was on the board of directors of the regional branches of the master builder associations.

Emil Fietz & Jakob Leuthold. The establishment of their company goes back to 1889, when the "*grosse Bauperiode*" of Zurich, encouraged Ferdinand Emil Fietz-Leuthold (1855-1919), and Colonel Johann Jakob Leuthold-Balthasar (1862-1925) to come together and establish a familial construction business. Two years later in 1891, they expanded their construction business by adding a carpentry shop and a sawmill to it, and by turning their local construction business into a general contractor. This carpentry sector, allowed them to develop timber beyond an auxiliary material for the formwork of concrete structures, by the very early construction of several glulam structures of various functions.

Emil Fietz was a master builder, and son of a stone-mason master (it could be then argued that the professional background of Emil was probably not in carpentry, but rather in masonry),[27] who teamed up with Jakob Leuthold, an architect who graduated from the technical school of Stuttgart and

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[25] *Bauunternehmungen, Sägegeschält, Holzhandlung und Imprägniranstali.*

[26] All the information about the background of the contractors in the army has been found in the following journals: Helvetische Militärzeitschrift, Revue Militaire Suisse, Schweizerische Militärzeitschrift. *Allgemeine schweizerische Militärzeitung.*

[27] He (Fietz the son) was as well president of a quarry association (Steinbruchgesellschaft Mägenwil in 1905).

Cologne. They founded a general contractor company that undertook many private and public projects, buildings, and infrastructures, including several glulam projects.

Recognized as the first licensed contractor for the production of glulam in Switzerland,[28] Fietz & Leuthold, showed a strong early interest in glulam. The prospect of the glulam consortium published in 1913, is clearly dominated by the glulam projects of Fietz & Leuthold, with a noticeable diversity of building functions and typologies of glulam structures.[29] Over time, however, glulam in this company developed merely in the shadow of other structural materials, mainly reinforced concrete. To speculate about the possible reasons for the decline of interest in glulam within this company, we could mention first the nature of the projects of the company, where a transition to urban infrastructure and public works can be observed. As a consequence, a significant shift to reinforced concrete took place. Besides, it should be noticed that neither Fietz nor Leuthold was carpenter, and their expertise was not directly related to timber. As already mentioned, the carpentry and sawmill branches were in fact added to their construction company only two years after the establishment of their company as a general contractor.

Emil Fietz, similar to other early glulam contractors was among the board members of the employers' associations. It was under his presidency that the board of directors of the master carpenters' association of Switzerland was transferred from St. Gallen to Zurich in 1909. Master carpenters' association in Eastern Switzerland was founded as early as 1905, from which the Swiss master carpenters' association emerged in 1906. The board of directors of the latter was moved from St Gallen to Zurich in 1909 since Zurich showed a big jump in its share of the members, and thus it was also necessary to elect a new association leadership.[30] Emil Fietz, was selected for this post and remained in this function until 1915. He was as well a board member of the Swiss Master Builders' Association from 1909-1919: the period when glulam experienced the most intense development within this company.

1.3. Future of the contractors

Assessing the future of these contractors, the following questions arise: how the early glulam contractors grew, evolved, or failed over time, and how their know-how was transferred to the following generations? How they reacted to many economic upheavals and disruptions of the 20th century?

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[28] "Neue Holzbauweisen, System Hetzer". *Hoch-und Tiefbau, offiz. Organ des schweiz. Baumeister-Verbandes und des schweiz. Zimmermeister-Verbandes*, Zurich, Arnold Bopp, 1910, pp. 146-149.
[29] From 21 illustrated Swiss glulam projects, 11 of them were Fietz & Leuthold projects, and the rest from other contractors, namely: Zöllig, Bugnion, Gribi & Cie., Riester-Asmus, and Construction Business Chur AG.
[30] 100 from the total of 322 members. *Schweiz. Zimmermeister-Verband: Jahres-Bericht und Mitglieder-Verzeichnis pro 1910.* Zurich, Buchdruckerei Arnold Bopp, 1910.

The future of these firms followed somehow the known trends existing in the past century. Some of them dissolved naturally after the death of the owner, some others got dissolved in times of stagnation and recession, and few continued to operate while being acquired by other companies.

Bugnion

After its bankruptcy in 1922 and following the suicide of the owner, the company of master carpenter Bugnion was sold in an auction to the construction company Dupont & Desarzens. The successors of Bugnion did not survive the sharp slump in the mid-1970s, and therefore the only traces of early glulam contractors in the French-speaking part of Switzerland were lost definitely in 1973. The glulam industry, at the time being, is mainly dominated by the German-speaking part of the country.

Zöllig

The two sons of Zöllig, Werner and Burkard junior took over the business of the father in 1934 and invested in the further development of laminated wood construction. In 1970 the sawmill got closed, but the gluing hall saw an expansion by adding a finger-jointing plant. During the crisis of the 1990s, the Swiss construction industry underwent far-reaching changes, and a considerable shrink in the number of companies and employees could be observed.[31] This wave affected as well the Zöllig company.

In 1999 Werner Zöllig AG was taken over by the Häring Group, the latter being based in Pratteln in the Canton of Basel-Landschaft. In February 2004, the new owner decided to close Arbon's branch, which had started to falter financially. In April 2004 the Häring group transferred the business of Arbon to the company Roth AG, located in Burgdorf in the Canton of Bern, which had itself taken over the company Gribi & Cie., during the economic crisis of the 1970s.

Gribi

The second world war, the need for standardization, the factory-based door and window fabrication, the then-new synthetic glue, and the shortage of coal needed for the production of steel and cement, all were in favour of the rise of the company of Gribi, which had expanded the business in different branches of the timber trade. Operation of a construction business with an impregnation plant, window factory, large-scale joinery and carpentry, timber construction, in particular, Hetzer, ring dowel and nail truss construction, sawmill and planning mill, manufacture and trade of sawn timber, construction timber and firewood, furniture and related articles, crates and sleepers, import and export of timber or timber products, were all among the activities of this company in the 1940s. The economic crisis of the 1970s influenced nevertheless this company as well. It was acquired in 1976 by Emil Roth + Co.

[31] Between the business censuses of 1995 and 1998, the number of companies with more than 10 employees (extrapolated to full-time equivalents) fell by 13.7%. The number of employees in companies of this size fell by more than 20%. (Source: Die Volkswirtschaft by Staatssekretariat für Wirtschaft (Seco), Bern, https://dievolkswirtschaft.ch/de/2007/11/koerber/, visited online on 2020).

AG. that was bought itself, during the crisis of the 1990s, by the Häring company in 1994. After the transfer of the business of Zöllig, and its fusion with Roth, the Häring group changed the name of this branch of their company, from 2012 to Roth Burgdorf AG. The company Häring stands today for the only remaining traces of the first generation of glulam constructors of the country. This company will be studied in the last chapter, on the occasion of the role of synthetic glue in the revitalization of the glulam industry.

Fietz-Leuthold

The company got dissolved in 1994.

1.4. Glulam licensees, a "cartel of elites"?

The early glulam contractors, as the study of their foundation and development, demonstrated, were a diverse and evolving group of actors who emerged from different social and educational backgrounds. This latter influenced the social and political roles that they adopted during their professional life, their strategies into the foreground, and consequently the scale and the scope of the function of their companies. Their various patterns of development shaped differently their strategies in developing and supporting glulam. In the following, the accumulation of roles of these contractors in three main professional and political fields will be distinguished.

1.4.1. Employer's associations' presidents

The contractors who had significant contributions to the development of early glulam, as studied in this chapter, were with no exception, among the board members, if not the president of the regional or national associations of the master carpenters and/or master builders. In this context, it should be clarified that there were several reasons for the close collaboration between these associations. It was mainly for the purpose of gaining more backing in that desperate situation of the carpentry trade at the turn of the 20th century, but also for reputation and members, that the Swiss Master Carpenters' Association joined a similar association for the master builders in 1907, the year the patent of glulam was registered in Switzerland. These associations, not only regulated industrial relations but also systematically promoted glulam. For example, the master builders' association's magazine Hoch- und Tiefbau, which became, in 1907, the official organ of the master carpenters' association as well, particularly promoted the use of glulam.

This fusion was also partly due to the special structure of the carpentry trade and the fact that carpenters shared the same construction site with the master builders.[32] These latter could be themselves, master carpenters, initially however they were mainly masons and bricklayers.[33] Because of the close interrelation of the work of master carpenters and master builders on the construction site,

[32] *75 Jahre Schweizerischer Zimmermeisterverband (SZV),* Zurich, 1981, p. 1.
[33] Adrian Knoepfli, (see note 1 above), p. 262.

and also the design process, the actors of these two fields were socially, economically, and politically, closely related to each other. That's why these two sections were collaborating closely together not only on the construction site, but also whenever collective actions were needed. It should however be noticed that the key members of these associations were not necessarily those whose careers were related to the associations' principal trade. The underlying network of these associations was beyond the craftsmen. Here the example of the contractor Locher should be mentioned. Locher was trained as an engineer and was the co-founder of the Swiss Master Carpenters' Association, without being himself a master carpenter or being trained as such. The strong affiliation between the master carpenters and master builders' associations and the glulam consortium, indicates that glulam was very early understood as a new technology not merely to make curved wooden elements, but to reorganize the construction sites, both as the main structural materials, mainly for the master carpenter, and also for the formworks and auxiliary structures, mainly for the general contractors. The mentioned affiliation reveals also that glulam, through those associations' presidents was a technological choice over its other alternatives and got promoted for re-organizing the labour market. The analysis of the complex relationship between contractors and the workers in the previous chapter supports this hypothesis and prepares the context for a broader understanding of the early development of glulam technology and Swiss political conservatism, a subject which will be studied at the end of the first part of the present chapter.

1.4.2. Trades associations and elected politicians

In the case of the politician-craftsmen, namely Bugnion and Zöllig, one thing deserves special mention: these two master craftsmen were presiding members not only in employer associations but also in trade associations (hereafter EAs and TAs respectively) and influenced collective action in these two essentially different fields. These associations have different organizational structures and exercise their influence on business through different political actions. In the case of the EAs, the policies are more related to the regulation of the labour market. The TAs, on the contrary, are concerned rather with the product category, since "they have to bring out the peculiar interests of specific groups of producers and firms, […] act as pressure groups (or lobbies) for defining, promoting, and defending the interests of their membership in the political arena vis-à-vis government authorities, public administrations, and state agencies". [34]

Being involved in the TAs, and consequently, in public relations activities such as advertising, publishing, lobbying, etc., Bugnion and Zöllig were the two glulam contractors, who were as well in the directing board of the glulam consortium as the top governing body: Bugnion presided over the consortium in 1915 and remained in that position until 1919, the year when Zöllig entered the board of

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[34] Lanzalaco, Luca. "Business Interest Associations". *The Oxford Handbook of Business History*, edited by Geoffrey Jones and Jonathan Zeitlin, pp. 294-295.

directors as the vice president until 1922.[35] Establishing the policies, setting the goals, maintaining resources, assessing and monitoring market developments, aligning the marketing with the consortium's overall strategies, etc., were among the roles of these contractors as the board members who were themselves also members of different TAs while holding simultaneously political offices; Bugnion and Zöllig were both elected politicians in the city and cantonal levels respectively. Lobbying and advocacy, policy influencing, and securing the relevant permissions could have been more effective by engaging the elected politicians on the board of directors of the consortium.

1.4.3. Army officials

Besides the clear connection between the employers and trades associations' representatives and the early glulam consortium, what is quite remarkable is the relatively high-level involvement of some of these contractors in the Swiss Army. Colonel Locher (*Oberst* Edouard Locher), Lieutenant-Colonel Gribi (*Oberstleutnant* Fritz-Hermann Gribi, who took over the company founded by Hans and Friedrich Gribi, both ranked as Major (*Major*) in the army), and Colonel Leuthold (*Oberst* Johann Jakob Leuthold) were all high-ranked officers in the army. Moreover, Locher, Fietz & Leuthold, and Gribi companies, were all among the strongest and oldest general contractors of the 19th and 20th centuries,[36] and were involved in many railways, tunnels, infrastructures, and important projects of the time.

The Swiss Army then was one of the major networks which connected the elites together, where important unofficial business discussions and decisions were made. Cumulating roles in different circles of military and business, and quite often in politics as well, was not limited to the contractors of the early glulam consortium. This dense network of relations between those circles constituted in Switzerland a group of highly privileged people called the "elites".

As a consequence of the liberal movement and from 1830 on, as Albert Tanner explains, a new political and social elite was established, which was no longer based on origin (like nobility), but on the economic situation and academic education.[37] These elites influenced the course of society by taking decisions that were crucial for its development at the national level.[38]

In Switzerland in the early 20th century, being a high-ranked officer in the army was a "key for the functioning of Swiss elites", as Felix Bühlmann and his colleagues demonstrate in a study on the Swiss elites.[39] Understanding the early glulam contractors as part of the Swiss elites of the turn of the

[35] The only contractor, who besides Bugnion and Zöllig was part of the directing board was Gribi, who stayed at this post only few months before the glulam consortium was dissolved following the expiry of the patent.
[36] Adrian Knoepfli, (see note 1 above). The contractor Gribi is not mentinned there.
[37] Tanner, Albert. *Arbeitsame Patrioten - wohlanständige Damen: Bürgertum und Bürgerlichkeit in der Schweiz 1830-1914*. Zürich, Orell Füssli, 1995, pp. 477-568.
[38] Based on the definition of sociologist Michael Hartmann. Hartmann, *Eliten und Macht in Europa ein internationaler Vergleich,* Frankfurt am Main, Campus, 2007, p. 17.
[39] Bühlman, Felix, et al. "Elites in Switzerland: The Rise and Fall of a Model of Elite Coordination." *Tempo Social: Revista de Sociologia* Da USP, vol. 29, no. 3, 2017, pp. 181–99. All the authors are currently based at the University of Lausanne.

20th century, connected through a dense network of interlocking and overlapping interests offers a new perspective on and a better understanding of the circumstances that gave rise to the early development of this technology in Switzerland.[40]

1.4.4. Glulam consortium as an "Elites cartel"

In the first chapter, it was discussed that one of the main reasons for the early particular development of timber engineering in Switzerland, was the semi-persistence of the guild's structures beyond the Old Confederacy, until the establishment of the Federal State. These structures, as demonstrated previously, made it possible to keep semi-institutionalized the practice of carpenters, who, from a technological point of view could develop innovative ideas needed for the survival of the timber industry. However, if we expand our understanding of the importance of the persistence of these structures beyond the technological aspects, covering the political arenas, we will realize that there are many similarities between the Old Confederation and the Swiss modern State which can help explain the reasons for such a rapid taken up of the glulam technology by the timber industry.

The political foundations of the Old Confederation, as Andreas Würgler demonstrates in *Zünftige Politiker* (guild-associated politicians), were tightly associated with the business elites' associations. Based on the case studies of Bern, Zurich, and Basel, Würgler argues:

> Virtually all political decision-makers in the pre-modern era were members of a guild or a guild-like society. This is not altered by the fact that the specific rules for election to the council (or councils) were different in each city. If one understands the members of the Small or Great Council and corresponding commissions or secret councils as political decision-makers, then guilds controlled the job market for politicians in the old Confederation almost one hundred percent.[41]

Masnata-Rubattel admits as well in *le pouvoir Suisse*, that already from the 16th century, the guilds "took full political power" in the country.[42] Hence, the tradition of an overlapping network of business elites and politicians goes far back in the history of the country.

With the modern Swiss confederation, no professionalization or particular background was defined as necessary for the governors. This pushed the survival of the old traditions of the interrelation of business and politics. The new confederation was then "nothing revolutionary" as described by

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[40] For more about this specific way of networking see: Bühlmann Felix, et al. "The Swiss Business Elite (1980-2000): How the Changing Composition of the Elite Explains the Decline of the Swiss Company Network". *Economy and Society*, vol. 41, no. 3, 2012, pp. 199-226.

[41] Würgler, Andreas. "Zünftige Politiker. Korporative Regulierung Des Zugangs Zu Politischen Ämtern in Der Eidgenossenschaft (16.-18.Jahrhundert)." *Regulierte Märkte: Zünfte Und Kartelle = Marchés Régulés: Corporations et Cartels*, edited by Margrit Müller et al., Zurich, Chronos, 2011, p. 151. Original text: "*Sowohl in den sogenannten Zunftstädten Basel und Zürich als auch in der Patrizierstadt Bern waren in der Vormoderne so gut wie alle politischen Entscheidungsträger Mitglieder einer Zunft oder einer zunftähnlichen Gesellschaft. Daran ändert auch die Tatsache nichts, dass die konkreten Regelungen der Wahl in den Rat (oder in die Räte) in jeder Stadt wieder anders waren. Versteht man die Mitglieder des Kleinen oder Grossen Rates und entsprechender Kommissionen oder Geheimer Räte als politische Entscheidungsträger, so kontrollierten Zünfte den Jobmarkt für Politiker in der alten Eidgenossenschaft fast zu hundert Prozent.*" (translated by the author)

[42] Original text in french: "*dès 1336 les corporations réduisissent à s'assurer une solide représentation dans le Conseil ; elles assument la totalité du pouvoir politique dès le XVIe siècle*." Masnata, François, et al. *Le pouvoir suisse, 1291-1991: Séduction Démocratique et Répression Suave.* Lausanne, éd. de l'Aire, 1991, p. 31

William Martin in *Histoire de la Suisse: essai sur la formation d'une confédération d'Etats,* but only some more steps towards a "political unity, which was a necessity for the economic unity" of the cantons.[43] Accordingly, the new confederation grew up from a necessity, rather than an ideology, that's why it is usually regarded as an "economic evolution rather than a political one".[44]

In the Swiss modern state, the owners of prominent companies, in a similar way as in the past, made power structures, in which they organized themselves both economically (as we saw in the case of cartels), but also politically (as we saw in the case of some members of the glulam consortium). Terner and Chopard, via the early glulam consortium, developed in fact strong organizational ties with other elite members, like the president or board members of other employers' associations, trades associations, high-ranked army officers, and elected politicians.[45] The cohesive power of the glulam consortium members, or the elites who were leaders in different fields with multiple roles, gave an early and rapid push to the development of glulam. This particularly dense and closed elites' network, notably effective in the case of Switzerland (not exclusive though) and operative during the first half of the 20th century, has been the subject of several studies by scholars.[46] These latter demonstrated that at the time that Swiss elites accumulated different roles in the Swiss elites' networks, the common thread running through all the actions and decisions remained always business.

In the study "The Core of Swiss Elite Networks", co-authored by Thierry Rossier, it is argued and demonstrated that the relations between Swiss elites, at the end of the 19th century until 1945, followed a "consolidation" logic.[47] The strong intention to take up glulam as a new technology should definitely be understood as a result of the consolidating nature of this network, where it brought together the elites who happened to be themselves the early major clients of glulam or closely linked to these latter.

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[43] Martin, William. *Histoire de la Suisse : essai sur la formation d'une confédération d'Etats*. Lausanne, Payot, 1943, p. 265.

[44] *Ibid.* Orinignal text in French: "*une évolution économique plus que politique*".

[45] David, Thomas, et al. "Networks of coordination: Swiss Business associations as an intermediary between business, politics and administration during the 20th century". *Business and Politics*, vol. 11, no. 4, pp. 1–38. Eichenberger, pierre and Stephanie Ginalski. "Si Vis Pacem, Para bellum"—The construction of business cooperation in the swiss machinery industry. *Socio-Economic Review*, vol. 15, no. 3, 2017, pp. 615–635.

[46] However, it is not only specific to Switzerland: "Because of their early dependence on international markets and their ensuing vulnerability to their external environment, small European states have tended to develop strong mechanisms of cooperation among economic and political elites, and their elites are among the most interwoven and transversal". As explains: Katzenstein, Peter J. "Small states in world markets: Industrial policy in Europe". New York, Cornell University Press, 1985. For more in this regard see: Munk Christiansen, Peter, and Hilmar Rommetvedt. "From corporatism to lobbyism: Parliaments, executives and organized interests in Denmark and Norway". *Scandinavian Political Studies*, vol. 22, no. 3, 1999, pp. 195-220. –David, Thomas, and André Mach. "The specificity of corporate governance in small states: Institutionalisation and questioning of ownership restrictions in Switzerland and Sweden". *Corporate governance in a changing economic and political environment: Trajectories of institutional change on the European continent*, edited by R. Aguilera and M. Federowicz. London, Palgrave Macmillan, 2003, pp. 220-246. – Nollert, Michael. "Interlocking directorates in Switzerland: A network analysis". *Schweizerische Zeitschrift für Soziologie*, vol. 24, no. 1, 1998, pp. 31-58.

[47] Rossier, Thierry et al. "From Integrated to Fragmented Elites. The Core of Swiss Elite Networks 1910–2015." *The British journal of sociology*, vol. 73, no. 2, 2022, pp. 315–335.

Here we can again extend further our observation about the early glulam consortium, and understand it as a "cartel of elites",[48] a network of personalities who were present simultaneously in several elite spheres, while the decisive linking element was glulam.

Glulam was introduced, as we saw, at a time that the political parties, cooperatives, as well as labour unions, and employer organizations had just emerged. The role of the early glulam consortium in influencing the reshaping of the relationship between the contractors and the workers in the carpentry trade, discussed in the previous chapter, can be reassessed in light of the significance of the consortium as a cartel of elites.

Historically, since the formation of the Federal State, the major right-wing parties had a politically clear dominant position in the government and entertained close relations with the major business associations. From 1848 until 1891, the Federal Council was composed entirely of liberals and the political left and the labour unions were practically absent in the official political discourses. These could only gradually become integrated into the government from the 1930s. It was only from 1937 on, that the workers' unions and the interest groups of entrepreneurs experienced peaceful relations.[49] A few years later in 1943, the social-democratic party, as initially representatives of the rising working class, had their first seat in government. Therefore, the early period of the development of glulam coincided with the political control of the conservative block and the dominance of right-wing parties and business associations at the expense of the power of social democratic forces and trade unions. The three most important right-wing parties, as explained by Mach and Trampusch, namely the Free Democratic Party (FDP), the Christian Democratic Party (CVP), and the Swiss People's Party (SVP) that represented a clear majority in parliament and in the government throughout the twentieth century, always maintained close relations with the major business associations.[50] André Mach and his colleagues at the University of Lausanne contextualized this particular situation by stating that "Switzerland is probably the only European country in which the political left has never played a dominant role in the government or the parliament but has remained in the position of a "junior partner" of the dominant right-wing parties".[51]

These right-wing parties directly influenced industrial relations, the constitution of which happened in the core period of the development of glulam. As we saw for example in the particular Swiss case of the *Gesamtarbeitsvertrag* (an exclusively Swiss term, translated mainly as Collective Labour Agreement),[52] the State played no direct role in the conditions of agreements, letting it be an issue

[48] The term is borrowed from: Katzenstein, Peter J. (See note 46 above), p. 34.
[49] Bühlman, Felix, et al. "Elites in Switzerland: The Rise and Fall of a Model of Elite Coordination." *Tempo Social: Revista de Sociologia Da USP*, vol. 29, no. 3, 2017, pp. 181–99. Particularly p. 184.
[50] Mach, André, and Christine Trampusch. "The Swiss Political Economy in Comparative Perspective". *Switzerland in Europe: Continuity and Change in the Swiss Political Economy,* edited by André Mach and Christine Trampusch. London, Routledge, 2011, pp. 11-26. (Citation on page 15.)
[51] Mach, André, et al. «From Quiet to Noisy Politics: Transformations of Swiss Business Elites Power". *Politics & Society*, 2021, vol. 49, no 1, pp. 17–41.
[52] Translation by the website of Unia: the Swiss umbrella organization of trade unions. Although the term is used only for Switzerland, the concept of the agreements based on the collective bargaining is not limited to this country. In Sweden,

between the employers' associations and the trades unions. This way, the relationship between these two groups was reduced to and defined and regulated essentially in terms of a purely economic affair, rather than a political one, at the time that workers had no representative and no voice in the governing body.

Studying the power relations between contractors and workers in the previous chapter and the close relation between the glulam consortium and the employers' associations in the present chapter demonstrates how the early consortium as a cartel of elites (with strong ties to politicians and employers' associations), was concentrated on the development of a technology which professionally (as we saw in the previous chapter), but also politically limited the influence of the workers on the production process in the carpentry trade, a trade that was traditionally an intensely (if not the most intensely) craft-based and skill-based trade in the construction sector.

Thus, the success story of the early glulam can be hence better understood in the larger context of Swiss history, which, according to Masnata-Rubattel in their major work *Le pouvoir Suisse 1291-1991*, "can be reduced to successive responses of the major ruling classes to economic necessities".[53] Reciprocally, this history of early glulam contributes to a better understanding of Swiss history, in Masnata-Rubattel's terms.

The consolidation effect of the early glulam consortium as studied in this part, had a crucial impact on the early acceptance and development of glulam, through a system of networking that brought the clients, the builders, the authorities, the associations (EAs and TAs), and institutions (army, EMPA, SBB, etc.) together around a shared interest: glulam. However, among the early interested parties, it was not only the glulam consortium whose members accumulated roles in different legislative, executive, and leadership positions. Among others, the Swiss Federal Railways should definitely be mentioned, which as an institution performed far beyond its principal role as an early client of glulam, and had a fundamental contribution to the early legitimization and development of this technology. Although the SBB itself was as well-founded by the elites, who were entrepreneurs, industrialists, bankers, and politicians, giving rise to the term "Eisenbahnbarone",[54] the focus of the following study will be shifted away from this characteristic, to be placed on the multiple roles that the SBB overtook, resulting in the legitimization of the use of such a young material in the public projects of national importance.

Finland and Germany for example, a similar collective agreement is in function. However, details about the minimum wage, the representation of the workers in the company boards, the influence of being a union member for the workers to benefit from these agreements, and so on, are different.

[53] Masnata, François, et al. *Le pouvoir suisse, 1291-1991 : Séduction Démocratique et Répression Suave.* Lausanne, éd. de l'Aire, 1991. P. 27. Original texte : "L'Histoire Suisse – c'est là sa première et principale caractéristique – peut se réduire aux réponses successives que les classes dominantes ont données aux nécessités économiques."

[54] The most important one being Alfred Escher (1819-1882) See: Bärtschi, Hans-Peter. *Schweizer Bahnen 1844-2024 : Mythos, Geschichte, Politik*. Zürich, Orell Füssli, 2019, pp. 13-31.

Thanks to the general contractors involved in the glulam consortium, who were also the constructors of the railway's infrastructures, such as Fietz & Leuthold and Gribi, as well as the engineers Terner and Chopard who were similarly involved in the railway's projects (discussed in the first chapter), the SBB became one of the earliest clients of the new technology.

The following part of this chapter, through the study of some early glulam projects of the SBB, will demonstrate how the early broad involvement of this institution within a strongly interconnected network of established players was decisive for the legitimization and promotion of such a young building material: cumulating roles ranging from a local client to public authority, the SBB quickly established glulam as a construction alternative and contributed to the standardization and codification of the practice on a national scale.

The following part of this chapter will be based particularly on archival material of executed projects, documenting the design process and construction phases as well as reports and letters from clients, designers, and contractors involved.[55]

[55] This following part of this chapter has already been partially published as : Haddadi, Roshanak, and Mario Rinke. "Entanglements within an emerging technology: Swiss Federal Railways and early glulam in Switzerland". *History of Construction Cultures. Proceedings of the Seventh International Congress on Construction History, (Lisbon, Portugal, 12–16 July 2021),* edited by Mascarenhas-Mateus & Paula Pires, Taylor & Francis, 2021, pp. 517-523.

2. The SBB and its cumulated roles

In the first railway law of 1852, the federal government left the construction and operation of railways and the power to grant concessions to the cantons, without giving them any regulations regarding route layout, coordination, technical implementation, or tariff policy. Railways were financed by private capital and by contributions from the beneficiary municipalities and cantons. This mode of financing forced the railway stock corporations to use profit-oriented construction planning and operational management.[56] This, as shown in the second chapter, made a challenging situation for the export branch of the timber industry, for which the railway was a practical transport means, but an expensive one.

The first systematic approach to the provision of railway communication in Switzerland was made in 1850, by projecting a railway connecting the main cities of the country.[57] In 1872 the Federal Government took over from the cantons the right to grant concessions for new constructions. It became then necessary to submit all railways' plans to Bern for approval, and federal engineers were appointed to supervise construction work and check all safety measures and appliances. This was an important step for the young institution in order to centralize all the decisions for future plans. Thirty years later in 1902, the SBB *Schweizerische Bundesbahnen* (Swiss Federal Railways) came into being. From 1872 until the early 1930s and by several waves of expansion of regional railways, the country saw for almost half a century, a nationwide construction site of railway infrastructures.[58]

The railways demanded projects ranging from platform roofs to power plants, locomotive depots, and repair workshops, but also bridges and scaffoldings for viaducts. Having this broad spectrum of projects in the perspective together with the public investment and responsibility for the safety of the public, rendered the SBB a more influential and decisive client than any other. From the early glulam projects inventoried in this research (numbering 261 buildings), 20% of them were commissioned by railway companies, which indicates the importance of this institution as a client. Platform roofs constitute the majority of the projects (56 %), followed by power plants, locomotive depots, workshops (altogether 30%), and bridge formworks (14% of the projects).

In the initial phases of the expansion of the railways' network, most of the structures were built mainly in timber, at a low cost. Later on, steel replaced timber in more representative halls, and until the turn of the 20th century, most of the wooden bridges were replaced by steel due to the common belief of the time in the better performance of steel in case of fire, in comparison to wood. Many of the existing iron roofs of railway stations or depots however showed considerable damage due to corrosion. Very

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[56] Bärtschi, Hans-Peter, and Anne-Marie Dubler, "Eisenbahnen". *Historisches Lexikon der Schweiz (HLS)*, Version of 11.02.2015. Online: https://hls-dhs-dss.ch/de/articles/007961/2015-02-11/, consulted on 02.03.2019.

[57] Although the first railway on Swiss soil dates back to 1844, the first Swiss railway was built in 1847. For a more comprehensive view on the matter see: Della Gana, Giles. *A History of the Swiss Federal Railways*. Billericay, Heath Publishing Services, 1995.

[58] For the milestones of the expansion of the railways see Dinan, Thomas E. *A Short History of the Swiss Railways*. Worcester Polytechnic Institute, 1979.

soon the high cost of maintenance of steel damaged by the smoke of the engines became a major problem and resulted in the revival of timber in the railway infrastructures.[59] The heavier and fatal damages caused by steel in case of fire, in comparison to wood, encouraged the privileged use of wood in structures.

Glulam was considered particularly suitable for the SBB infrastructure since it was seen as more resistant to the acid smoke of the engines. An important milestone was reached in 1911, when the SBB constructed a locomotive depot in Bern, a project which achieved very soon international recognition. The SBB then advised all its subdivisions to use timber instead of steel for halls and sheds. Moreover, the SBB was a client which had previously made pioneering projects in other structural materials such as regular timber, steel, and concrete, and had gained therefore comprehensive knowledge of structures and materials.[60] This extensive knowledge and experience amplified and expanded the impact of the SBB beyond the limits of a client.

Besides the role of the SBB as a client that was particular in terms of the extent, variety, and infrastructural nature of its projects, this institution developed glulam practice by adopting roles in three different fields: load testing, material research, and structural design. The following will discuss these roles.

2.1. Client with nationwide projects

One of the important characteristics of the SBB as a client was that it had projects all over the country, for which it had to collaborate with different contractors.[61] This situation qualified the SBB with particular competencies in comparison with the other clients, by giving this institution a comprehensive overview of different practices of glulam production. To this, we should add that the SBB was almost for half a century continuously expanding its structures and infrastructures all over the country. The development of the technology, therefore, was beneficial to this institution and its future projects. So, the fact that the SBB, with broad perspectives in time and space, was a regular client, significantly extended its potential areas of influence beyond any other private or public client. Therefore, in collaboration with the glulam consortium and on the basis of mutual interest and mutual benefit, this institution directly took part in the development of the technology, at a time when there were no standards for the selection of the raw material and the fabrication process, and not even a consistent design practice. The broad and long process of monitoring the production process of glulam by different contractors and collaborating with other builders to respond to the recurring problems

[59] SBB Chief engineer in his letter of 10 Nov. 1911 advertised the use of timber for such infrastructural buildings, and described its advantages over steel, including its much higher resistance to smoke. (the letter can be found in SBB Historic Archives, GD-BAU-SBBBAU1-108-05).

[60] For the timber part, see the ongoing research of Kylie Russnaik, *Dachwerkskonstruktionen in der Schweiz: Die Entwicklung von weitgespannten Holzkonstruktionen im 19. Jahrhundert*, started in 2019 at the chair of prof. Stephan Holzer "Bauforschung und Konstruktionsgeschichte", at the Department Architecture of ETH Zurich.

[61] In the database dressed in this research, projects of the SBB in collaboration with Fietz & Leuthold, Bugnion, Zöllig, Gribi & Cie., and Nielson-Bohny & Co., have been identified.

gave the SBB the capacity to publish the first guidelines for the production of glulam in Switzerland, which will be discussed further in the following sections.

Here it should be mentioned that other public clients like the army, were as well regular clients of glulam on a smaller scale, however different degrees of requirements in comparison to the SBB restricted their capacities in influencing the development of the technology. In contrast to the SBB, the army projects were mainly temporary ones, like airplane hangars, barracks, etc. These buildings, based on their temporary nature and restricted access had a different degree of responsibility towards public safety in comparison to the SBB, which, being responsible for the safety of the mass of the public as the users of its infrastructures, required greater safety measures. In the following, it will be demonstrated how this requirement influenced the role of the SBB in the development of the technology.

2.2. Load testing

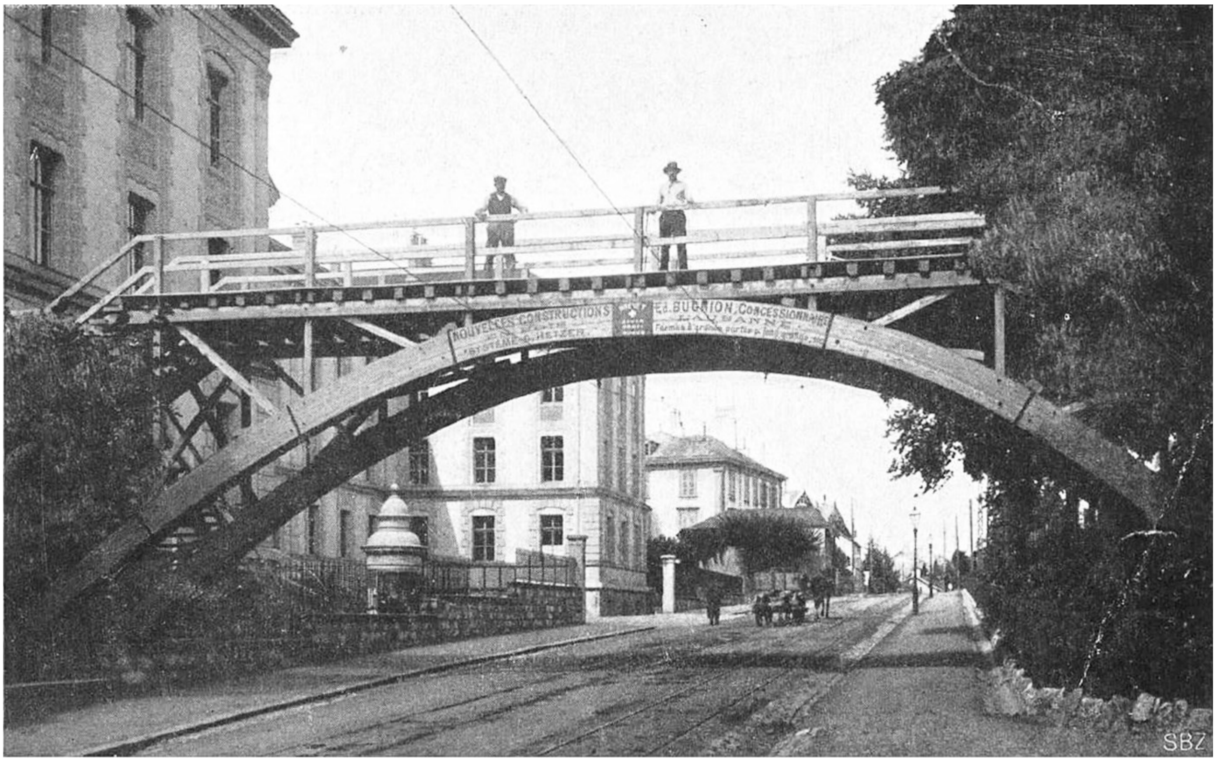

Fig. 6 Glulam pedestrian bridge on the occasion of the 8th National Exhibition of Agriculture, Lausanne, 1910. contractor: Ed. Bugnion.

Dealing with the mass transportation of thousands of people every day, the SBB aimed for an increased degree of safety when projecting its infrastructures. Accordingly, they demanded extensive loading tests in order to ascertain the required performance of the structure and to verify the assumptions made in analytical models and calculations related to the actual behaviour. The SBB, with its highly specific loading conditions, developed hence its own testing regime parallel to the EMPA.

The first loading test of glulam carried out by the SBB dates back to 1910. It was on the occasion of the construction of a pedestrian walkway in Lausanne that served to connect the two parts of the Swiss Agricultural Exhibition in September 1910, which were separated by a street and tram lines (Fig. 6).

Since the footbridge led over a tram line, the railway department found the occasion for a loading test in order to assure the safety of its passengers and infrastructures. This test was performed on September 8th, two days before the inauguration of the exhibition. The report of the controlling engineer of the SBB, Fritz Hübner on the loading test describes “a very satisfactory result”.[62] Although in similar situations, loading tests have been demanded to be planned and carried out by the project designer (contractors, architect, or engineer), the fact that in this particular case, the SBB itself performed the tests indicates a very early interest of the SBB in this new material, glulam. This early interest could be explained by the fact that already in the January of 1910 (8 months before performing the first load test), the engineers Terner and Chopard had submitted to the SBB, two bids (both of them proposing glulam structures) for the project of a locomotive depot in Bern. These proposals have possibly encouraged the engineers of the SBB to perform a load test on the footbridge and to gain insight into the new material and its performance. This test would have enabled the SBB engineers to evaluate those bids and eventually decide in favour of them.

The testing regime of the footbridge together with all required methods and instruments were specified by the SBB collaboratively with the EMPA. As soon as the establishment of the EMPA at the Polytechnic Institute of Zurich in 1880, as we will see in the last chapter, research on wood as a structural material started. However, this research and tests were principally limited to and aimed at defining the characteristics of Swiss structural timber. Loading tests on glulam were not initiated and operated within the EMPA but within the SBB.

The SBB was conducting systematic loading tests on these structures, years before they became the subject of tests and research for any other institution (EMPA, SVMT, and academia). This constellation empowered the SBB with an authority: the legitimization of the use of glulam in public projects when no construction tradition and no building code and regulations regarding glulam existed. In the absence of an official glulam building code, the SBB thus set a quasi-standard for glulam structures, defined testing regimes, and established criteria for the performance of glulam structures. This particular role of the SBB contributed effectively to the early acceptance of glulam.

Two years later, on the occasion of the approval of a glulam structure for a locomotive depot in Bern, loading tests carried out by the SBB allowed the construction of the first glulam building for this institution. To increase the capacity for the storage of locomotives in Bern, the Swiss Federal Railways decided to build a new depot near the main station in the Muesmatt district at Depotstrasse in Bern.

[62] “Die Hetzersche Holzbauweise”. *Schweizerische Bauzeitung*, vol. 57/58, no. 16, 1911, p. 216.

The design process of the building began in 1910. At that time, steel structures have still been the standard solution while reinforced concrete was on the rise as a new robust form of construction. The question can be raised why the SBB favoured timber over the other more common materials.

In this context, it is interesting to look into the design history of the depot since, as usual, several material and construction options have been discussed. The very first step of planning a locomotive depot in Bern was taken in 1904 when the general management of the SBB decided on a railway layout following the pattern of the Stuttgart main station.[63] Four projects were proposed; three of them followed the common systems of their time:

1. a reinforced concrete roof on steel columns following the Manheim station model;[64]
2. a wooden truss placed on reinforced concrete columns like in a depot in Lausanne;
3. another, rather innovative project was proposed by Terner and Chopard who used glue-laminated girders as the main structural components while
4. the last project proposed a combination of wooden trusses as a standard system together with Hetzer girders for the largest span.

The type of construction, whether steel, reinforced concrete, wood, or glulam, has been decided in favour of the latter. After many discussions and consultations, the SBB chose the Terner and Chopard project proposing Hetzer girders for all the spans. The two major criteria for rejecting the other projects were "smoke and heat" and "costs": the concrete, although resistant to smoke, was considered the most expensive solution,[65] as for the steel the major disadvantage was the corrosion problem. For this reason, also the Hetzer construction had to be revised omitting the steel drawbars which were initially proposed by Terner and Chopard. According to the request of the SBB, an inquiry was to be made to the Hetzer Company in order to figure out if there had been any German application of glue-laminated timber structures for railway sheds. The negative answer revealed that until that date, steel has always been preferred over wood for almost all the larger locomotive depots for German railways "probably for reasons of higher fire safety".[66] However, major fire disasters and practical fire tests have demonstrated the very high danger of iron and steel in cases of fire. Combining its smoke resistance with better fire protection thanks to its compact volume and the easier and cheaper application of a plaster envelope,[67] glue laminated timber was the choice for the project. Moreover, SBB advised all its subdivisions to use timber instead of steel for halls and sheds.

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[63] SBB Historic Archives, GD-BAU-SBBBAU1-107, SBB Obermaschineningenieur, 8 Feb. 1904.
[64] SBB Historic Archives, GD-BAU-SBBBAU1-108-05, SBB Kreisdirektion II, 2 Sep. 1910.
[65] Cost estimation for the projects in reinforced concrete: 910,000, in glulam: 800,000, in glulam and wooden truss: 860,000 francs, (ibid., GD-BAU-SBBBAU1-107-13, 20 Mar. 1911).
[66] SBB Historic Archives, GD-BAU-SBBBAU1-108-05, Ch. Chopard, 12 Sep. 1910
[67] Chopard also confirms that in the case of Hetzer constructions with their simple arrangements and the almost complete elimination of trusses of all kinds in glulam girders, it is possible to achieve a complete fire safety by means of a fireproof plaster, which had already been applied by the Hetzer Company on many occasions. This could also eventually justify the preference of Terner and Chopard to use the simple rectangular cross sections over I-shaped ones.

Terner and Chopard designed in collaboration with the licensed contractor Gribi & Cie. in Bern, the entire glulam structure for the building whose construction finished in September 1912.

The depot comprises four parallel halls whose structure consists of massive frame girders with spacings of 5 m, three of which span 21.2 and one 24.4 m (Fig. 7). In total, 56 glulam frame girders have been used covering a surface of 780 m^2.

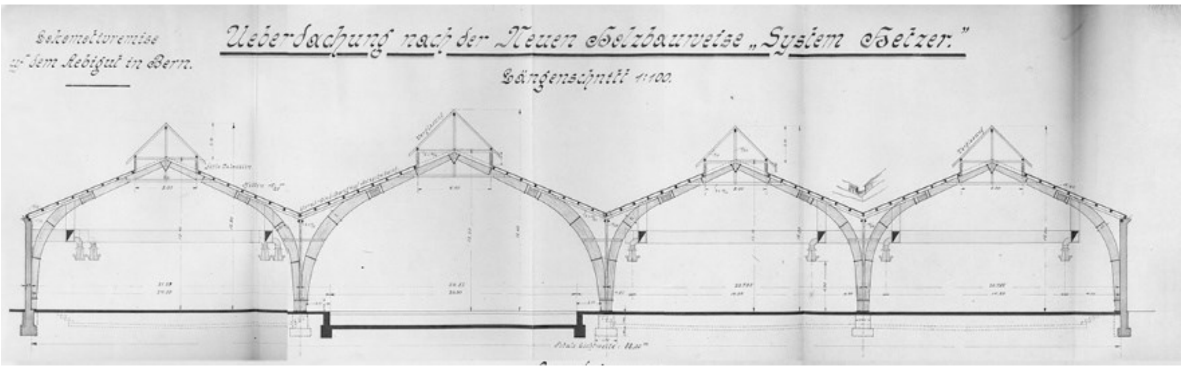


Fig. 7 Locomotive depot, Bern. 1912. Project proposed in 1910, based on the "new timber construction method: Hetzer system". Contractor: Gribi & Cie.

The depot in Bern was the first SBB project where glulam was used. Although a few glulam structures had already been successfully finished in Switzerland at that time,[68] in view of the novelty of the construction technique, the railway building department emphasized the expediency of carrying out a loading test until the structural failure. It was intended to show to what extent the static calculations provided by the engineering company Terner & Chopard conformed to the actual behaviour of the structure,[69] but also to learn about the behaviour of the new material when it is being loaded.

Terner & Chopard were required to provide scaled (1:3) frame girders and to carry out the testing, while the SBB covered all related costs. As figure 8 demonstrates, loads were provided by hanging railroad tracks from the specific points of the girders

[68] Among them in Lausanne, 1909: provisional footbridge bridge and Hotel Beauregard's roof; in Geneva, 1910: skating ring; in Zurich, 1910: Krematorium Sihlfeld and Aeschbssacher furniture factory.
[69] The calculations will be studied in chapter four.

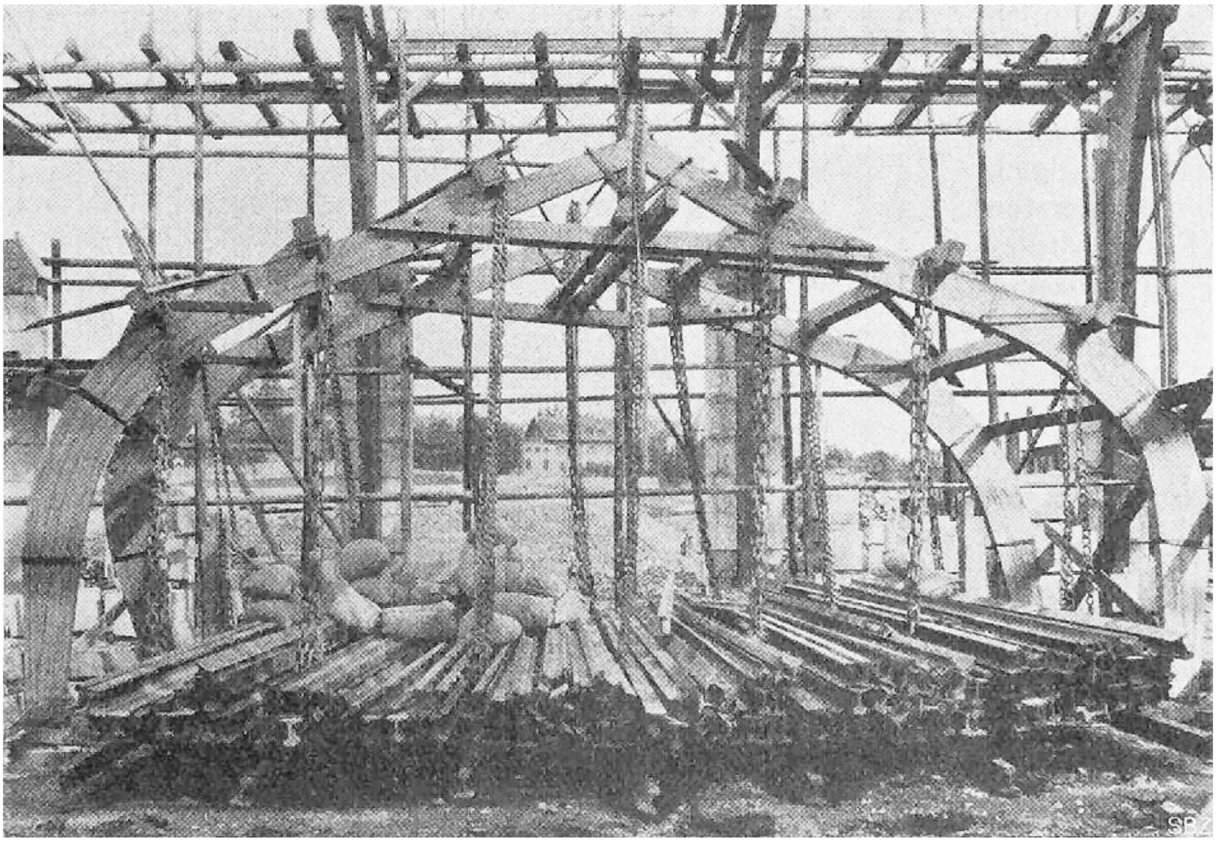


Fig. 8 Load test of scale model, glulam girders of the locomotive depot in Bern, 1912.

The frames were tested from May 29 to June 3, 1912, in the workshop of Fietz & Leuthold in Zurich, who were also responsible for providing the scaled glulam frames for the load test. The test was performed in the presence of the engineers Terner and Chopard, and Fritz Hübner as the representative of the SBB, who was known to be a "Well-known friend of timber construction".[70]

The reason why Gribi & Cie. who was contracted for this project was not involved in the load testing, and instead Fietz & Leuthold performed the test, is not mentioned in the report on this test published in the *Schweizerische Bauzeitung*. It can however be argued that since Gribi was, arguably, doing his first glulam project and therefore did not have prior experience with this material, the engineers and the SBB asked the most experienced contractor of the time, Fietz & Leuthold to conduct the test, as the representative of the contractors of the glulam consortium.

The vertex of the tested girders sagged by 72 mm under a load 5 times higher than the normal charge without showing any signs of breakage. The glue joints have proven to be very good as all cracks occurred in the wood and not in the joints.[71] Eventually, by the end of 1912, the glulam frame girders were erected and the construction of the depot got completed. The result received great recognition in

[70] "als Brückeninspektor und Freund des Holzbaues wohlbekannt". *Schweizerische Bauzeitung*, vol. 75, no. 52, 1957, p. 836. Hübner was appointed extraordinary professor of metal and wooden constructions at the Ecole polytechnique of the University of Lausane Lausanne in 1935.

[71] "Die neue Lokomotiv-Remise der S.B.B. auf dem Aebigut in Bern". *Schweizerische Bauzeitung*, vol. 61, no. 22, 1913, p. 290.

Swiss, French, and German engineering milieus.[72] The building, which is still standing, was used for about ten years (1912-1922) as a depot for steam engines and subsequently, it housed electric locomotives.

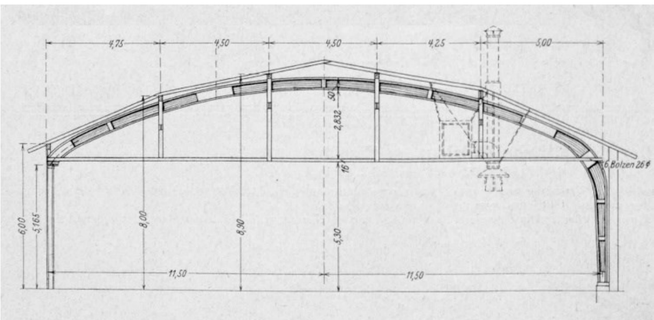
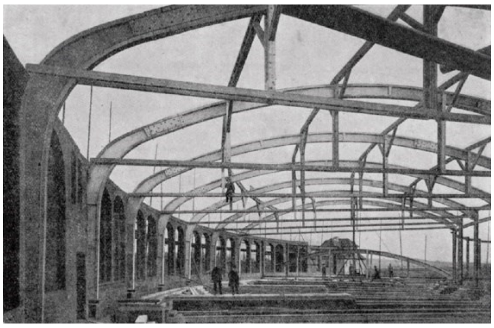
The process of the test and the sequences were planned by the control engineer of the SBB. The purpose of these tests was not only to prove the capacity of the structure under certain loading conditions but also to gain a deeper understanding of the material behaviour and the influence of glulam fabrication on its performance. For instance, when the first phase of the test, the breaking test resulted in the open joints in the glued lamellas, the SBB demanded a further test in order to determine the shear strength of the material or to determine how decisive is the time during which the lamellas to be glued were left in press, on the strength of the material.

The SBB designed the test setup, process, and machinery, and the fabrication of the test samples was done by Fietz & Leuthold, in the workshop of whom the loading test was performed. This cooperation of the SBB and this glulam contractor (not this specific project's contractor though) was beneficial for both parties (the SBB and the glulam consortium). The contractors, via Fietz & Leuthold could get informed about the expectations of the SBB of the new material and their criteria to evaluate it. The SBB in turn and through different projects obtained insight into the different tools and technics used by different licensed contractors, and learned about the most recent developments of the fabrication process in all parts of the country. Here it should be noted that the construction of the material (the glulam elements and even the glue itself) was planned and carried out with slight differences by the licensed contractors. For example, the archival documents demonstrate that different types of agitator used in the contractors' workshops for the production of liquid glue, resulted in various qualities of this substance. The amount of bubbles produced while mixing the liquid depended on the type of agitators, which eventually resulted in different viscosities of the final adhesive, significantly influencing the spread of the substance on the lamellas' surfaces. Controlling the viscosity was highly important, especially for the glulam elements with a smaller radius of curvature, where the glue was pressed out due to the big pressure applied necessary for attaining lower curvatures.[73] This comprehensive overview of different construction methods enabled the SBB to find solutions for unsolved problems related to the fabrication, quality, and function of glulam and granted them an office of authority in the states of uncertainty occurring in other projects, at the time that neither the fabrication of the material nor its structural practice was standardized.

Beyond the national borders, also in Germany, the glulam project of the SBB found admirers in different engineering circles. The German journal "*Zentralblatt der Bauverwaltung*", in its article on

[72] SBB Historic Archives, GD-BAU-SBBBAU1-108-05, Schweiz. A.-G. für Hetzer'sche .Holzbauweisen, 15 Nov. 1913.
[73] Steinhaus, Max. Archiv schweizerischer, europäischer und arnerikanischer Holzbau- und Holzleimtechnologie; Autographen und Dokumentation meist aus den Jahren 1940 – 1970. ETH Zürich, Handschriften und Autographen der ETH-Bibliothek, 1987. Document ref. no.: 1198.16, report of the EMPA on the quality of gluing of the Bern locomotive depot's structural elements.

“the importance of modern timber construction methods for long-span roof truss and hall buildings”, in 1919, used only the example of the locomotive depot in Bern to illustrate the article and refered to the trust of the SBB in the new material, and the fact that this federal institution advised all its subdivisions to use timber instead of steel for halls and sheds, “ Of course, not without first having carried out detailed tests and having gained impeccably good experience”.[74] In another article, “The modern timber construction in the railway industry”, which appeared in the *Die Bautechnik* in 1923, the writer began with the locomotive depot in Bern, as “one of the most famous” glulam structures, and highlighted the technical details of the tests that this institution performed (among many projects of various engineered timber structures studied in this article, this was the only mentioned loading test).[75] To this, it should be added that during the same year in 1912, a glulam project has been designed and erected by Hetzer in Weimar, which was also briefly mentioned in the article, which never gained the monumental image and the status of a milestone that did the locomotive depot in Bern (Figs 9-10).

Figs 9-10 Plan and construction site photo of the locomotive depot in Weimar, with a span of 23m, Otto Hetzer, 1912.

In order to better understand the crucial role of the SBB in the legitimization and hence the promotion of glulam construction, the study of the project of the cinema “Scala” will be beneficial.

Constructed in 1916 in the Swiss city of La Chaux-de-Fonds, the cinema Scala is the collaborative project of René Chapallaz and Charles Edouard Jeanneret (Le Corbusier). When the construction of the city's first cinema was announced, the importance of the event prompted the organization of a competition for ideas for the construction of the southern facade. No first prize was awarded though. Le Corbusier succeeded in convincing the client to entrust him with the execution of his project. The structure of the main hall was designed in reinforced concrete, on which a glulam structure for the large roof rested.

The architects, mainly driven by Le Corbusier, pushed the city authorities to allow the execution of the glulam roof despite their repetitive refusal. Before granting permission, the authorities required a loading test of 500 kg per m^2 in presence of the delegate of the building department of the city. In

[74] “die Bedeutung der neuzeitlichen Holzbauweisen für weitgespannte Dachstuhl- und Hallenbauten”. *Zentrallblatt der Bauverwaltung*, 1919, no. 94, pp. 561-563.
[75] Gesetschi Theodor. “Der neuzeitliche Holzbau im Eisenbahnwesen”. *Die Bautechnik*. 1923, vol. 1, no. 12, pp. 89-98.

order to ensure the stability of the glulam structure, Le Corbusier argued in favour of glulam by referring to reinforced concrete as:

> The structure has been calculated by the engineer's [Terner and Chopard] specialist in reinforced concrete, based on the measure dictated by the federal law, which is very strict and implies absolute safety.[76]

By referring to reinforced concrete, a material that had already at that time established practical regulation, Le Corbusier saw glulam technically as an equivalent. The cantonal authorities backed the approach of the city to require a loading test, emphasizing that "it is not enough that the structure is calculated by the specialized engineers, but it is the execution of the work which plays an important role". They also stressed that the duty of the authorities was not to verify the calculations but to control the executed work. Le Corbusier, at least at the first stage, refused to pay for the test since he believed that "he had taken all the precautions in order to insure the absolute stability of the structure".[77]

In this conflict, the SBB could solve the technical and legal controversy by exercising the particular authority that it had established already in the field of glulam construction. The authorities organized a jury of experts, in order to oversee the required testing and to decide on the performance and safety of the structure. This jury was headed by the SBB.

Having insight into almost all facets of glulam through their involvement in various different projects for its infrastructure, the SBB gained unique technical knowledge. Based on this knowledge, it mobilized a series of resources in order to provide solutions for the problems that occurred in the early phases of the adoption of new material in the construction practice. This expanded the agency of the SBB beyond its legitimizing role by influencing as well the design phase. For instance, the SBB advised strongly in its report on the protection of the feet of the glulam girders on the west façade against rot and referred to it as a very delicate and difficult question that deserved, according to the SBB, to be studied in detail. A problem that the SBB was at that time facing in his Bern locomotive depot project (see Appendix 3.2).

Different glulam projects discussed in this part demonstrate the particularities of the early loading tests: firstly, those tests were mainly initiated by the SBB, and within their role as a client of glulam. In comparison with that, the example of the cinema Scala showed that not all the clients of glulam had the same interest in the new material; neither initiating the load testing nor even welcoming the demand of testing by the public authorities. The fact that besides the private clients, such an important public institution with a high level of demand for the security of its projects became involved in the network of early glulam, demonstrates their particular role in pushing the development of the material.

[76] Letter of Le Corbusier to the Conseil Communal of the City of la Cahux-de-Fonds, 21 August 1916. Archives de la Bibliothèque La Chaux-de-Fonds, Fonds spéciaux, LC-102, Fonds Le Corbusier. Correspondance diverse concernant la construction du cinéma "La Scala" à La Chaux-de-Fonds, p. 4.
[77] *Ibid.*

The third particularity of the early loading tests is in fact the organization of the testing process in such a way that a plurality of the interested parties can be seen involved in the early testing regime. In difference from the testing processes performed in professional testing institutions, this early and sometimes improvised testing network brought all the actors to the direct observation and monitoring of the testing process and to the evaluation of the process and the product; from the selection of the timber, production of the glue, the process of gluing and laminating, to the design decisions, but also criteria to be considered to examine the performance of the structure. The situation accelerated the process of solution findings in the case of ambiguities and problems in the testing process but also, more importantly, made a global awareness of the interests, competencies, and influences of other actors in the new material. For Le Corbusier, glulam was a much cheaper substitute material for concrete, thus he was not interested in carrying out tests that imposed extra costs on the project. For the authorities, glulam was a new timber, with an unknown execution process and thus, unknown structural performance. This meant that they needed the judgment of a jury that had the knowledge of these unknown fields, but also shared the same responsibilities towards the safety of the public. For the contractor, glulam was the gateway to a new timber market. It could guarantee the future of sawmill plants and carpentry shops which were suffering from the prejudices of the construction market towards traditional timber structures. Testing glulam and legitimizing its practice could then save their workshops from disappearing one after another due to the mass production of steel. And finally, for the patent holders of glulam, this constellation was only beneficial, since the early recognition and legitimization of the practice were fundamental steps towards a flourishing market and economic success of the patent.

In this network, the SBB as a client shared the interest of Le Corbusier in glulam, and as an infrastructure provider shared the responsibility of the authorities towards public safety. The SBB needed all the same, the expertise of the contractor in investigating and understanding the influence of their tools and process involved in the construction of glulam on its behaviour as a structural element. They needed as well the presence of the engineers in this constellation so that the results of the tests inform the design of the structure of their future projects for the SBB.

2.3. Material research

Together with the establishment of the EMPA, general research into wood started in 1880, focusing mainly on the testing methods and properties of Swiss structural timber. This research played only a minor role given the relevance of timber at that time and continued until 1896 when the last series of the results of the research got published. The EMPA then shifted the focus away from timber in their research for a period of three decades. This situation can be explained by the decline in interest in timber as a structural material due to the mass production of steel. Nonetheless, the first swiss timber building code was published by the EMPA in 1925. The publication of this norm cannot be thus explained only in the context of the research within this institution. The following section clarifies how the research on timber carried out by the SBB during those 30 years resulted in the development and publication of the first timber building code in Switzerland.

Parallel to the official testing and research on steel by the EMPA, the pioneers of glulam in Switzerland were applying and promoting this new material until it became a rival for steel, mainly through its beneficial cost. Different testing discussed in the previous section resulted in systematic research on glulam, and glulam pushed the general research in timber. The results of the research were published in the technical journals of the time by glulam patent holders and mostly in collaboration with the SBB and laid the groundwork for developing and publishing the first timber code in 1925 (see Appendix 3.3). Publishing the result of that research meant claiming the latest knowledge of the field by the SBB and becoming a leading scientific authority in glulam practice.

The first timber code published in 1925 reflected in fact the need of the construction market to recognize timber and regulate its use as a structural material when modern timber construction systems such as glulam were gradually replacing steel for large-scale structures. One part of this research focused on the glue used in the fabrication process of glulam. This part was mainly headed by the EMPA. Another aspect of the research was on the fabrication of glulam elements, and the construction of glulam as a material. This part was mainly headed by the SBB. Findings and experiences gained during the execution of different projects provided the SBB with a global vision and holistic view of different approaches for constructing this material and gave them authority to draw up regulations in order to standardize this practice throughout the country and to give criteria and quasi-standards to the subdivisions of SBB for the quality control of the fabrication of glulam. A two-page document entitled "Regulation for Glue-Laminated Timber Structures" published in 1943, covered different issues from the selection of wood and type of glue to conditions of gluing and laminating in the carpentry workshops, which served as a guideline for all subsequent executions and became valid in the entire SBB area by decree of 7 January 1944 of the Department for Railway Construction and Power Plants at the General Management. The following year, in 1945, the first "Guidelines for Glue-Laminated Timber Structures" of the EMPA got published. This report was in fact reflecting the internal regulations of the SBB, which had already been in use within the institution.

In conclusion, the material research carried out by the SBB and published in the technical journals of the time had a double function: on the one hand, systematic research on glulam pushed the general research on timber and laid the groundwork for developing and publishing the first timber building code in 1925, at the time that EMPA had shifted away the focus of its research from timbre. On the other, publishing the result of the research meant claiming the latest knowledge of the field and becoming a leading scientific authority in glulam practice. The application of glulam by the SBB with such authorities legitimized its practice at a time when there was no official timber code.

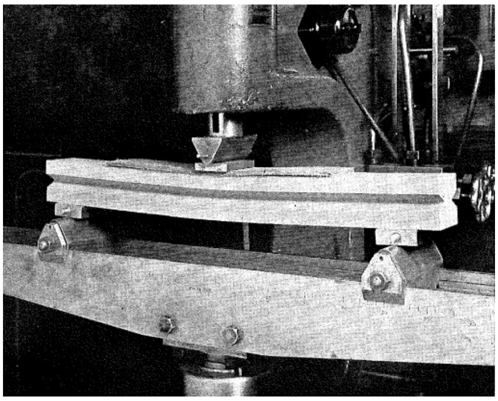
2.4. Structural design

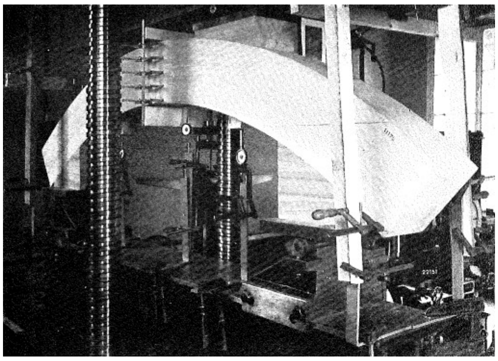
In addition to its application for the roofing of depots and halls and for bridges and viaducts' scaffolding, glulam has also been widely used by the Swiss railways for roofing platform halls of all kinds. These structures are, for some reasons, of special interest: they are open to the public and serve as a representative image of the SBB as a federal institution. In this context, the SBB should be considered beyond all its other functions in transport and in promoting new materials and new technics, as a complex of permanent exhibitions for the national and international visitors and users of its infrastructures. Design of this category of structures representing a federal institution of a national scale demanded therefore, among others, formal and aesthetical considerations. A deeper look into the design development of platform roofs will be used in this section to understand the role of the SBB in designing glulam structures.

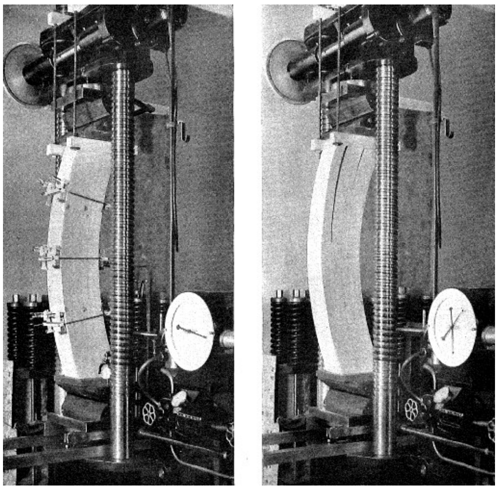
After the patent protection of glulam in Switzerland expired in 1924, the concept becomes available for any institution or individual to freely use, redesign, and market it. The SBB, who had gained broad constructional knowledge of the material over the years, made significant steps in the design of glulam structures.

Table 3.2 documents different glulam designs for platform roof structures. At the very beginning, glulam replaced other materials: in the roofs, glulam elements replaced mainly ordinary timber or steel girders, with no particular curvatures and were paired with an accompanying material for the supporting parts which were constructed principally in timber or concrete (Table 3.2 – projects for Gossau and Schlieren). Later on, the design principles changed in favour of facilitating human traffic on the platforms resulting in the reduction of supports to one central column. The sheds were then two curved glulam cantilevers, connecting to the central column which rested on a concrete base, anchored by means of iron shoes (Table 3.2 – projects for Palézieux and Interlaken). This shift in the design opened new questions regarding the effect of quite sharp curves running from the column to the cantilevered arm. In all the designs to be described, the most important supporting parts consisted without exception of glulam pillars with full rectangular cross-sections. The inclination of the sloping parts of the roof for drainage questions which affected also the formal conception of the structure influenced strongly the curves of the cantilevered arms.

The experience gained through these projects influenced the design of not only the succeeding platform roofs but also other structures of the SBB: sharply bent lamellas and strong curves which were unprecedented, entailed the tests and research on the elastic and plastic behaviour of the lamellas under sharp bends. These tests, as figures 11-13 demonstrate, were mostly carried out in the portions of structures with basic geometrical forms, straight beams, parabolas, or circular curves in order to have a comparative study of the influence of the form on the performance of the girders.







Figs 11-13 Load tests on glulam girders & glulam structures. EMPA, report no. 152:
"Die Melocol-Leime der CIBA Aktiengesellschaft", Zürich, 1945.

This research resulted in more compact and basic geometrical forms for the platform roofs (Table 3.2: projects for Däniken, Sissach, Liestal). The projects for all three roofs with basic compact geometrical forms were developed by the Construction Department of the SBB (Table 3.2). This tendency for structural elements with basic forms was not restricted to the platform roofs and can be seen in the workshops and depot buildings of the SBB with glulam straight girders for roofing (Fig. 14). The simultaneous emergence of glulam columns in combination with the straight glulam girders for roofing, which was known as "trend from curved to straight member", indicates a particular phase in the development of the material: glulam was no more only a replacing material for some structural components of the roofs, it was then a material with known properties that could be used in practically every structural part of the buildings.

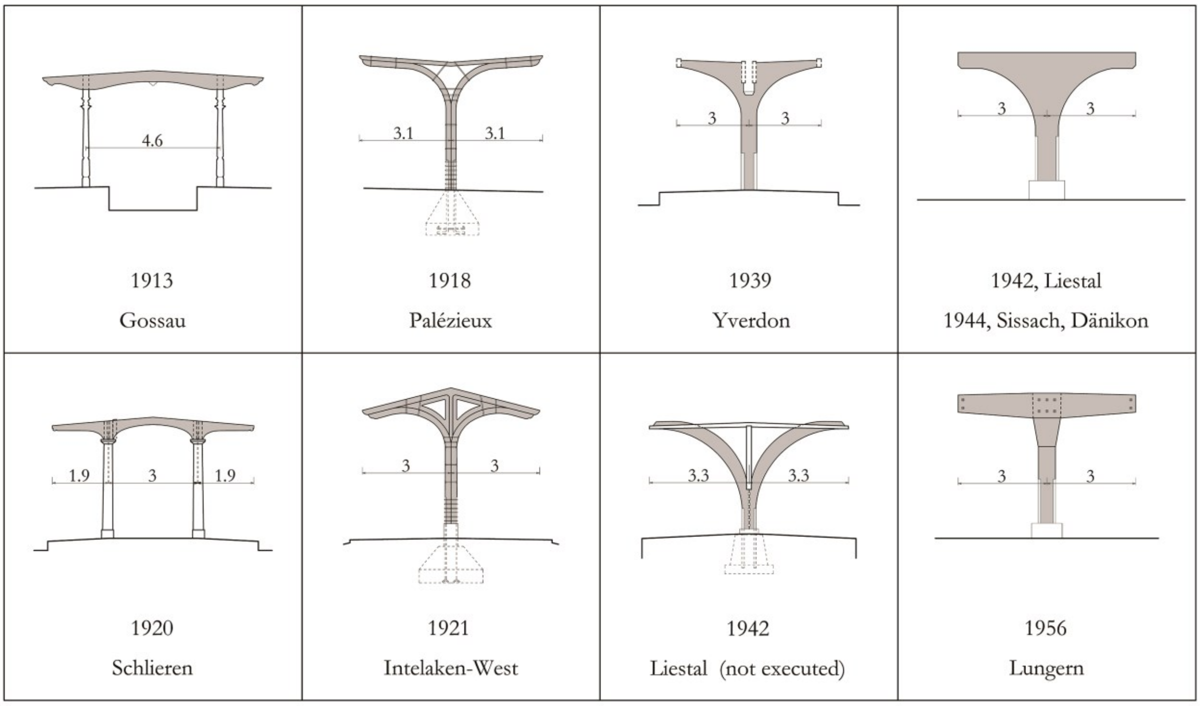


Table 3.2 Development of design of glulam structures of the SBB's platform roofs from 1913 to 1956.
Fig. 14 Repair workshop of trams, where glulam has been used for both beam and column, Dreispitz, Basel, 1953.

3. Concluding remarks

The development of an early glulam practice has been particular in Switzerland for several politico-economic reasons discussed in the first two chapters. What the present chapter brought into focus was the particular characteristics of the early network of glulam, mainly an early broad involvement of a wide range of established players (individuals and institutions) in the early phases of this technology. In that network, beyond the interested parties (mainly the builders), there were as well involved and affected parties in the development of the technology, who were not particularly interested in the technology (at least not from an economical point of view), like the city authorities and the EMPA.

The study of the organization of the early glulam consortium demonstrated how its members, the elites who cumulated different roles in executive, legislative, and leadership positions such as major entrepreneurs, industrial groups, scientific institutions, army officials, elected politicians, government authorities, major clients, and professional practitioners with different interests or suspicions, resource, and competences, entangled together towards establishing and regulating the practice of glulam.

Parallel to this consortium as a "cartel of elites", the SBB as a federal institution held several key roles, beyond its initial one as a client, and influenced the development of the technology at different levels, particularly through its authority office at the time that the interests of different parties were in conflict.

The SBB shared common interests in the new material with some interested parties, but also common concerns about its performance, with some others. These areas of common interest and concern (examples of the project of the pedestrian bridge in Lausanne, the locomotive depot in Bern, the cinema Scale in La Chau-de-Fonds, and many others) shaped the very particular capacity of the SBB in this network. Given the infrastructural character of their structures affecting the safety of the public, the SBB demanded levels of strength and performance at a time when no timber code existed whatsoever. Through regular applications of the material in its projects, the SBB gave glulam technical recognition as an equally acceptable construction material, and through systematic loading tests and material research, the SBB laid the groundwork for developing and publishing the first timber code in 1925 (one of the first industrial timber building codes in Europe), and later the first regulations on glue-laminated timber Structures in 1945.

In the context of this study, the construction of the material was understood beyond the technically correct and efficient arrangement of components of the material. We could see that it was not only the material under transformation and development, but also the actors themselves reorganized themselves parallel to the new technology, being themselves historical and ongoing social and cultural constructs.

Appendix 3.1

The following tables show the available information on the early glulam structures (function of the building, construction date and location, architect, and contractor) inventoried in this research. The names of the buildings are kept in their original language, as they appeared in the archival records, in the periodicals, or in other printed sources. Therefore, they appear in different languages namely in German, in French, or in Italian.

	Building	Construction year	City	Canton	Architect	Contractor
1	Schokoladenfabrik Tobler	1914	Lugano	TI	-	-
2	Strassenbahndepot Dreispitz	1915	Basel	BS	Hans Benno Bernoulli, R. leisinger	Nielsen, Bohny & Cie., Basel
3	Perronüberdeckung	1913-1915	Gossau	SG	-	B. Zöllig Söhne, Arbon
4	Maschinenfabrik Landquart (OLMA - Giroud OLMA AG)	1918	Olten	SO	-	Nielsen, Bohny & Cie., Basel
5	SBB Reparaturwerkstätte Bellinzona - Lokomotivremise	1919	Bellinzona	TI	-	B. Zöllig Söhne, Arbon
6	Halle für Eidgenössisches Schützenfest	1924	Aarau	AG	K. Schneider, Aarau	B. Zöllig Söhne, Arbon
7	Reithalle der Eidg. Remontendepots	1928	Bern	BE	-	Gribi & Cie., Burgdorf
8	Werkhalle	1928	Wallisellen	ZU	-	-
9	Pont du Galicien (formwork)	1922	Prilly	VD	-	-
10	Getreidespeicher	1944	Basel	BS	-	-
11	Füssgängersteg	1910	Basel	BS	-	Riesterer-Asmus, Basel
12	Papierfabrik Landquart	1920	Landquart	GR	-	B. Zöllig Söhne, Arbon
13	Lokomotivdepot Aebigut	1912	Bern	BE	-	Gribi & Cie AG, Burgdorf
14	Reithalle	1910	St. Moritz	GR	Nicolaus Hartmann	Ultrich Trippel, Chur
15	SBB Werkstätte Biel - Lokomotivremise	1919-1922	Biel	BE	-	-
16	Skating Rink Genf	1910	Geneva	GE	Edmond Fatio	Ed. Bugnion, Lausanne
17	Panorama gebäude	1913	Bern	BE	plan signed by Hetzer AG.	-
18	Fussgängersteg (eidg. Landwirtschaftlichen Ausst.)	1910	Lausanne	VD	-	Ed. Bugnion, Lausanne
19	Sängerfesthalle	1911	Küsnacht	ZH	-	Fietz & Leuthold, Zürich
20	Hôtel Beauregard, Dachkonstruktion	1909	Lausanne	VD	Van Dorsser & Bonjour	Ed. Bugnion, Lausanne
21	Wolff und Aeschbacher Möbelfabrik	1910	Zürich	ZH	Pfleghard und Haefeli	-
22	Bezirksgebäude Uster, Kuppelkonstruktion	1919	Uster	ZH	Hanauer & Witschi, Arch. B.S.A., Zürich	-
23	Bahnsteigüberdachung, Interlaken-West	1921, 1926	Interlaken	BE	BLS	-
24	Landesausstellung - Halle für Lebensmittel	1913-1914	Bern	BE	Polak & Piollenc	Ed. Bugnion, Lausanne
25	Landesausstellung - Halle für Hochbau	1913-1914	Bern	BE	Otto Ingold	B. Zöllig Söhne, Arbon
26	Landesausstellung - Hallen für chemische…	1913-1914	Bern	BE	Baumgart	Gribi & Cie., Burgdorf
27	Flugzeughalle auf dem eidgen. Flugplatz (abgrs.)	1917	Dübendorf	ZH	-	Fietz & Leuthold, and B. Zöllig
28	Krematorium Sihlfeld, Dachkonstruktion	1910	Zürich	ZH	Albert Frölich	-
29	Lebensmittelverein Zürich, Dachkonstruktion	1909-1910	Zürich	ZH	Eduard Hess	Fietz & Leuthold, Zürich
30	Katholische Kirche Romanshorn	1909-1911	Romanshorn	TG	-	-
31	Turnhalle, schulhaus	1910	Adliswil	ZH	-	-
32	kuppel UZH, Hygienisches Institut	1911-1913	Zürich	ZH	Robert Curjel - Karl Moser- Fietz, Hermann	Fietz & Leuthold, Zürich
33	Kuppel Schweiz. Unfallversicherungsgebäude	1913-1915	Luzern	LU	Gebrueder Pfister	-
34	Cellulosefabrik Attisholz werkhalle	1916	Solothurn	SO	-	Nielsen-Bohny & Co, Basel
35	Automobilfabrik		Arbon	TG	-	-
36	ex magazzino militare	1939 (?)	Gordola	TI	-	-
37	Turnhalle	1924–25	Holderbank	AG	Albert Froelich	-
38	Waisenhaus Butzen bei Zürich (Kinderhaus Entlisberg)	1911-1912	Zürich	ZH	Friedrich Wilhelm Fissler	Fietz & Leuthold, Zürich
39	Turnhalle/Schulhause Altstetten	1909-1910	Zürich	ZH	otto & Wener Pfister	-
40	Auditorium	1893	Basel	BS	-	-
41	Turnhalle	1910-1911	Birsfelden	BS	-	Riesterer-Asmus, Basel
42	Technikum, Maschinenlaboratium	1926	Winthertur	ZH	-	-
43	psychiatrische Pflegeanstalt (Universitätsklinik Zürich)	1916-1919	Rheinau	ZH	-	-
44	Pavillon Bourget	1915	Lausanne	VD	Service des bât. de l'Etat de Vaud	Ed. Bugnion, Lausanne
45	Château Chillon	1920	Veytaux	VD	Bureau de l'architect du château de chillon	B. Zöllig Söhne, Arbon
46	sangaller Festhütte	1922	Arbon	TG	-	B. Zöllig Söhne, Arbon
47	Flugzeughalle	1917-1918	Frauenfeld	TG	Kauffmann & Freyenmuth, Frauenfeld	B. Zöllig Söhne, Arbon
48	Festhütte, eidg. Turnfest	1922-1924	St gallen	SG	-	B. Zöllig Söhne, Arbon
49	Turnhalle	1911-1912	Windisch	AG	Albert Froelich (1876-1953)	Fietz & Leuthold, Zürich
50	Turnhalle	1909-1910	Kölliken	AG	Von Arx & Real (Olten & Zürich)	-

	Building	Construction year	City	Canton	Architect	Contractor
51	Kinderpflege, Anstalt Balgrist	1911	Zürich	ZH	E. Usteri, W. Winkler	Fietz & Leuthold, Zürich
52	Reussbrücke	1912	Bremgarten	AG	-	Locher & Cie., Zürich
53	Montagehalle Lokomotiv- und Maschinenfabrik	1918	Winthertur	ZH	H. Knobel.H. Knobel. Ing.-Bureau für modernen Fabrikbau	-
54	Binnenschiffahrt und Wasserkraftnutzung Ausstellung	1926	Basel	BS	-	-
55	Lokomotivremise der Bodensee-Toggenburg Bahn in Herisa	1916-1917	Herisau	AR	der Gemeinde Baumeister	-
56	Cinema Scala	1916	la chaux de fonds	NE	Le Corbusier, Rene Chapallaz, Jean Emmery	-
57	Immeuble Locatif	1911	Lausanne	VD	Taillens et Dubois Archtiects	-
58	Perronüberdeckung	1914-1915	Visp	VS	SBB	Ed. Bugnion, Lausanne
59	Reparaturwerkstätten der berne Alpenbahn	1915-1917	Bönigen	BE	BLS	Gribi & Cie., Burgdorf
60	Fabrikbau Rüegger & Cie.	1914	Zofingen	AG	-	-
61	Fabrik Ed. Geistlich & Söhne AG für chemische Industrie	1923	Wolhusen	LU	-	-
62	Lagerhaus		Arbon	TG	-	-
63	Lehrgerüst	1918	Rodi-fiesso	TI	-	B. Zöllig Söhne, Arbon
64	Kirche	1933	Rheineck	SG	Albert Otto Lindner (1891 - 1976)	B. Zöllig Söhne, Arbon
65	Theodor Wilhelm A.-G. Fabrik	1919	Zürich	ZH	Joh. Emil Ganz	-
66	Lehrgerüst Viadukt	1923-1925	Paudex	VD	SBB	-
67	Halle de comptoir	1922-1938	Lausanne	VD	-	-
68	Hangar avion	1914	Lausanne	VD	-	-
69	Salle de gymnastique	1921	Prilly	VD	-	-
70	Aparatenhaus der Konserenfabrik Henkel & Roth, Hero	1916	Lenzburg	AG	-	-
71	kasernenstallungen	-	Thun	BE	Direktion der Eidg. Bauten in Bern	-
72	Sandoz Chemischefabrik	-	Basel	BS	-	-
73	Entrepôt-lagerhaus francillon & cie	1912	Renens	VD	-	Ed. Bugnion, Lausanne
74	Güterschuppen SBB	-	Biel	BE	-	-
75	Lehrgerüst Brücke	-	Göschenen	UR	-	-
76	Lagerhaus für das Kaufmännische Direktorium	-	St gallen	SG	-	-
77	Lagerschuppen Sch. Eternitwerke AG	-	Niederurnen	GL	-	B. Zöllig Söhne, Arbon
78	Leistmacherei niedergösgen der Schuhfabrik Bally	-	Schönenwerd	SO	-	-
79	Maschinen Fabrik Ad. Schulthess & Cie.	1919	Wolfhausen	ZH	Emil Ganz	-
80	Workstätte Aluminium-Schweisswerk AG	-	Schlieren	ZH	-	-
81	Davos Platz-Kino Meyer	1913	Davos	GR	-	B. Zöllig Söhne, Arbon
82	Cinema Lux	1912	Montreux	VD	-	-
83	Perrondach	1918	Palézieux	VD	-	-
84	Turnhalle, Schulhaus	1922	Hätzingen	GL	-	-
85	Reithalle	-	Thun	BE	-	-
86	maison Béchert	1911	Lausanne	VD	-	-
87	villa Scheitlin	1911	Zurich	ZH	-	-
88	hôtel Monopole	1911	St moritz	GR	-	-
89	hôtel Beauséjour	1910	Lausanne	VD	-	-
90	villa Dr. Veltmann	1909	Küsnacht Am See	ZH	-	Fietz & Leuthold, Zürich
91	Ökonomiegebäude Scheune Furrer	1909-1910	St. Saphorin	VD	-	-
92	Scheune Grossenbacher	1910	Hindelbank	BE	-	-
93	Scheune der Abbaye	1912	Mont bei rolle	VD	-	-
94	Scheune Landgut	1913	Bleiche bei arbon	TG	-	-
95	Gewächshaus der Stadtgärtnerei	1915	St gallen	SG	-	-
96	Klinger s., Haslenmühle	1916	Gossau	SG	-	-
97	Werkstätten der Emmentalbahn	1914	Burgdorf	BE	-	-
98	eidgenössische Waffenfabrik	1910	Bern	BE	-	-
99	Schulhaus Mühlebach	1909-1910	Amriswil	TG	-	-
100	schweiz. Anstalt für krüppelhafte Kinder	1911	Zürich	ZH	-	-

	Building	Construction year	City	Canton	Architect	Contractor
101	temple national	1913	Glion, Montreux	VD	-	-
102	Davos Platz-russische Kirche	1914	Davos	GR	-	-
103	Turnhalle	1912	Niederschöntal	BS	-	-
104	Lokomotiv-Schuppen PLM	1909-1910	Le Locle	NE	-	-
105	Chapelle de la rue de rumine	1915	Lausanne	VD	-	-
106	Sekundarschule des quai de la Poste	1916	Genève	GE	-	-
107	Erweiterungsbau der Pflegeanstalt	1917	Uster	ZH	-	-
108	Zeughaus	1916	Kloten	ZH	-	-
109	Schulhaus Bürglen Turnhalle bei Altdorf	1909-1910	Bürglen	UR	-	Fietz & Leuthold, Zürich
110	Turnhalle	1909-1910	Gerliswil	LU	-	-
111	Turnhalle	1909-1910	Kölliken	AG	-	-
112	Turnhalle	1912	Niederschöntal	BS	-	-
113	Turnhalle	1912	Flawil	SG	-	B. Zöllig Söhne, Arbon
114	Turnhalle	1913	Steckborn	TG	-	-
115	Turnhalle	1913	Kreuzbleiche	SG	-	-
116	Turnhalle	1913	Wald	ZH	-	-
117	Turnhalle	1913	Strengelbach	AG	-	-
118	Turnhalle	1914	Glarus	GL	-	B. Zöllig Söhne, Arbon
119	Turnhalle	1914	Pully	VD	-	-
120	Turnhalle	1914	Seengen	AG	-	-
121	Gemeindehaus	1909	Saignelégier	JU	-	-
122	Kirche	1909	Mellingen	AG	-	-
123	basler Droschken-Anstalt Gebr. Keller	1909-1910	Basel	BS	-	-
124	propriété la Gentiane, Geschäfthaus	1911	Lausanne	VD	-	-
125	Färberei Schetty Söhne AG, chemische Fabrik	1911	Basel	BS	-	Riesterer-Asmus, Basel
126	Scieries mecaniques Boillot & Cie	1915	La chaux-de-fonds	NE	-	-
127	Montagehalle Adolph Saurer	1916	Arbon	TG	-	-
128	Giesserei Hegi & Löscher	1916	Oberburg	BE	-	-
129	Montagehalle der Kesselschmiede	1916	Richterswil	ZH	-	-
130	Fabrikerweiterung der Tuchfabrik Pfenninger & Co.	1916	Wädenswil	ZH	-	-
131	Lagerhaussimonius Strohl & cie	1916	Basel	BS	-	-
132	Tröcknerei der Viscose AG	1916	Emmenbrücke	LU	-	B. Zöllig Söhne, Arbon
133	Fabrikbau Hollenweger & Co.	1916	Zofingen	AG	-	-
134	Lagerschuppen der Spinnereien von Heinrich Kunz	1916	Adliswil	ZH	-	-
135	Mayer's Hutfabrik	1917	Locarno	ZH	-	-
136	Gerberei Gimmel	1917	Arbon	TG	-	-
137	Glashütte der Th. Wilhelm AG	1917	Zürich	ZH	-	-
138	Fabrikatiomlokal der ehern. Fabrik J. R. Geigy AG	1917	Basel	BS	-	-
139	Tannerie Huguenin	1917	La sarraz	VD	-	-
140	Walzwerkhalle für die von Moos'schen Eisenwerke	1917	Luzern	LU	-	B. Zöllig Söhne, Arbon
141	Perrondach Bahnhof	1914	Schübelbach	SZ	-	-
142	Perrondach Bahnhof	1914	Frick	AG	-	-
143	Perrondach Bahnhof	1915	Letten	ZH	-	-
144	Perrondach Bahnhof (Postgebäude)	1915	Aarau	AG	-	-
145	Perrondach Bahnhof	-	Oberrieden	ZH	-	-
146	Kübelfabrik	1926	Chur	GR	-	-
147	Mostereigenossenschaft	-	Egnach	TG	-	-
148	Robert Victor Neher AG, Aluminiumwarenfabrik	-	Emmishofen	TG	-	B. Zöllig Söhne, Arbon
149	Raduner & Cie. (Textile)	-	Horn	TG	-	B. Zöllig Söhne, Arbon
150	Ringier & Cie.	-	Zofingen	AG	-	B. Zöllig Söhne, Arbon

	Building	Construction year	City	Canton	Architect	Contractor
201	Kahn s., Eisen- und Metallabfälle	-	Zürich	ZH	-	B. Zöllig Söhne, Arbon
202	Kaufmännisches Direktorium	-	St gallen	SG	-	B. Zöllig Söhne, Arbon
203	Perrondächer	-	Kradolf	TG	-	B. Zöllig Söhne, Arbon
204	Perrondächer	1912	Landquart	GE	-	B. Zöllig Söhne, Arbon
205	Strandbad	-	Zürich	ZH	-	B. Zöllig Söhne, Arbon
206	Perrondächer	-	Lengnau	AG	-	B. Zöllig Söhne, Arbon
207	Perrondächer	-	Othmarsingen	AG	-	B. Zöllig Söhne, Arbon
208	Perrondächer	1918	Schänis	SG	-	B. Zöllig Söhne, Arbon
209	Perrondächer	-	Weinfelden	TG	-	B. Zöllig Söhne, Arbon
210	Perrondächer	-	wil	SG	-	B. Zöllig Söhne, Arbon
211	Reithalle Lengensand	-	Luzern	LU	-	B. Zöllig Söhne, Arbon
212	Bühler H., Schlossberg Reithalle	-	Am Irchel	ZH	-	B. Zöllig Söhne, Arbon
213	Reitanstalt	-	Schaffhausen	SH	-	-
214	Balteschwiler Sägerei und Hobelwerk	-	Laufenburg	AG	-	B. Zöllig Söhne, Arbon
215	Dorner Gebr. Sägerei und Hobelwerk	-	Romanshorn	TG	-	B. Zöllig Söhne, Arbon
216	Hart- und Weichholz AG Sägerei und Hobelwerk	-	Zürich	ZH	-	B. Zöllig Söhne, Arbon
217	Holzindustrie AG Sägerei und Hobelwerk	-	St. margrethen	SG	-	B. Zöllig Söhne, Arbon
218	Kälin und Cie. Sägerei und Hobelwerk	-	Oberwinterthur	ZH	-	B. Zöllig Söhne, Arbon
219	Kühnis Kaspar Sägerei und Hobelwerk	-	Oberrieth	SG	-	B. Zöllig Söhne, Arbon
220	Bauamt Winterthur Scheune	-	Winterthur	ZH	-	-
221	Turn- und Sporthalle (Reithalle Oeflingen)	-	Baden	AG	-	-
222	Turn- und Sporthalle	-	Berlingen	TG	-	Riesterer-Asmus, Basel
223	Turn- und Sporthalle	-	Glarus	GL	-	-
224	Turn- und Sporthalle	-	Kradolf	TH	-	-
225	Turn- und Sporthalle	-	Oberaach, amriswil	TG	-	-
226	Turn- und Sporthalle	-	Schinznach, brugg	AG	-	-
227	Tennishalle	-	St gallen	SG	-	-
228	Turnhalle	-	Steckborn	TG	-	-
229	Turnhalle	1920	Thusis	GR	-	-
230	Turnhalle	1909-1910	Oerlikon	ZH	-	-
231	société immobilière de Bourg	1909-1910	Lausanne	VD	-	-
232	Gemeindehaus	1909-1910	Saignelégier	BE	-	-
233	Ökonomiegebäude Scheune	1909-1910	Cossonay	VD	-	-
234	Wohnhaus Brockmann	1909-1910	Zürich	ZH	-	-
235	Gartenpavillion	1910	Basel	BS	-	Fietz & Leuthold, Zürich
236	Schuppen des Herrn Vogt-Gut	before 1913	Arbon	TG	-	Riesterer-Asmus, Basel
237	Universitäts-Instituts für Hygiene und Pharmakologie	1912	Zürich	ZH	-	-
238	Theater in Olten	before 1913	Olten	SO	-	-
239	Wohnhaus Stiffler & Conrad	before 1913	Chur	GR	-	-
240	Wohnhaus dr. Veltmann in Küsnacht	before 1913	Küsnacht Am See	ZH	-	-
241	Wohnhaus Scheitlin an der Freiestrasse	before 1913	Zürich	ZH	-	-
242	Wohnhäuser im Loogarten in Altstetten	before 1913	Zürich	ZH	-	-
243	maison Pascal	before 1913	Lausnane	VD	-	-
244	Baugeschäft Chur, Werkstattgebäude	before 1913	Chur	GR	-	-
245	fourragère pour Belmont	before 1913	Lausanne	VD	-	-
246	Ökonomigebäude des Herrn Montigel	before 1913	Chur	GR	-	-
247	Remise de mm. Barblan et Meylan	before 1913	Lausanne	VD	-	-
248	Stickfachschule Amriswil	before 1913	Amirswil	TG	-	-
249	château de St. Bartélémy près Échallens	before 1913	Echallens	VD	-	-
250	garage Pfister	before 1913	Lausanne	VD	-	-

	Building	Construction year	City	Canton	Architect	Contractor
151	Kunstseide AG	-	Steckborn	TG	-	B. Zöllig Söhne, Arbon
152	Vigogne-Spinnerei	-	Pfyn	TG	-	B. Zöllig Söhne, Arbon
153	eidgen. Schützenfest	-	Bellinzona	TI	-	B. Zöllig Söhne, Arbon
154	Passions-Spiele	-	Rorschach	SG	-	B. Zöllig Söhne, Arbon
155	Bezirks-Sängerfest	-	Wiedikon	ZH	-	B. Zöllig Söhne, Arbon
156	Ostschweiz. Aero-Gesellschaft	-	Altenrhein	SG	-	B. Zöllig Söhne, Arbon
157	Kino	-	Glarus	GL	-	B. Zöllig Söhne, Arbon
158	Habisreutinger-Ottiker	-	Flawil	SG	-	B. Zöllig Söhne, Arbon
159	Schmid J. P., Holzgeschäft	-	Filisur	GR	-	B. Zöllig Söhne, Arbon
160	schweiz. Genossensch. F.Gemüsebau	-	Kerzers	FR	-	B. Zöllig Söhne, Arbon
161	Spengler Alb. AG. Fournierfabrik	-	Lengwil	TG	-	B. Zöllig Söhne, Arbon
162	Oel- und Fettwerke SAIS	1916	Horn	TG	-	B. Zöllig Söhne, Arbon
163	Reithalle Sulzer	-	Winterthur	ZH	-	-
164	Reitanstalt Rosenberg AG	-	Winterthur	ZH	-	-
165	Reitanstalt	-	Schaffhausen	SH	-	-
166	Reithalle	-	Wetzikon	ZH	-	B. Zöllig Söhne, Arbon
167	Daepp w. Landwirt	-	Arbon	TG	-	-
168	Geistlich Factory	1916	Schlieren	ZH	-	-
169	Restaurationshalle	1912	Zürich, Silholzli	ZH	-	locher & cie
170	Perrondächer	1910-1914	St Gallen	SG	A. von Senger	B. Zöllig Söhne, Arbon
171	Perrondächer	-	Chiasso	TI	-	B. Zöllig Söhne, Arbon
172	Perrondächer	-	Brugg	AG	-	B. Zöllig Söhne, Arbon
173	Perrondächer	-	Giswil	OW	-	B. Zöllig Söhne, Arbon
174	Perrondächer	-	Lugano	TI	-	B. Zöllig Söhne, Arbon
175	Perrondächer	-	Luzern	LU	-	B. Zöllig Söhne, Arbon
176	Perrondächer	-	Magadino	TI	-	B. Zöllig Söhne, Arbon
177	Ruedi o., el. Werkstätte für Autos, Autogarage	-	Kreuzlingen	TG	-	B. Zöllig Söhne, Arbon
178	Bundesbahn Diazzobrücke	-	Basel	BS	-	B. Zöllig Söhne, Arbon
179	Bundesbahn Rotbachbrücke	-	Teufen	AR	-	B. Zöllig Söhne, Arbon
180	Bundesbahn Ribistöcklibrücke	-	-	-	-	B. Zöllig Söhne, Arbon
181	Sihlbrücke	-	Zürich	ZH	-	B. Zöllig Söhne, Arbon
182	Aluminiumwarenfabrik	-	Emmishofen	TG	-	-
183	Lokomotivremise	1920	Fribourg	FR	-	-
184	Vordach SBB	1914-1915	Schübelbach	SZ	-	B. Zöllig Söhne, Arbon
185	St.Laurentius Pfarrei, Kassettendecke	1911	Flawil	SG	-	-
186	Kirche St. Andreas, Binderkonstruktion	1913	Gossau	SG	-	B. Zöllig Söhne, Arbon
187	Kirche, Kuppelkonstruktion	19(30)	Goldach	SG	-	B. Zöllig Söhne, Arbon
188	Kirche, Kassettendecke	-	Niederuzwil	SG	-	B. Zöllig Söhne, Arbon
189	Kirche, Laterne	-	St. Fiden	SG	-	B. Zöllig Söhne, Arbon
190	Kirche, Kuppelkonstruktion	-	St. Gallen	SG	-	B. Zöllig Söhne, Arbon
191	pont du Guillermaux,Lehrgerüste	1921	Payern	VD	-	B. Zöllig Söhne, Arbon
192	Bezirkschulhaus	1923	Schinznach	AG	Rudolf Christ, Basel	-
193	Tellspielhaus	1927	Altdorf	UR		-
194	SBB Kraftwerk Bundesbahn	1920-1921	Amsteg	UR	Th. Nager, SBB generaldirektion	-
195	SBB Kraftwerk Ritom	1918-1919	Piotta, Quinto	TI	-	B. Zöllig Söhne, Arbon
196	schweiz. Unfallvers. -Gebäude	-	Luzern	LU	-	B. Zöllig Söhne, Arbon
197	Privathütte SAC schweiz. Alpen Club	1932	Fählensee	SG	-	B. Zöllig Söhne, Arbon
198	Schweiz. Alpen-Club Mels	-	Pizol	SG	-	B. Zöllig Söhne, Arbon
199	Bachmann und Kleiner AG	1933	Örlikon	ZH	-	B. Zöllig Söhne, Arbon
200	Papier und Karton Handlung P. Gimmi & Co.	-	St Gallen	SG	-	B. Zöllig Söhne, Arbon

	Building	Construction year	City	Canton	Architect	Contractor
251	Bauerhof Grosenbacher in Hindelbank	before 1913	Bern	BE	-	-
252	Perrondächer	1914-1915	Pratteln	BL	-	-
253	Perrondächer	1920	Schlieren	ZH	-	-
254	Perrondächer	1912	Uerikon	ZH	-	-
255	Perrondächer	1922	Thalwil	ZH	-	-
256	Perrondächer (1939: Yverdon. 1949: Martigny)	1917 (1939?)	Martigny	VS	-	-
257	not precised	1910	Seughalle	VD	-	B. Zöllig Söhne, Arbon
258	Goetheanum	1913/1924	Dornach	SO	-	-
259	Depot (tram-lokomotive ?)	1924	Basel	BS	-	-
260	Bototanischer Garten	1913	St gallen	SG	-	Nielsen, Bohny & Cie., Basel
261	Bauwerkstätte	1932	Baesl	BS	-	-

Appendix 3.2

Cases of decay of early glulam structures

A few years after completion, a couple of early glulam structures saw unexpected damages which required quite extensive repair work. These damages were mainly related to the performance of the material, which itself was the result of the fabrication quality of the structural elements. In a report written by T.R.C. Wilson, senior engineer at Forest Products Laboratory in Wisconsin, on the early Swiss glulam structures, the writer emphasizes on the “severe checking” of glulam arches of the locomotive depot in Bern, constructed in 1912. The checking, according to Wilson, was “evident near a conductor pipe into which locomotive fumes had been discharged. Less severe checking was evident in some other parts.” The reason for these checking, according to the Bridge Engineer of the Swiss Railway were related to the lack of good seasoning of lumber before gluing, […] and some of the checking was due to imperfect seasoning”.[78]

However, according to Wilson who had inspected about 40 early glulam structures in Europe, particularly in Switzerland, the deterioration of the locomotive depot in Bern has been the worst case. The other ones, were not "not serious enough to endanger the structural integrity of the structures."

The archival records demonstrate another case of decay in this structure. Just six years after the opening of the building, there was decay detected in 1918 at the foots of the girders. The foundations originally were set to start just above the floor level where they received the lower ends of the frame girders. At this point, the timber elements were wrapped in metal sheets of one to two-millimetre thickness. Probably, this very unusual detail (Fig. 15) has been arranged to protect the foot points from the steam of the locomotives. To repair, Terner and Chopard proposed to cut off the affected parts and to rise the concrete foundations by that height. The surface of the extended foundation (the pedestal) incorporated the steel shoe by clasping the foot of the arch (Fig. 16).

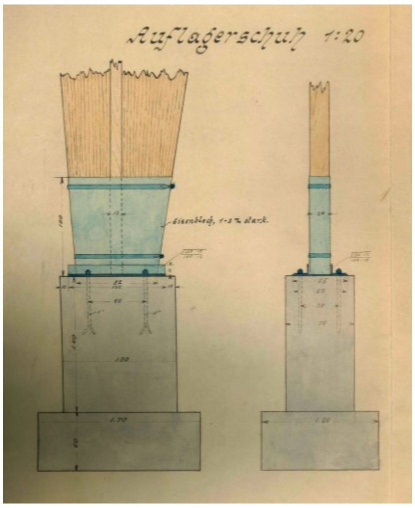


Fig. 15 Transversal section of the locomotive depot. Footing wrapped in metal sheets is coloured blue.

[78] Wilson, T.R.C. *The Glued Laminated Wooden Arch*. Technical Bulletin no. 691, United States Department of Agriculture, Washington D.C. 1939, p. 92.

Fig 16 Locomotive depot, Bern. State of the base of one girder after the removal of the decayed section and its replacement by a concrete pedestal.

Besides this case, the riding hall in St. Moritz, built in 1910 should be mentioned, which showed several damages in its early years. The riding hall consists of a main building and an annex containing the horse stables and storage rooms (Fig. 17)

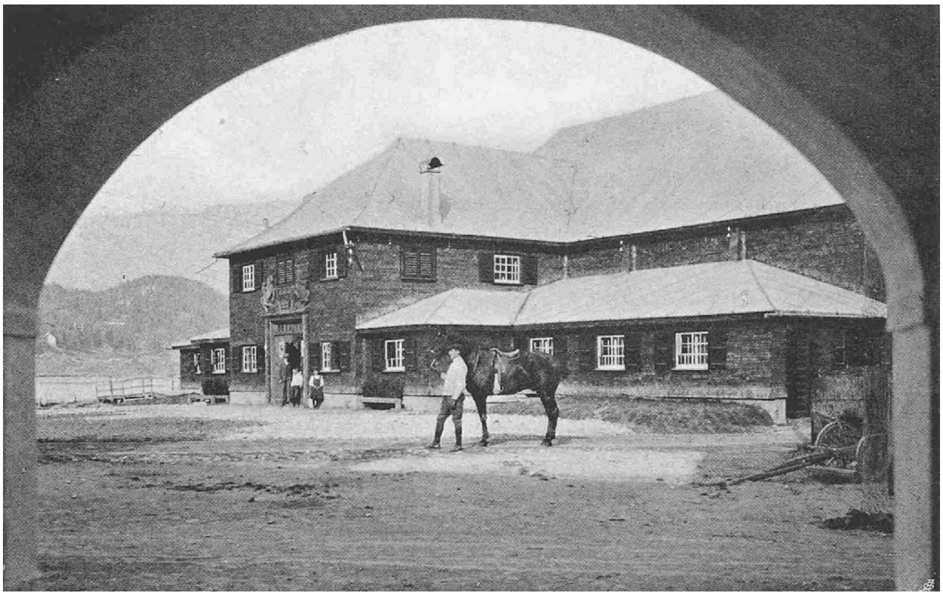


Fig 17 Riding arena, St. Moritz. Architect, N. Hartmann, 1911.
Entrance, stables and behind, the riding arena.

zThe major damage appeared in 1928: the feet of the arches on one side of the arena, near the annex where the horse stables are located, were found to be subject to decay. from the beginning, when the building was finished in 1910, there was a light timber fence covering all feet of the arches. It has been suggested that the decay was caused by the poorly ventilated space, between the interior fence and the wall next to the stables which might have contributed to an unfavorable humidity level, and an alternate wetting and drying condition.[79] Terner and Chopard proposed to cut away the damaged pieces of the arch feet and replace them with steel beams (U profiles) filled with concrete, following the original form of the girders (Fig. 18).

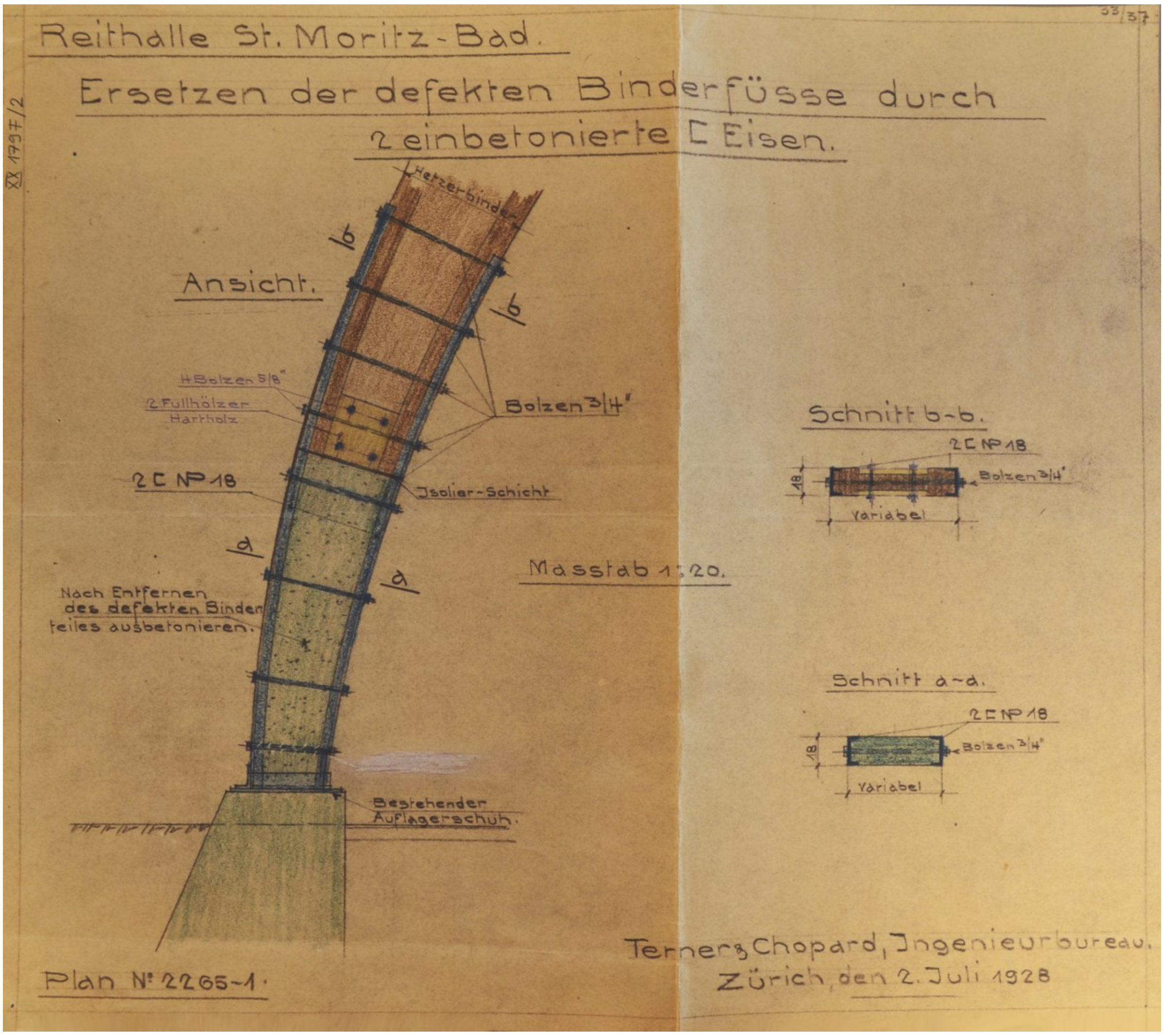


Fig. 18. Riding arena, St. Moritz. Engineers, B. Terner and Ch. Chopard, 1911. Base of girders, replacement of decayed sections by concrete components straddled by iron U-profiles in 1928

[79] Müller, Christian. Die Entwicklung des Holzleimbaues unter besonder Berücksichtigung der Erfindungen Otto Hetzer- ein Beitrag zu Geschichte der Bautechnik. PhD dissertation, Bauhaus-Universität Weimar, 1998, p. 106.

Appendix 3.3

List of publications on structural timber published from 1883 to February 1949

rapporteur	institution	titel	Year
L. v. Tetmajer	EMPA	Buckling strength of construction timber	1883
L. v. Tetmajer	EMPA	Methods and results of testing Swiss structural timber	1884
L. v. Tetmajer	EMPA	Buckling strength of construction timber	1888
L. v. Tetmajer	EMPA	Methods and results of testing Swiss structural timber	1896
Ch. Chopard	Private + SBB	Fracture test of Hetzer girders	1913
F. Hübner	SBB	Tests with wooden beams built according to Hetzer wooden construction method	1924
Ch. Chopard	Private + SBB	Single-stem platform roofs in Hetzer wooden construction method	1924
M. Roš	EMPA	S. I. A. standards for wooden structures	1925
M. Roš	EMPA	Construction of scaffolding and wooden structures in Switzerland	1925
J. Brunner	EMPA	Construction of wooden bridges in Switzerland	1925
M. Roš	EMPA	Results of the strength tests with green Douglaise	1925
M. Roš	EMPA	Dimensioning of centrically and eccentrically pressed bars in buckling	1928
M. Roš	EMPA	Studies on the influence of the felling time on the structural properties of spruce and fir wood	1933
J. Jaccard	EMPA	Anatomical structure and technical value of wood	1934
E. Staudacher	EMPA	Wood as a Building Material (dissertation)	1932-1936
M. Roš	EMPA	Construction of bridges, scaffolding and wooden structures in Switzerland (supplement)	1936
M. Roš	EMPA	Wood as a Building Material (1st Swiss congress for the promotion of the use of wood)	1936
E. Staudacher	EMPA	Swiss literature on forestry and wood use (1st Swiss congress ...)	1936
P. Schläpfer	EMPA	Basic information on the combustion of wood (1st Swiss congress ...)	1936
J. Tobler	EMPA	Production and use of wood gas for motor purposes (1st Swiss congress ...)	1936
O. Stadler	EMPA	New ways of production and use of wood gas for motor purposes (1st Swiss congress ...)	1936
P. Jaccard	EMPA	Modern wood combustion in small plants (1st Swiss congress ...)	1936
E. Staudacher	EMPA	Formation and distribution of resin in larch	1939
Schläpfer & Stadler	EMPA	Combustion of wood in central heating systems	1940
E.Staudacher	EMPA	Summery of responses to the questionnaire on structural assessment and sorting of sawn timberSwiss	1942
P. Haller	EMPA	building construction and commercial timber	1942
E. Schubiger	EMPA	Tests and experiences on nailed wooden constructions	1942
M. Roš	EMPA	Material quality and safety in the construction and engineering industries (including timber)	1943
-	SBB	Specifications for glue-laminated timber constructions	1943
M. Roš	EMPA	Melocol glues of CIBA co., Basel	1945
M. Roš	EMPA	EMPA guidelines for glue-laminated timber constructions	1945
O. Wichser	SBB	Modern wooden constructions at the Swiss Federal Railways	1946
M. Roš	EMPA	Progress in the field of wooden construction glues in Switzerland (international conference)	1946
M. Roš	EMPA	Technical progress in Swiss timber construction (international colloquium)	1947
M. Roš	EMPA	The current state and prospects of wooden constructions in the field of civil engineering (conf.)	1948
P. Schläpfer & Brown	EMPA	About the structure of charcoal	1948
H. kühne	EMPA	Wood drying (Swiss Congress for the Promotion of the Rational Use of Wood, Zurich)	1949
H. Kühne, et al.	EMPA	Internal stresses in planar material composites	1949

Publications on the occasion of the congress for the promotion of the use of wood , Bern, 1936.

* in red: publications by the SBB, on the basis of the tests performed on the ocassion of the projects of this institution.
* in green: standards and guidelines publsihed by the EMPA, regulating the practice of structural timber and glulam.

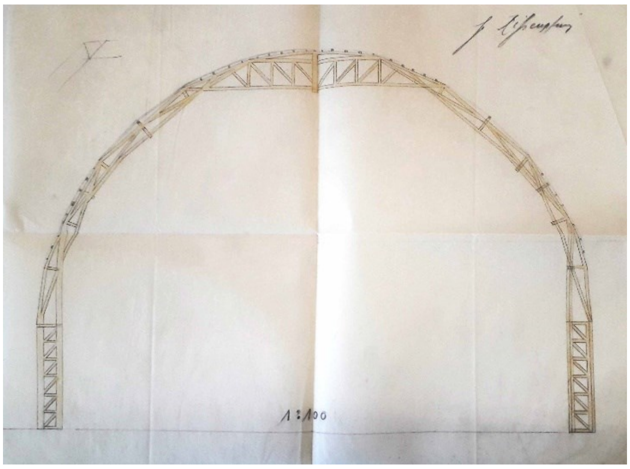
Chapter four

Hybrid structural logic

timber and steel

Timber is one of the few traditional building materials that indicate a form. It has its characteristic rod-like shape and is, therefore, suitable for the formation of rod-shaped supporting structures. This basic property of timber has dominated construction for centuries.[1] The lack of shapeability of normal timber resulted in most cases and particularly for large-scale structures, in overlapping patterns of the truss elements, structured geometrically in a way to be able to distribute the loads on the structural elements.

Otto Hetzer claimed a new way of producing "skeleton frames, which, with covering material, form roofs or entire buildings made from building elements composed of layers of wood." [2] These glue-laminated elements have been regularly used for larger spans since they are allowed to be fabricated in virtually unlimited sizes bringing larger cross-sections and longer components. More importantly, their fabrication method allowed the modified timber to be used in different typologies than usually associated with it, e.g. arches and frame girders. Curved elements could replace traditional combinations of linear components such as from roof frameworks using rafters, beams, and posts (Figs 1-2).



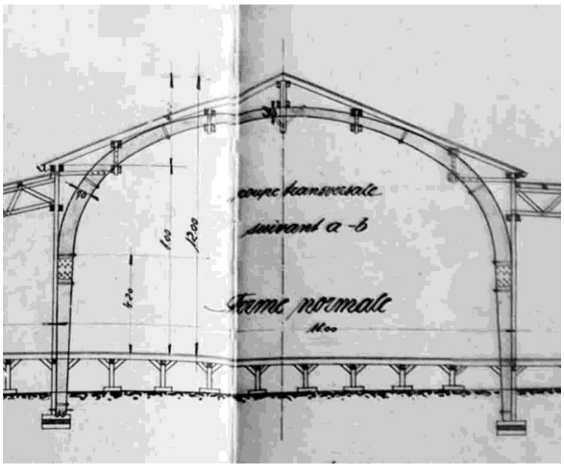


Fig. 1 Draft of a project for the cupola of the Food Industry Hall of the Swiss National Exhibition, Bern, 1914. Different configurations of truss patterns were proposed to bring the shape of girders closer to the curves needed to form a cupola.
Fig. 2 The final project for the cupola of the Food Industry Hall was a glulam structure, consisting of 2 half girders, shaped according to the architect's proposed geometry for the cupola.

The process of glue-laminating, decomposition of natural wood into lamellas and their reassembling by means of adhesives, results in a material that is no longer limited to the natural form and dimensions of the original solid wood. It can be then theoretically formed to almost any desired geometry.

[1] See Schwartz, Joseph. "Moderne Holzkonstruktionen zwischen Tradition und Innovation-Grenzüberschreitungen am Beispiel des Novartis Learning Center in Risch". *Holz, Stoff oder Form. Transformationen einer Konstruktionslogik,* edited by Mario Rinke and Joseph Schwartz. Sulgen, Niggli, 2014, pp. 35-46.
[2] Otto Hetzer, UK Patent No 20684, Apr.1907, pp.1-2.

If the rod-like shape of timber gave rise to the column and beam and later truss structures, informing a shapeless material, gave rise to a "morphological understanding of the structure", and to new typologies of structures. In the former case, the structural design was ruled by "empirical methods", but in the latter case, it was mainly materializing what was "found to be theoretically sound", based on the scientific understanding of structures.[3]

Glulam technology was penetrating one of the most traditional fields of the construction sector. Its introduction process hence met many participants of different qualifications, interests, and intentions. Even when glulam became readily available, it did not lead to an immediate change, but simply provided an alternative material that could be used either instead of traditional timber or in combination with it. It was simply absorbed into an existing craft practice.[4] So, the question that arises here is how did glulam change the basic organization of design?

The licensed contractors had to bring together a long-standing knowledge of local timber craftsmanship and patented glulam technology. So, the early development of glulam, in the early phases, was in fact both the adoption of the new material into vernacular construction, and also in parallel, establishing the construction culture of the new material. By this, the capacities and responsibilities of the involved parties, mainly contractors and engineers, and to a lesser extent the architects were to be rebalanced. The niche role of the architects, in the case of early glulam structures, was usually limited to defining the overall form of the roof or the building and controlling the internal space, to ensure that it met the functional and aesthetic requirements of the clients. The rest of the project relied on the engineers' knowledge of statics and the comprehensive service and trade skills of the contractors, to develop the technical details.[5] Therefore, the development of the know-how of early glulam was directly related to the collaboration of the engineers and the contractors.

In this context, what is quite particular in the case of Switzerland, is the significant role played by the glulam consortium in organizing the design and construction processes of early glulam structures, by bringing together the mainstream structural knowledge, craft skills, and material know-how. In the second chapter, the role of the consortium was studied considering its marketing aspects. In the present chapter, this role will be studied in shaping an early construction culture of the new material.

Regarding Germany, the whole process of design and execution of projects was organized in such a way that the statics calculations were done by the company of Hetzer, but the execution could be

[3] Rinke, Mario, and Toni Kotnik. "The changing concept of truss design caused by the influence of science". *Structures and architecture, preceeding of the first international conference on structures and archtiecture, 21-23 July 2010, Guimarães Portugal.* London, Taylor & Francis Group, 2010, pp. 1959-1967.
[4] As discussed in Rinke, Mario, and Roshanak Haddadi. "The riding arena in St. Moritz and the locomotive depot in Bern – a comparative study of early glulam construction in Switzerland". *Studies in the History of Services and Construction. Proceedings of the Fifth Conference of the Construction History Society,* edited by James Campbell et al., Cambridge, Construction History Society, 2018, pp. 451-462.
[5] For the role of architects in the construction of regular timber structures see Yeomans, David T. *The Trussed Roof: Its History and Development*. Aldershot, Scolar Press, 1992, pp. 71-85.

carried out either by his own company or by other licensed contractors.[6] The separation of design and construction was a common practice that can be seen in other patented technologies of the time as well. In the case of the diffusion of the patented reinforced-concrete construction system of Hennebique in the 1900s, we read that:

> From his Paris headquarters on the rue Danton, Hennebique built up an international network of agents and licensees; and he separated design from construction […]. For a license fee, which could amount to 10% or even more of the building sum, he could supply sets of drawings to the licensed contractors.[7]

In Switzerland, during the first four years before the establishment of the glulam consortium at the end of 1912, project contracts were set up between the engineers Terner and Chopard, and the architect of the project (mainly as the representative of the client). For example, in the case of the project for a skating rink in Geneva in 1910, the name of the contractor Ed. Bugnion is not mentioned in the contract. "The offer of the execution" is set up between the engineers Terner and Chopard, and architect Ed. Fatio. After the establishment of the consortium, however, the contractors became the involved party in the contracts, representing the glulam consortium. For example, for the project of the Food Industry Hall of the Swiss National Exhibition of Bern in 1914 (Fig. 2), the main contract for the structure of the project was concluded between the client (the central committee of the exhibition) represented by the architects, and the contractor, Bugnion.
The demarcation of responsibilities of the contractors with the engineers is however not an easy task. It is in some cases influenced by the scale, function, and nature of the project, and of course, whatever the general trend, it may not have been followed in all cases. For example, in the temporary structures the role of the contractors, as we will see in the last part of this chapter, was different from their role in the permanent and public projects.

The present chapter discusses the role of different involved parties in the early development of glulam's construction culture in Switzerland, as well as the influence of the technical knowledge of other construction materials on glulam. It is therefore needed to set up criteria or milestones to determine a time interval, within which the case studies should be analysed. For this purpose, the development of glulam structures from its very first projects, until reaching what is usually understood as the "dominant design", will be studied.[8] The dominant design of early glulam was reached in 1916 when the structure of the tram depot of Basel was constructed and promptly recognized as a standardized solution to a particular set of technical, and socio-economic conditions. We should note

[6] This is how it is explained by Urban, K. H. *Denkschrift über Hetzer's neue Holzbauweisen, Verfasst im Auftrage des «Schutzverbandes für neue Holzbauweisen».* Weimar, 1913. There are however some exceptions, for example Germany's Railways Pavilion at the Brussels International Exposition of 1910 can be mentioned: a collaboration of, among others, engineer Hermann Kügler, and Otto Steinbeis & Co sawmill responsible for the execution of the glulam girders, see chapter 1.
[7] Kurrer, Karl-Eugen, and Ekkehard Ramm. *The History of the Theory of Structures: From Arch Analysis to Computational Mechanics.* Berlin, Wilhelm Ernst & Sohn, 2008, p. 684.
[8] For more about the concept of dominant design see: Arthur, W. Brian. "Competing technologies: an overview". *Technical Change and Economic Theory*, edited by Giovanni Dosi et al., London and New York, Columbia University Press and Pint, 1988, pp. 590-607.

that in this early period of 1909 to 1917, already about 200 glulam projects of different functions and scales have been built in Switzerland. The table below shows the different functions of early glulam buildings (table 4.1).[9]

Table 4.1 Categories of first glulam applications (as identified in the glulam consortium's catalogue published in 1917. ca. 200 glulam projects were claimed, and the function of 126 of them was identified).

Category	Number	%
Industry + agriculture	41	33
Sport	24	19
Public (administrative, education, hospital)	17	13
Infrastructure	17	13
Culture	12	10
Housing	9	7
Church	6	5
Total	126	100

The path linking the initial concept of glulam presented in Hetzer's patent to the structure proposed for the tram depot in Basel was consisted of a series of incremental developments.[10] In order to understand the design process of this project, the design history of glulam structures will be traced considering the context and the boundary conditions, the model used, and the decisions made to determine relevant construction details such as component shapes, connections, assembly and erection process of the structures. This will be studied in relation to the common construction principles of popular building typologies and structural materials of the time.

1. Co-existence of different construction logics

1.1. Riding arena, St. Moritz, 1910

One of the earliest examples of glulam construction in Switzerland and also one of the finest architectural applications is the riding hall in St. Moritz.[11] The project was developed collaboratively by the well-known local architect Nicolaus Hartmann,[12] the engineers Terner and Chopard, and the contractor "Construction Business Chur AG" (before 1905, Ulrich Trippel carpentry and construction business). In 1910, the *Reithalle-Gesellschaft* of St. Moritz signed a contract with the architect Hartmann for the project of a riding hall on the west shore of the St. Moritz Lake (Fig. 3).

[9] In a sales brochure of the glulam consortium published in June 1917, the consortium proudly stated that in the years from 1909 to 1917, around 200 glulam projects could be constructed.
[10]
[11] This part of the chapter has been already partly published as Rinke, Mario, and Roshanak Haddadi. "The riding arena in St. Moritz and the locomotive depot in Bern – a comparative study of early glulam construction in Switzerland". *Studies in the History of Services and Construction. Proceedings of the Fifth Conference of the Construction History Society,* edited by James Campbell et al., Cambridge, Construction History Society, 2018, pp. 451-462.
[12] For the influence of him on the architecture of Graubünden see. the Hartmann, Kristiana. *Baumeister in Graubünden, drei Generationen Nicolaus Hartmann, 1850-1950.* Chur, Desertina, 2015, p. 102.

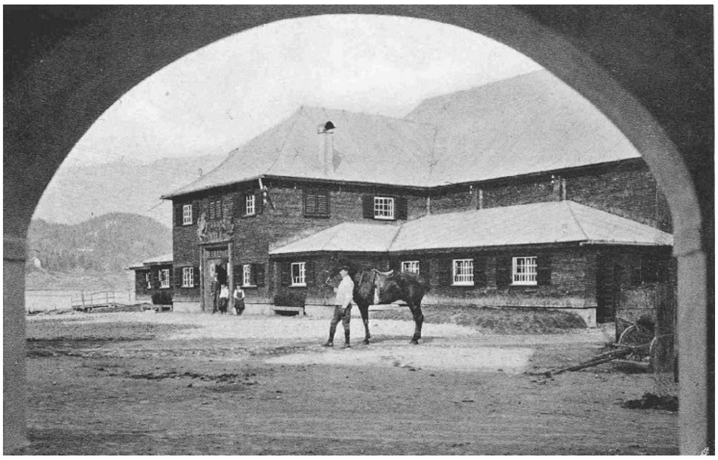


Fig. 3   Riding arena, St. Moritz, 1911. Entrance, stables, and behind, the riding arena.

A series of glulam arches made the structure of the 34.5 m long hall spanning 19.8 m, which was designed according to the roof shape as a segment of a circle (Fig. 4).

Due to the shape of the riding arena defined by the architect (probably to have a geometrically uniform inner space), Terner and Chopard designed two categories of glulam arches slightly different in their geometry: the central area is spanned by four circularly shaped arches with a spacing of 4.9 m, while the half hip arches span 14 m and have an oval shape (Figs 5-6).

Every central glulam arch consists of two symmetrical components. All glulam arches feature an I-shape cross-section and their depth varies from 45 cm at the basis going to 90 cm at the haunch and arriving at 40 cm at the vertex. Their flanges are 18 cm wide and their webs are 9 cm. While the overall structural layout of the arches seems to be a straightforward arrangement and the shape of the arches reflects the nature of the 'new' timber, the connections of the components do not appear to be based on consistent design practice.

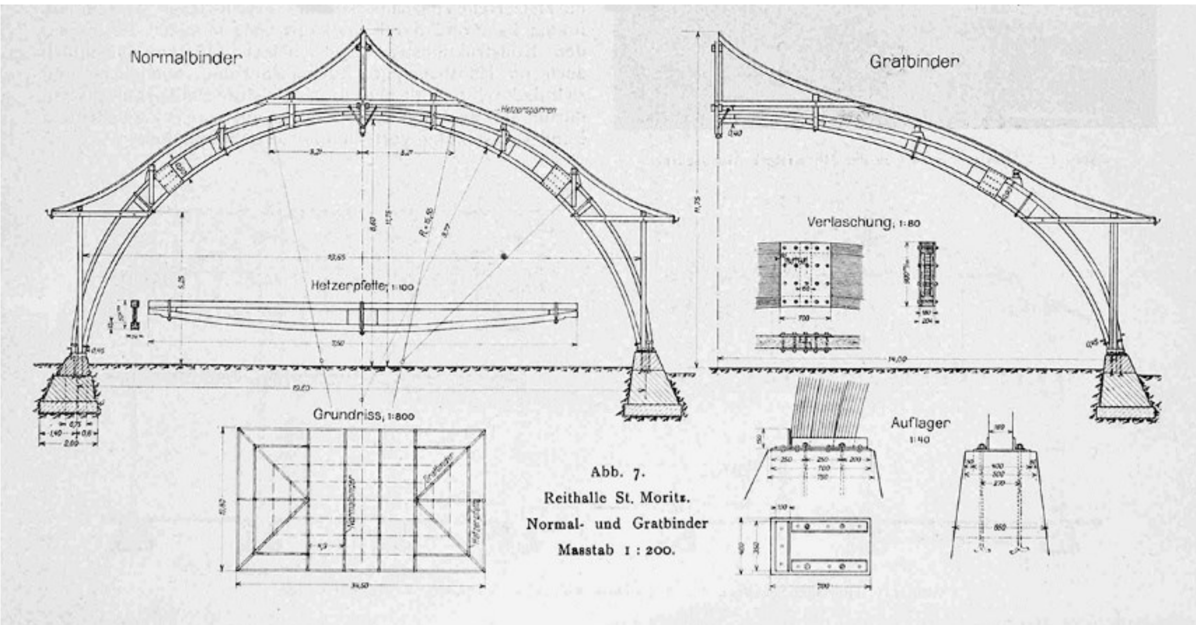


Fig. 4   Riding arena, St. Moritz. 1911. Normal and hip girders.

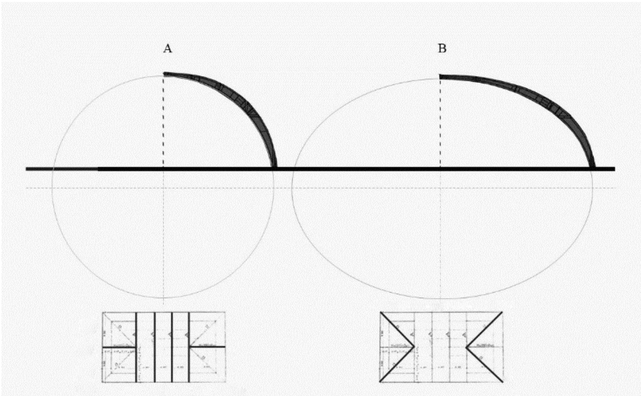


Fig. 5 Geometry of two types of half girders

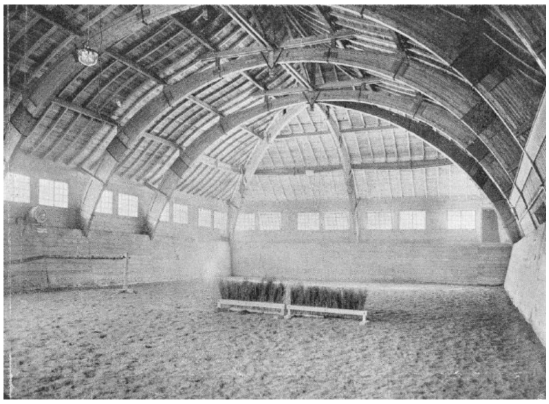


Fig. 6 Inner space of the riding arena, 1911.

At the apex, the two arch halves are connected through a vertical timber post, fastened with bolts, and suspended at the lower end from both ends of the arch halves. The upper end of the post forms the support of the ridge of the curved roof. Four more support points in the form of purlins are placed on each arch side right on the top of the glulam components. The foot of the arches is placed on a concrete base and is received by an iron shoe made of L-shaped steel beams (Fig. 7). As each half arch consists of two components a site joint is placed near the middle of the half consisting of a lapped scarf joint of the glulam components together with additional strapping using steel plates on both sides making for a stiff connection of the components (Fig. 8).

Figs 7-8 Details of the footing of a girder and a site joint. Visit in 2018.

The arches, however, are not the only structural glulam components of the building. While all purlins on the arches span 4.9 m at the most, they exceed that span in the corners of the buildings due to the geometrical distortion. Here 7.5m long curved glulam purlins are used featuring an I-section of varying depth of max 50 cm in the middle. Also, the rafters making the double curved shape of the roof are glulam beams (Fig. 9).[13]

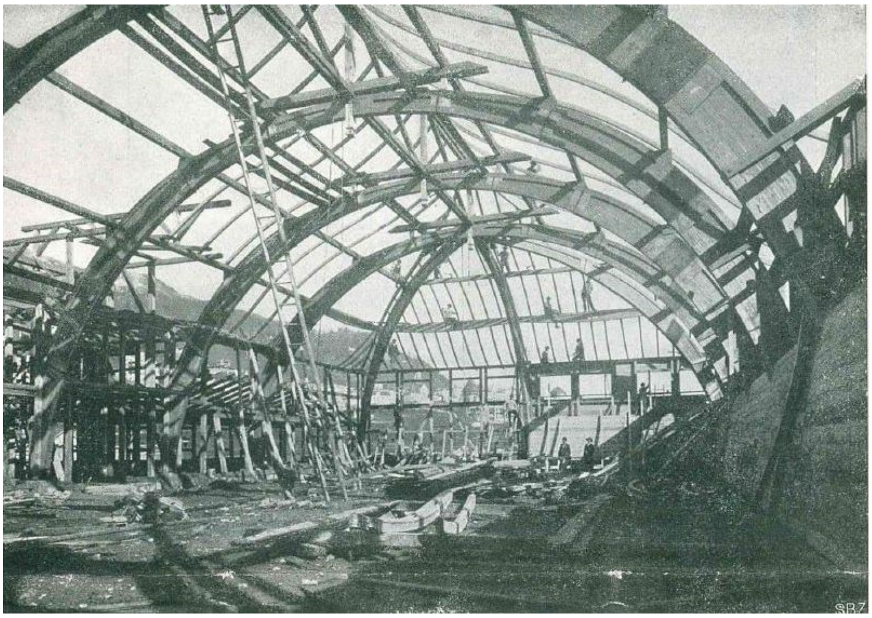


Fig. 9 Construction site, 1911. In the background, the curved glulam purlins, on which the workers are sitting can be distinguished. Some workers are fixing curved rafters, supported by the purlins.

This structural logic and detailing can be traced in many glulam projects of the very early years. Sometimes the inner space has been decisive for the overall geometry of the girders, and other times the structure has followed the form of the roof. The project of the locomotive depot in Bern, studied in chapter three from a different perspective, will be analysed here. The reason for this study is the availability of archival material on the static calculation of the structures, which helps to clarify the role of the engineers and to clarify the underlying logic of some details.

1.2. Locomotive depot, Bern, 1912

The locomotive depot of Bern, as discussed previously, comprises four parallel halls whose structure consists of massive frame girders with spacings of 5 m, three of which span 21.2 and one 24.4 m (Fig. 10). In total, 56 glulam frame girders have been used covering a surface of 780 m^2 (Fig. 11).

[13] In some cases, these double curve rafters, integrally provide both the structure and the shape of the roof. The dome of the University of Zurich constructed in 1913, is an example of this types of roof-structures. See: Rinke, Mario. "The domes of the University of Zurich and the SUVA head quarter in Lucerne – early glulam construction in Switzerland". *Building Histories: the proceedings of the Fourth Conference of the Construction History Society*, edited by James Campbell et al. Cambridge, Construction History Society, 2017, pp. 365-374.

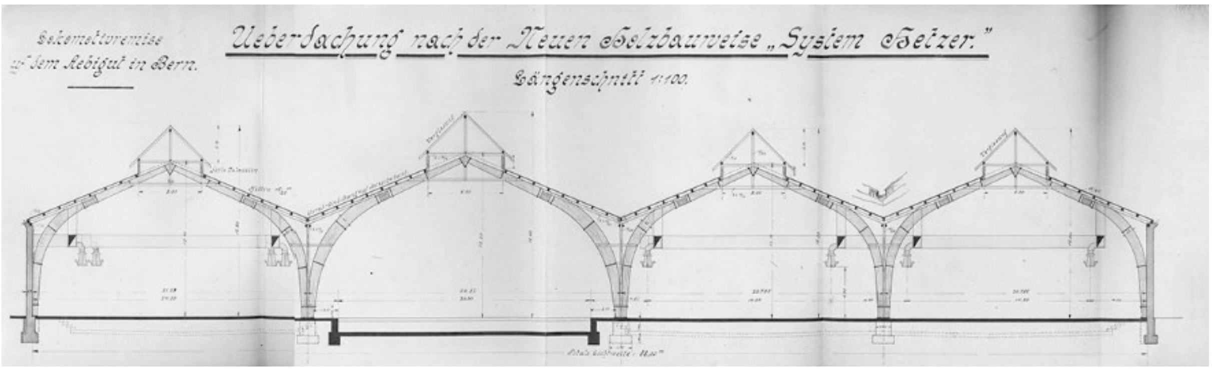


Fig. 10   glulam girders of four parallel halls of the locomotive depot, with the spans of 21.2 and 24.4 m.

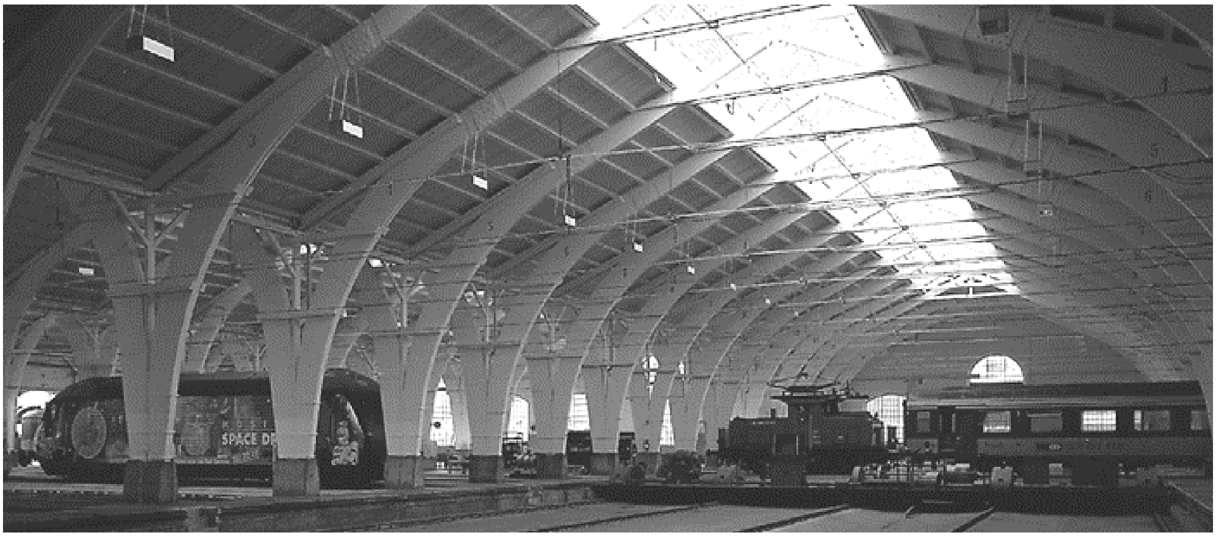


Fig. 11. Glulam structure of the locomotive depot in Bern, 1998. Due to the degraded condition of the structure, the glulam girders are now supported by wooden posts.

Analogously to the arches in the riding hall in St. Moritz, every glulam frame girder consists of two symmetrical parts forming a structural system similar to a three-hinged arch. Like for the arches there, the typical hinged connection at the apex and the base are very different: at the apex a traditional jointing technique is used where the two halves of the frame are put against a timber post, which is at its bottom standing on a collar tie connecting the frame parts. The upper part of the post extends into a skylight structure above the apex (Fig. 12).

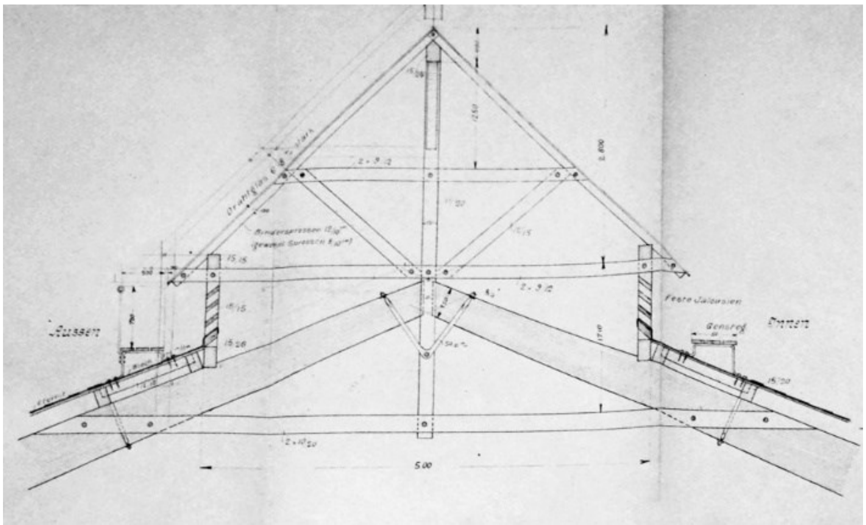


Fig. 12 Locomotive depot, Bern, apex detailing.

At the base, the frame girders are placed directly on the concrete footing and held by means of iron shoes made of L-shaped steel beams. Like in St. Moritz, every glulam component, i.e. both halves of the frame girder, consists of two segments meeting in a lapped scarf joint connected through bolts and steel plates on both sides of the girder making for a continuous stiffness of the glulam part. This joint could be related to transportation constraints since a full-length half-girder would have rendered a reasonable transport from fabrication to the construction site impossible (see Appendix 4.1). The choice of the location of the joint in the girder, and dimensioning of the girder have been made during the structural calculations.
In the following the static calculation of this structure done by the engineers Terner and Chopard will be traced (Figs 13-17).

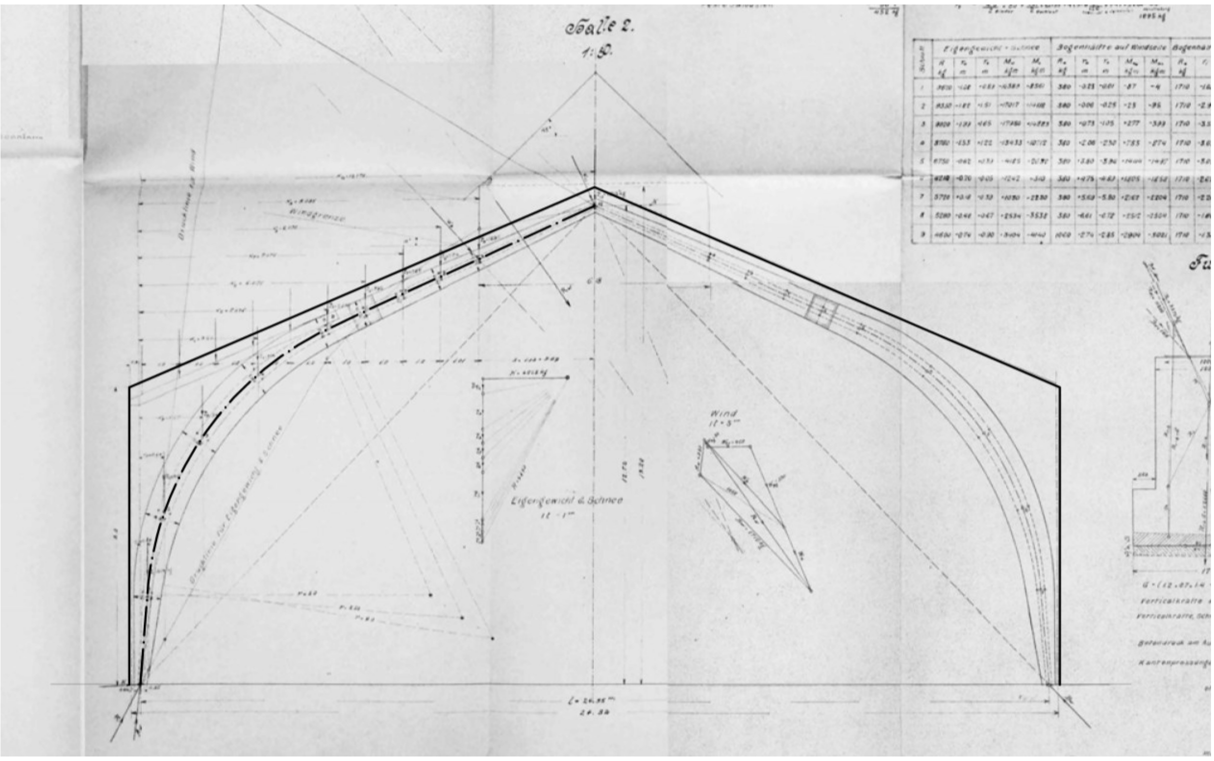


Fig. 13 step 1_ the client or the architect defined the roof outline, and the overall geometry and dimensions of the building. Based on this, the engineers could specify the axis of a girder that followed the roof shape.

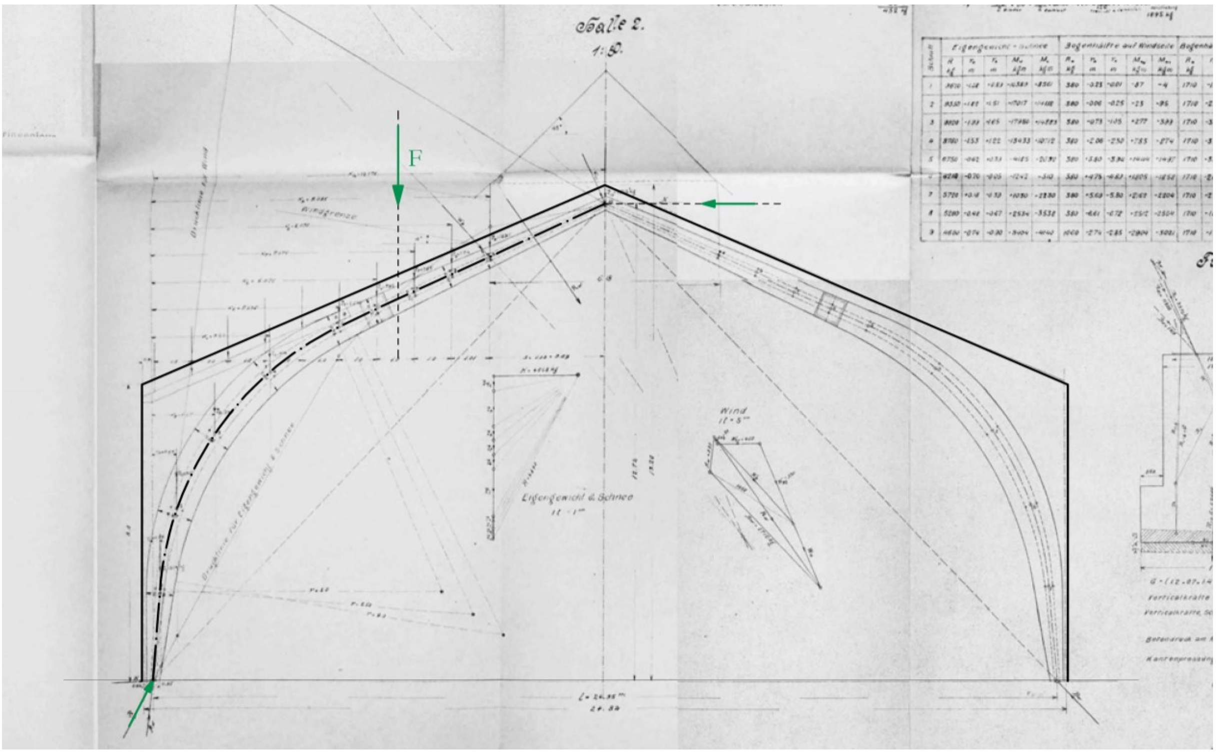


Fig. 14 step 2_ based on the resultant, resulting from the calculated dead and live loads of the asymmetrical load case for the roof, the reaction forces at the 2 ends of the half girders (apex and footing) can be determined.

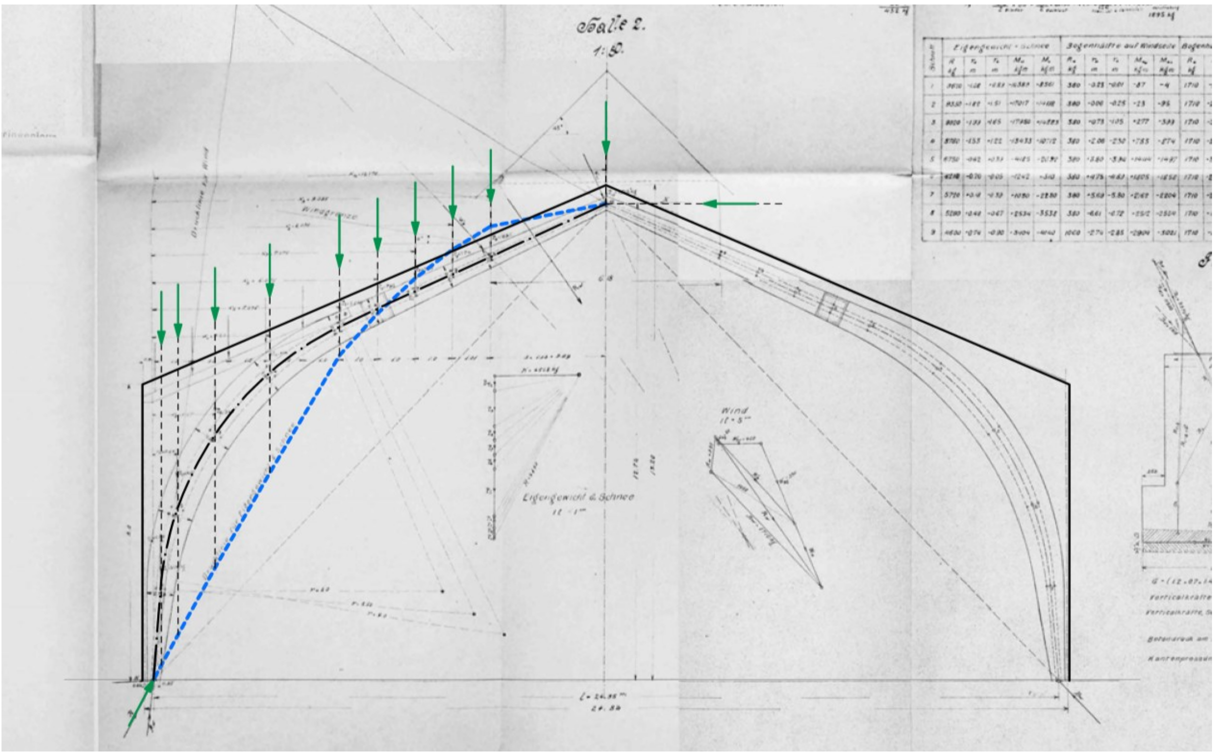


Fig. 15 step 3_starting from one of the determined reaction forces, the compression line can be developed, under the influence of the loads applied at the place of each purlin.

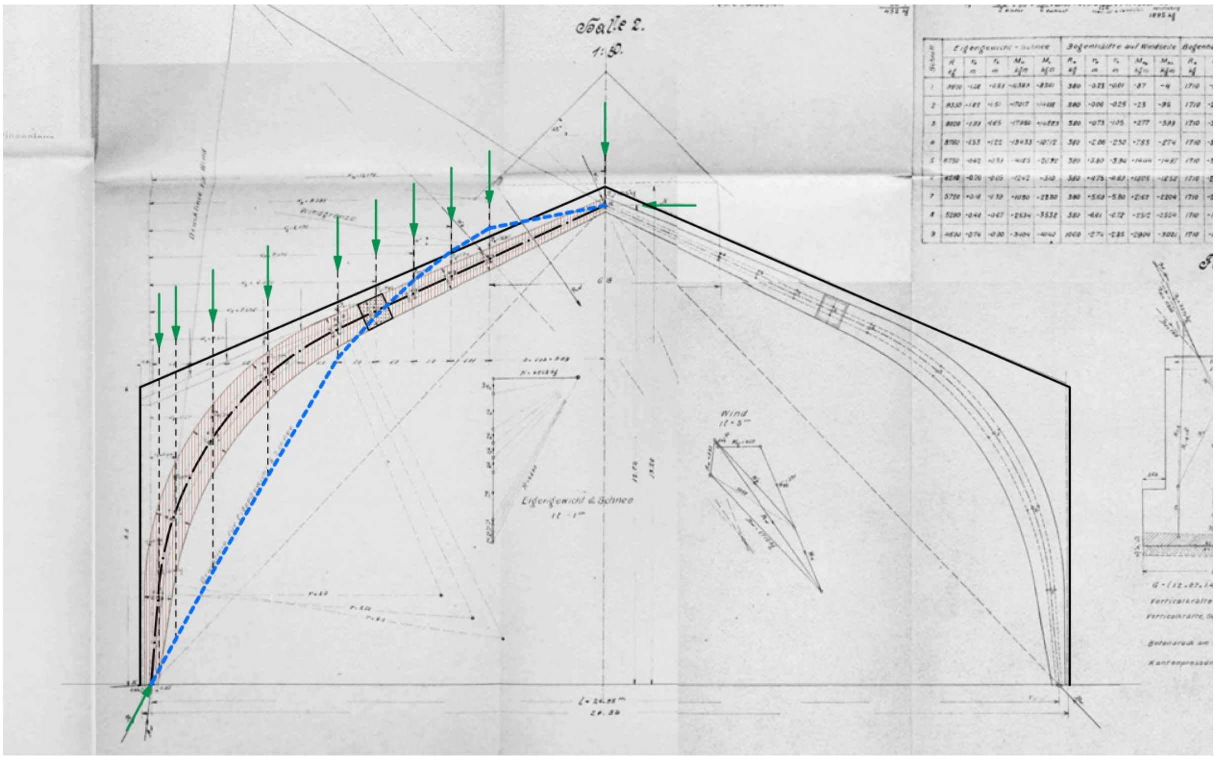


Fig. 16 step 4_the distance between the developed compression line and the axis of the girder does indicate the magnitude of the bending moment at a given point along the girder. The depth of the girders at any given point is proportional to the bending moment.

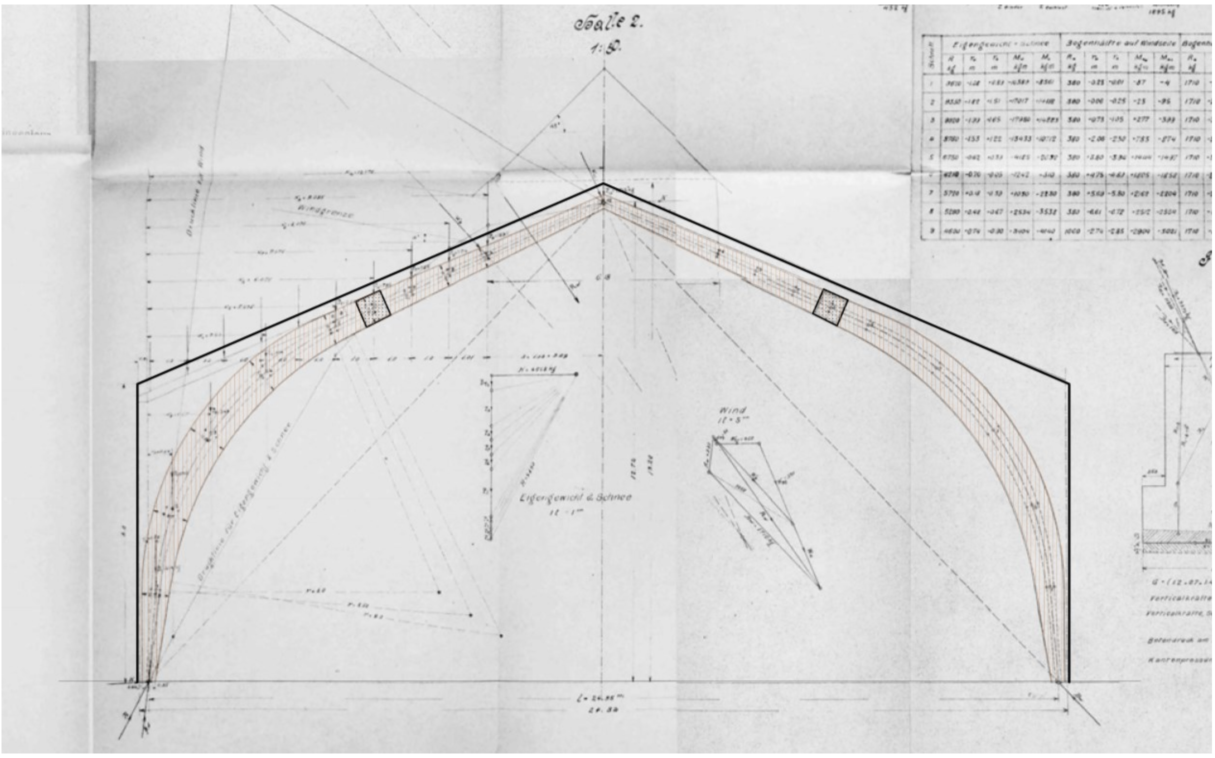


Fig. 17 Step 5_ at the point, where the compression line and the axis of the girder intersect, the bending moment is theoretically zero. The assembly joint, is consequently placed at this point.

The foundations originally were set to start just above the floor level where they received the lower ends of the frame girders. At this point, the timber elements were wrapped in metal sheets of one to two-millimetre thickness. Probably, this very unusual detail has been arranged to protect the foot points from the steam of the locomotives, which caused decay over time. (see Appendix 3.1).

1.3. The design practice of early glulam

There are two design levels that should be considered when examining the early applications of glulam technology. While the first level comprises the structural concept and model behind the design of the overall system, the second focuses on the constructional details of the parts, i.e. how the determined form is physically produced in the chosen material and how the components are connected. Reflecting on the design procedure of both the riding hall and the depot, it can be stated that the structural system used was independent of the new material. In both cases, a three-hinged arch was chosen as a basic model to determine the necessary resistance of the system according to the applied standard loads.
With a method of structural analysis that encompasses any material in principle, no additional assumptions or conditions regarding the new material have been noted in the context of the use of the structural model.[14] Given certain early assumptions and experiences of the limits of glulam,[15] the

[14] Rinke, Mario. “Wandel der strukturellen Form vom Konstrukt zum Typus im 18. und 19. Jahrhundert”. Phd Dissertation, ETH Zürich, 2013.
[15] “Die Hetzersche Holzbauweise”. *Schweizerische Bauzeitung*, vol. 57/58, no. 16, 1911, p. 217.

structural depth of the respective points was then determined and the final component shape developed. With the help of this model, also the exact location of the site joints was determined bringing together the estimated zone of minimum bending moments and suitable split of the structural part for transportation and assembling purposes. In addition to the determination of the site joints, also later adjustments to the structural functionality were set after an analysis based on this model. It can thus be noticed that the model for the structural design of the overall system and its components is similar to a standard modern engineering approach which discusses the structure regardless of the intended building material. This clearly reflects the design practice based on industrial building materials such as steel and reinforced concrete.

Regarding the second layer, it can now be looked at the constructional design decisions which have been made for the components. Both the glulam members of the riding hall and the depot have been designed and fabricated as curved parts with varying depth according the required resistance and with joints pragmatically arranged to comply transportation and assembling constrains. However, the cross section is different: While for the depot a compact form is chosen to allow for a minimal surface and easy plastering for fire protection, the glulam arches of the riding hall have a double-T beam section, apparently for the reduction of self-weight. The particular component shape, its varying depth and its specific cross section reflect the capacity of glulam as a new building material which allows to arrange the material purposefully where needed according to a higher understanding of the structural necessity, just as it was known from the typical steel design at that time.

Another important aspect of constructional design is the connection of the components. It has been found during the detailed look at the details of the two buildings in the earlier sections that the connections of the components are not based on a consistent design practice. If the structural modelling and the design of the overall system and the shape of its components can be linked to industrial materials like steel, what do the connections refer to? For both buildings the connection of the two glulam parts at the apex is part of traditional carpentry where the timber components run against another timber piece and the interfaces are specifically shaped to receive each other. The design of the girder frame footing hints to a concept outside timber construction. Here, the member is placed directly on the foundation clasped by an iron shoe which holds it in place. This decision refers to standard steel details of that time where a steel plate was attached at the end of the member and then placed on the concrete foundation (Figs 18-19).

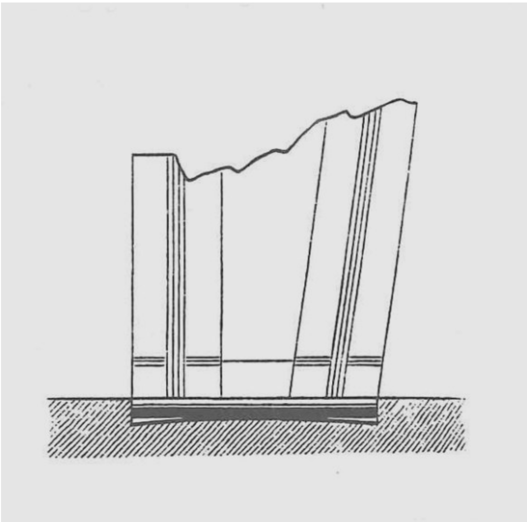


Fig. 18 Detail of a steel column connection to a concrete foundation by means of a slightly curved metal sheet to reproduce the hinge effect. (Königer, Otto, *Die Konstruktionen in Eisen,* 1902)
Fig. 19 Locomotive depot, Bern, footing detail in 2019 (after the intervention of 1928 discussed in the third chapter).

It was the simplest constructional form of a foot hinge; while allowing for a certain degree of rotation it also avoids stress concentration by placing the full depth of the member on the ground. The detailing of the site joint also reflects constructional thinking between the materials: While the two segments meet in a lapped scarf joint, a typical timber connection detail, they are actually connected and fixed through bolts and steel plates on both sides of the girder, representing a standard steel connection which was adopted early in the increasingly industrial timber construction during the second half of the 19th century.
It can be summarized that the design practice for both the overall structure and the specific constructional development is dominated by models and standards typical for industrial building materials such as steel.

The early glulam construction culture showed great pragmatism using the new technique of shaped wood compounds most directly to build large span arches and girders. The addition of pragmatic, singular solutions often led to a mix of traditional timber joints and modern steel connections. The connections used referred to different professional backgrounds. These three local construction details represent three different problems: timber-to-timber hinges at the top, timber-steel hinges (bottom), and timber-timber rigid joints (center, site joint).

It should however be noted that the early glulam structures were not limited to large-span halls. There were also small-scale projects within the early projects, which will be studied in the following. The design and construction of these structures met different problems than the large-span halls, and therefore different solutions were proposed.

2. Transforming the traditional timber roof

The present case study examines the process of applying the new glulam technology to the traditional roof scheme and its standard structural components.[16] Based on the planning process of a sports hall, which stands for a standard typology of early small-scale glulam construction, the introduction of glulam is driven by applying simple and successful patterns and radicalizing technical features through practical constructional considerations.

2.1. Early approaches of glulam application

Based on the leading idea of substituting a set of structural elements with a single piece and thus integrating the functionality of other elements in a precisely shaped glulam component, different approaches can be found at the same time of the first years of glulam in Switzerland. On the one hand, large structures such as depots and sports venues were conceptualized as modern three or two-hinged arches.

On the other hand, the application of glulam also took place on a scale of single parts of the structure. If a continuous open space was not necessary, this was most attractive choice, mainly for economic reasons.[17] This way, glulam rafters and purlins did not necessarily integrate a set of roof members in a single element but simply allowed for larger spans of these single components and thus for a larger scale of the overall structure.[18] These glulam structures, consequently, exhibit the same tectonic order and constructional configuration of their traditional predecessors but feature slightly different connections. Connections are often the most immediate manifestations of a constructional practice. Even if the industrial fabrication of the structural components is largely ruling their appearance, their connection is still driven by practical purposes and considerations of the construction site. It thus often embodies the scale and skilful handling of individuals, i.e. their knowledge of traditional craftsmanship and material techniques.

This adoption and transformation process is well documented for the Birsfelden structure and is now discussed in detail.

2.2. Guiding models of the Birsfelden hall

The municipality of Birsfelden, located near the river Rhein close to the city of Basel, decided to build a sports hall next to an existing school building in the Schulstrasse. The project proposed an ample

[16] This part of the chapter has been already partly published as Rinke, Mario, and Roshanak Haddadi. “Transforming the traditional timber roof – the sports hall in Birsfelden as an early glulam application in Switzerland.”. *Studies in the History of Services and Construction. Proceedings of the Seventh Conference of the Construction History Society,* edited by James Campbell et al., Cambridge, Construction History Society, 2020, pp. 665-678.

[17] Kaegi, Hans. “Industriebauten in Holz”. *Schweizer Holzbau*, edited by C. A. Schmidt, Zürich : Leipzig, Orell Füssli, 1936. p. 22

[18] A few early exeptions from the direct replacement of straight rafters are the warehouse furniture factory Aschbacher in Zurich and the hotel Beauregard in Lausanne from 1909.

space for various activities next to a changing room, toilets and storage space, above of which a gallery is located for spectators. The building is of a neo-classicist style, 36.2 m long and 14 m wide, providing an open space of 16 by 13 m for all kinds of sports activities (Fig. 20).

Fig. 20 Sports hall Birsfelden, ca 1920.

The original project envisaged a conventional roof structure for the steeply pitched gable roof with a hip. This structured consisted of a slender rafter roof with a pair of principal rafters connected by a split tie beam at their centre and additional diagonal struts meeting in a hanging post which is being held at its upper end by the rafters (Fig. 21). The raised tie beam was necessary to allow for the typical barrel roof which would extend the vertical space of the large sports room with a maximum height of 9 m at the centre.

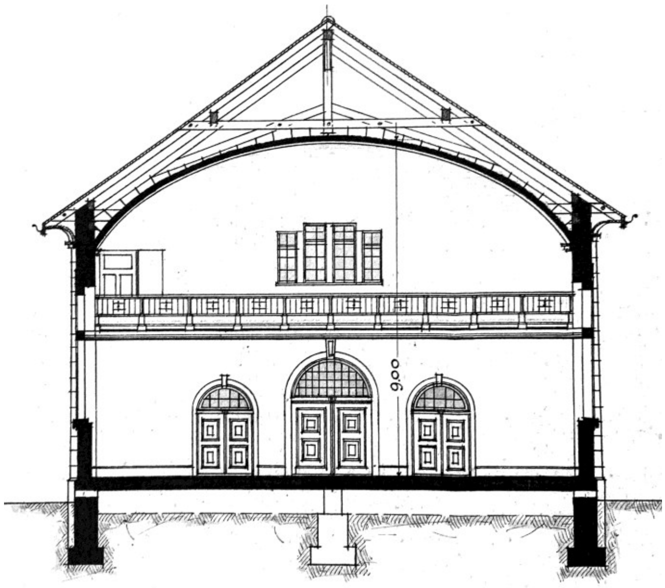


Fig.21 Sports hall Birsfelden, Conceptual design phase, Cross section.

The Birsfelden sports hall project falls into the time of the very early glulam applications in Switzerland. Nearly at the same time, in 1909, there was a similar sports hall just being finished in Altstetten, today a quarter of the city of Zurich. The Altstetten roof was an early glulam project developed by the young engineering office Terner & Chopard and became a model structure for the Birsfelden project. The engineering plan of the structure from 3 June 1909 (revised 5 August) is, together with a photo of the construction site, filed in the Birsfelden dossier at the state archive. Like in other projects, the timber roof of the Birsfelden project was probably changed later in the planning process, maybe even only during the tender process. The traditional roof was replaced mostly for economic reasons because the more compact structure meant fewer parts to lift and place and fewer connections to be worked by the carpenter. In the Altstetten roof glulam was only used for the principal rafters. The span of the structure was nearly the same for all of them: while the Altstetten roof had a clear span 12.40 m, Birsfelden roof was 13.00 m wide. Unlike the Birsfelden roof, although comparable in building size and typology, the Altstetten roof structure consists of a pair of glulam rafters which are tied together by two horizontal pairs of beams. One of which is placed at the lower third marking the ceiling of the ample open space and one at the upper third in the enclosed roof space (Fig. 22).

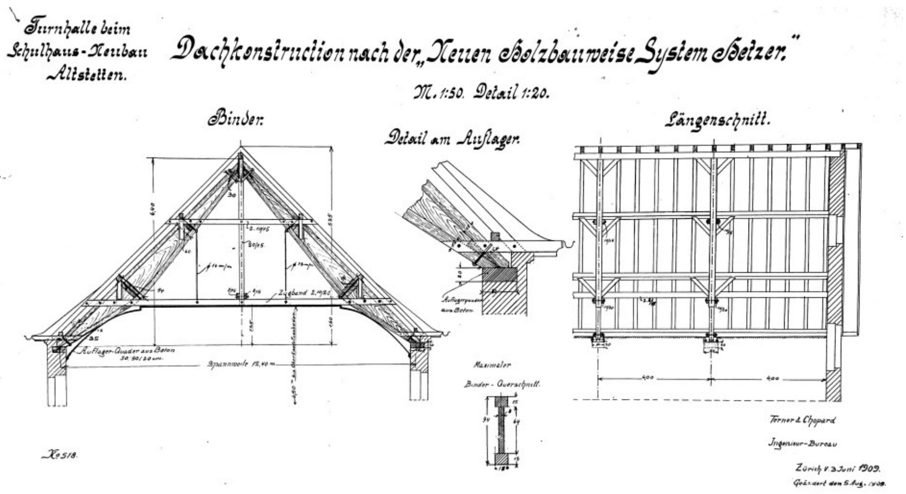


Fig. 22 Reference project sports hall in Altstetten, Terner & Chopard, 1909.

The glulam rafters are placed every 4 meters. They feature a precisely defined, asymmetric parabolic shape with a depth varying between 35 cm at the supports above the walls or the top and 94 cm towards its centre. The exact maximum is reached where the ceiling meets the rafters, thus reflecting the actual load distribution resulting in a precisely manufactured resistance of the glulam component. In the Altstetten roof structure, there were four beams placed on the glulam rafters, one inferior purlin at the lower end, one ridge beam at the top and two purlins equally distributed. These simple solid wood beams are of small dimensions (15/20 cm) to span the 4m between the rafters. At the two locations, where the purlins are placed on the rafter, an additional wooden board is placed on both sides of the girder web of the rafter, reinforcing it for the concentrated load according to the early practice of glulam. Just like in the traditional roof model, the glulam rafters in Altstetten are resting on massive prefabricated concrete blocks (50/50/20 cm) which are placed on the top of the masonry walls. The Altstetten roof structure was executed as planned by the engineers. Figure 23 shows the construction site with all glulam girders and purlins in place.

Fig. 23 Construction site of the sports hall in Altstetten, 1909.

2.3. The evolution of the Birsfelden project

For the roof structure of the sports hall in Birsfelden, the engineers Terner & Chopard adopted the Altstetten scheme very directly. A plan from 20 July 1910 shows the same configuration of roof components: pairs of glulam principal rafters tied together by a pair of horizontal beams at the lower third and purlins directly placed on the rafters (Fig. 24).

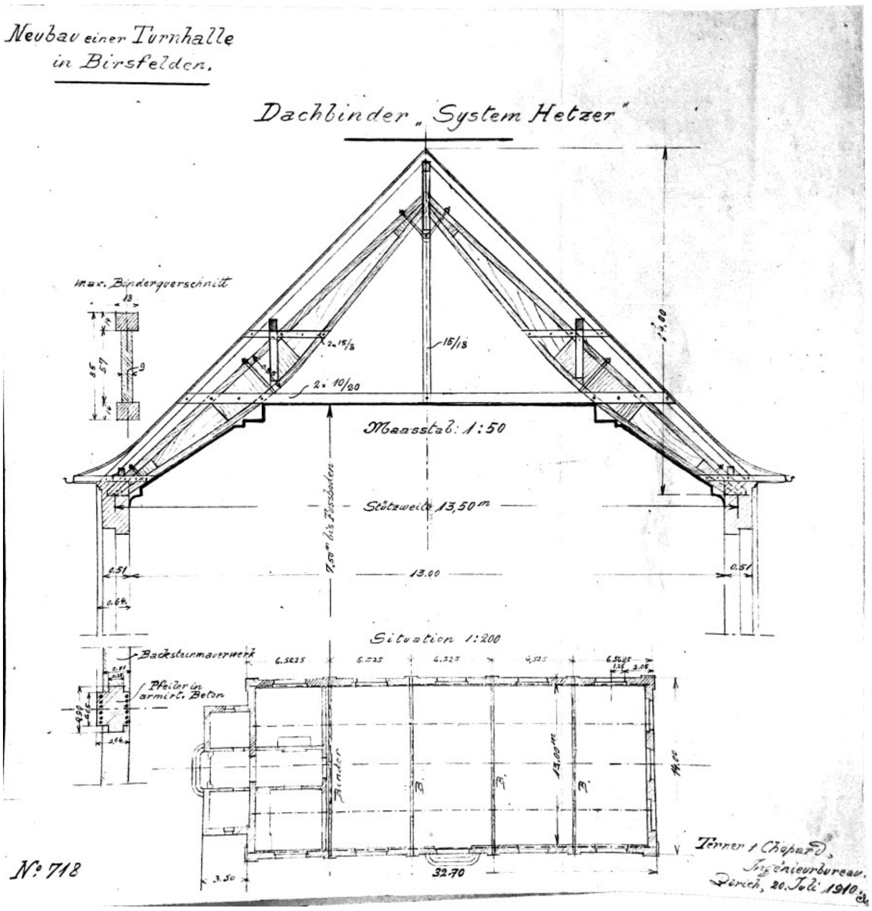


Fig.24 Project for the roof structure of the sports hall Birsfelden, Terner & Chopard, 1910.

However, there were considerable changes in proposed for Birsfelden. According to the window pattern given by the architect, the girders were placed with a distance of 6.52 m. Although the span of

the purlins was largely increased (63%), they were reduced in numbers from 4 to 3 with only one in the middle of the rafter. The maximum depth of the glulam rafters was reduced to 85 cm (10%) while keeping the same width of 18 cm. As the tie beam was raised in the Altstetten roof to one-third of the girder height, there might have been problems at the top of the masonry walls taking the resulting thrust. For the Birsfelden project, Terner & Chopard chose to integrate concrete buttresses into the masonry wall keeping its thickness of 50 cm.
As usual, the glulam construction was always carried out by one of the licensed carpenter firms. For the Birsfelden project, the carpenter in charge was the Basel-based Riesterer-Asmus. Just a week after the engineers issued their design proposal, Riesterer-Asmus delivered their construction plan on 28 July 1910 (Fig. 25).

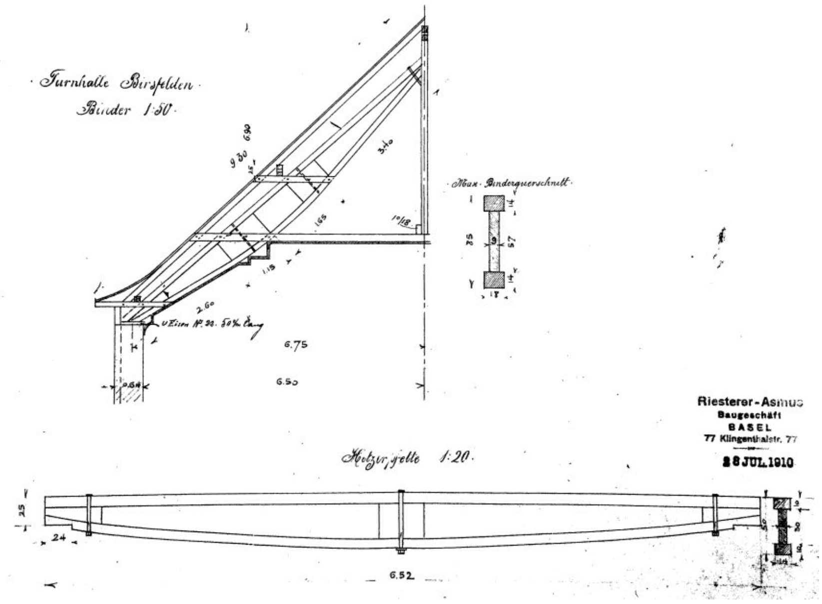


Fig. 25 Proposal from the contractor responding to project from Terner & Chopard, 1910.

Here the design of the roof structure was taken of a step further: most of the solid timber purlins were replaced by glulam components, all except the inferior purlin. Similar to the girders, the new glulam purlins varied in depth from 25 cm at the support to 50 cm at their centre featuring a parabolic shape. They were reinforced with additional timber plates on both sides of the girder web and tied vertically with steel stirrup at both ends and the centre. As the new purlins were specifically designed to start and end at the girders, they also feature detailed support areas so that the two purlins meeting can be precisely placed on the support beam fixed at both sides of the principal rafter. The purlins are connected by a simple mortise and tenon joint (Fig. 26).

Fig. 26 Sports hall Birsfelden, detail of the purlin support, 2019.

Another late alteration of the project was the footing detail of the rafters. While the Altstetten rafters were simply put on concrete blocks, the contractor of the Birsfelden roof proposed steel U-profiles to help to receive the rafter footings and holding them in place.
This revised project was executed like a photo of the construction site shows in figure 27. All the principal rafters and purlins are in place as are the rafters on the far side.

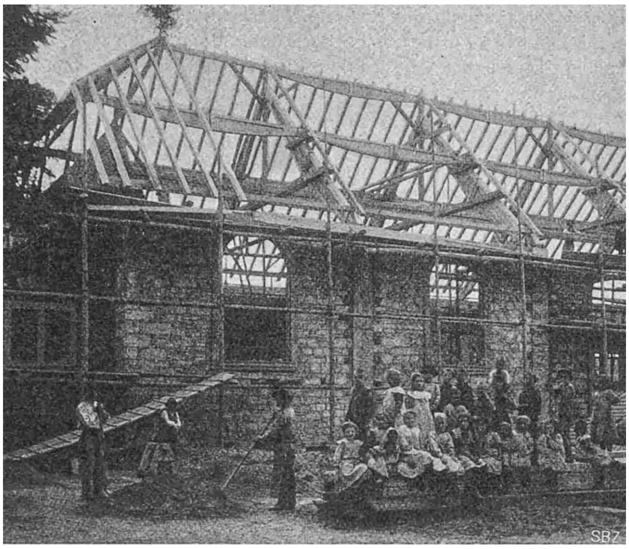


Fig. 27 Construction site of the sports hall Birsfelden, 1911.

The roof is now, 112 years after its construction, still in good shape, and all members of the structure are in place (Fig. 28). Only a few spots with delamination effects have been detected.
An additional structural element has been added next to the central purlin (Fig. 29). Probably to reinforce supporting structure for the ceiling of the sports hall, an additional cross-beam was added which is supported by a steel rod fixed to a pair of struts which is attached to the principal rafters. All these elements appear to be installed at the same time as the rest of the roof structure but might also be added later when there were some repairing works carried out. The thrust of free rafter ends must have caused some problems as there are now new steel bars added to tie both ends together at all pairs of rafters.

Fig. 28 Sports hall Birsfelden, view into the roof, 2019.

Fig. 29 Sports hall Birsfelden, detail of the purlin, 2019.

Although the engineers designed the overall configuration of the timber roof and specifically the new glulam components, they specified only very few details. Most of the actual timber connections seem to have been left to the contractor. Like in other early glulam projects, where construction plans of the contractor have been found, the explicit connection details are not given in the planning documents of Riesterer-Asmus. The not specified timber connections are standard carpentry details and are part of the contemporary construction practice. The rafters, for instance, do not meet directly but are placed against the hanging column and attached to that by iron clamps (similar to the steel stirrups of the standard glulam beams), as it can be seen in figure 30. The resulting construction details are – typically for the early glulam period – somewhat inconsistent as they are partly based on precise standard steel connections of engineering structures and partly on traditional timber connections based on contemporary modern craftsmanship. This ambiguous construction language seems to be the same for smaller-scale roof structures, such as the Birsfelden sports hall, or large-scale structures such as the tram or train depots form the same time.

Fig. 30 Sports hall Birsfelden, detail of the hanging post and rafter top, 2019.

2.4. Conclusion

The early glulam structures in Switzerland show mainly two different constructional approaches. One is based on engineering models of two or three-hinged arches developing structural forms responding to the architectural form of the space or an optimized parabolic shape which is applied to large-scale structures. The other starts from traditional roof structure configurations and seeks to replace single components for better performance or a better construction process which is mostly applied to smaller-scaled structures such as housing projects, churches or moderately sized sports halls. This representative project demonstrates the path from the starting point, when a conventional scissor braced rafter roof was proposed, to the final construction using precisely defined, engineered glulam rafters and purlins. It can be followed how the engineers roughly defined those parts of the structure where the new construction method of glue-laminated timber was applied, and other conventional parts were left undetailed and to be specified by the contractor.

The design steps presented show a radicalization of the use of glulam in the traditional roof structure. While very early glulam projects, such as the Romanshorn church or the sports hall in Altstetten, only use glulam components for their main parts like the principal rafters, the Birsfelden project shows how the glulam application is extended to more parts like the purlins.[19] As the roof structure is not visible to the interior of the hall and is thus in no way an architectural feature, and the carpentry work is tendered like any other part of the building, the increasing use of glulam must be clearly for economic reasons. Often, builders claim the shorter construction time as the main advantage of conventional structures. Interestingly, there seem to be considerably more early projects of simple glulam

[19] Charles Chopard clearly places the new engineered timber in the line with “centuries of achievements and experiences” which is why it should develop further from traditional concepts. Chopard, Charles. “Neuzeitliche Ingenieurholzbauten”. *Schweizer Holzbau*, edited by C. A. Schmidt, Zürich : Leipzig, Orell Füssli, 1936. p. 24.

replacements of single components in Switzerland than at the same time in Germany from where the glulam technology and early construction techniques were taken over.[20]

The few case studies analysed above discussed the dominant solutions proposed by the engineers and the contractors, for a hybrid use of structural timber and glulam within a structure, or the replacement of structural timber by glulam in large-scale projects. It also demonstrated that the connections of the components do not appear to be based on a consistent design practice, and a combination of craft-design and engineering-design of the connection details could be observed. The development of fully-engineered construction details seems to have found its first peak with the design and construction of the tram depot in Basel in 1916, which will be studied in the following part.

3. Mechanization of constructional design

3.1. Design brief and building characteristics

For the growing tram network in Basel, a third depot was needed. [21] A maximum of depot space for the tram wagons plus buildings for offices and apartments was asked for in the design brief.[22] The layout of the depot space should allow for a good overview of the space, and, in particular, the layout of the rail tracks would make possible the switching of the wagons indoors (Fig. 31).

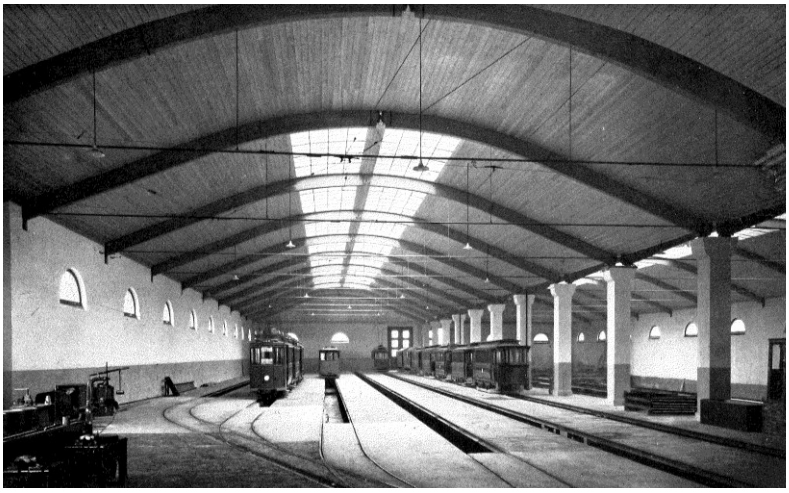


Fig. 31 Tram depot, Basel, interior space, 1918.

[20] In a broad research on the early Hetzer constructions in Germany, this type is rarely mentioned. Müller, Christian. Die Entwicklung des Holzleimbaues unter besonder Berücksichtigung der Erfindungen Otto Hetzer- ein Beitrag zu Geschichte der Bautechnik. PhD dissertation, Bauhaus-Universität Weimar, 1998.

[21] This part of the chapter has been already partly published as Rinke, Mario. "Mechanization and early hybrid material use in glulam construction – The tram depot in Basel from 1916". *Studies in the History of Services and Construction. Proceedings of the Sixth Conference of the Construction History Society,* edited by James Campbell et al., Cambridge, Construction History Society, 2019, pp. 651-660.

[22] "Strassenbahn-Depot auf dem "Dreispitz" in Basel". Schweizerische Bauzeitung, vol. 71/72, no. 14, 1918, pp. 154, 158. For more about the projects see: Birkner, OtHmar, and Hanspeter Rebsamen. " Basel ". *INSA: Inventar der neueren Schweizer Architektur, 1850-1920.* Zürich, Bern, Orell Füssli, Gesellschaft für schweizerische Kunstgeschichte, 1986, Pp. 186-187.

The overall project management and the exterior of the buildings were in the hands of the renowned architect Hans Bernoulli (1876-1959) from the Basler Baugesellschaft, later professor for urban design at ETH Zurich, whereas the interior design and the constructional detailing were in the responsibility of Karl Leisinger (1864- 1929), architect and building inspector for the city of Basel.

3.2. Design contributions and development

Leisinger specified the architectural layout and all dimensions of the building components in his drawings from July 1915. He detailed the exterior walls, the internal columns, roof and the floor system, where the rail tracks for the trams would be placed (Fig. 32). For the roof, he indicated the glulam arches with an initial geometry of a shallow parabolic arch. In fact, the precise dimensions for both the glulam components and the columns were not given and had to be determined by the engineers and the contractor. Also, there were no details given for the roof structure of how the arch should be connected to the wall and the internal column and, if it would be a typical arch system, of which parts it would comprise.

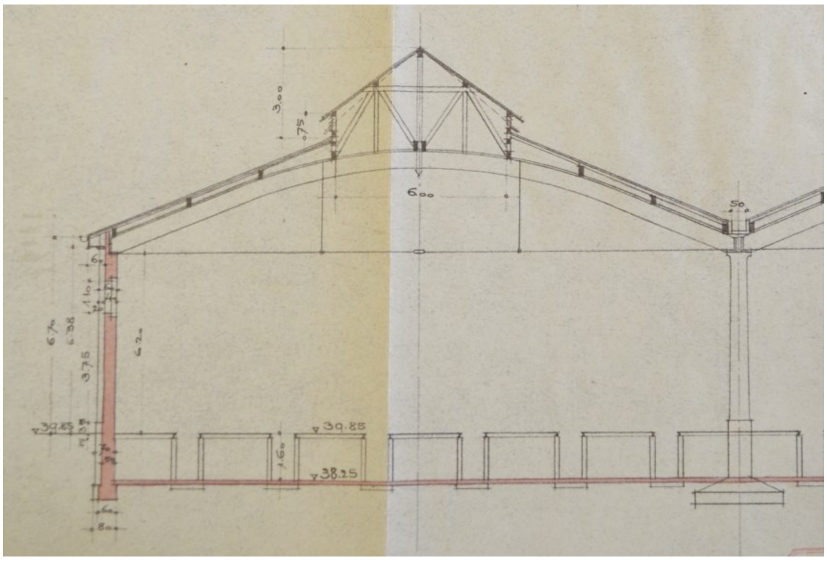


Fig. 32 Architect’s plan with the initial geometry.

The final dimensions of the timber arches and the columns were provided in August 1915 by the engineers. By defining all structural parts and details of the building, it turned out that the structural concept of the roof arches would rule all other parts. To achieve maximum control of the structural performance, the roof structure was developed as three hinged arches with a tie between the bottom hinges to eliminate the thrust from the arch action. The fixed bearings are placed on the columns in the central axis of the depot while the bearings allowing translational movements are located on the exterior walls. Walls and columns are around 6m high. Consequently, the walls only take vertical loads and are very thin with 50cm (buttresses 70 cm including the wall) made of brick (Fig. 33). The concrete column is 70 cm deep and made of reinforced concrete taking the wind loads on the roof alone. While the structural engineers Terner and Chopard were in charge of the concrete columns, the glulam arches were designed by the early glulam consortium, partly controlled by Terner & Chopard.

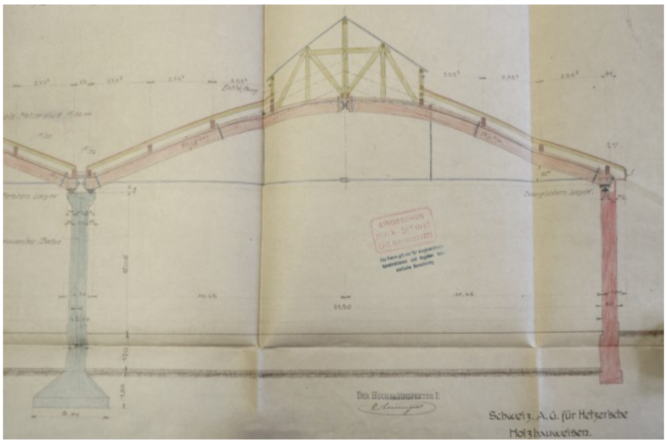


Fig. 33 Specifications of structural components, Schweiz. A.G. für Hetzer'sche Holzkonstruktionen.

3.3. The design of the glulam arches

The glulam arches were, given the greater portion of the project documentation and the reports in the journals, the main feature and the most innovative part of the building structure. They were placed with a regular spacing of 7 m. The primary goal, as the engineers noted in their report, was to have the best possible structural performance of the roof structure. For that goal, the roof itself was to be most evenly distributed using the lightest skylight structure. What follows is the parabolic shape following the thrust line which works, together with the rod connecting the two base points of the arch, as a tied-arch like for a bridge. Accordingly, the springing is a straight line for about a fourth of the total span and then curves to make the parabolic shape. In this way, the arch rises 3. 2 m with a total span of 21.3 m (Fig. 34).

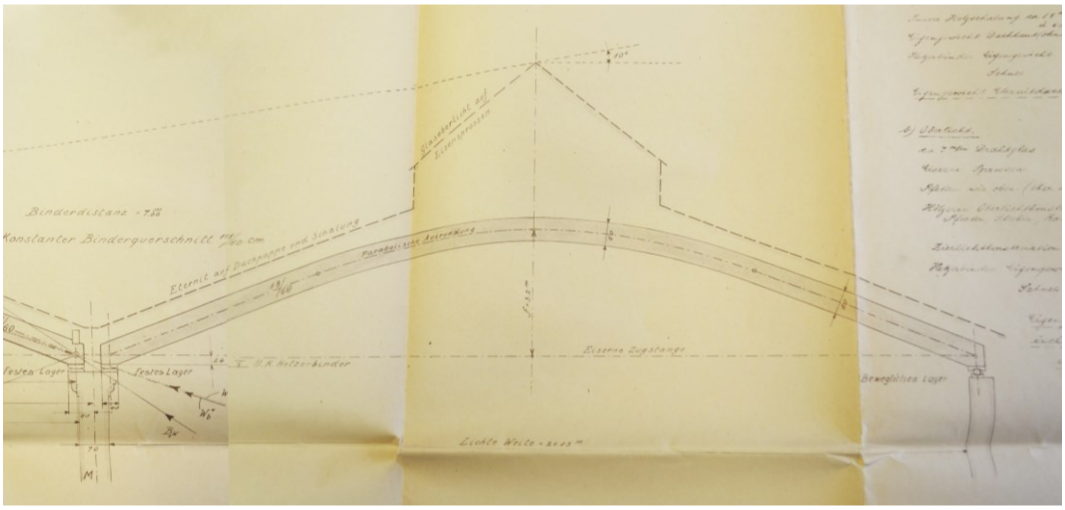


Fig. 34 Geometry development, Schweiz. A.G. für Hetzer'sche Holzkonstruktionen.

After defining the permanent loads from the structure and all parts of the roof (72 kg/m2 regular, skylight 85 kg/m2), the wind loads (28 kg/m2, skylight 59 kg/m2) and the snow loads (80 kg/m2), the resulting inner forces were calculated using graphic statics. From different basic load combinations, such as permanent load and snow ("g+s") as well as those together with the wind (from each side), the resulting thrust lines were drawn next to each other. The thrust line of the permanent loads together with snow almost remains within the given permanent cross section of the material and thus seems to be a design criterion, while the maximum distance of the thrust line resulting from all loads is marked to measure the maximum resulting stresses in the glulam components (Fig. 35).

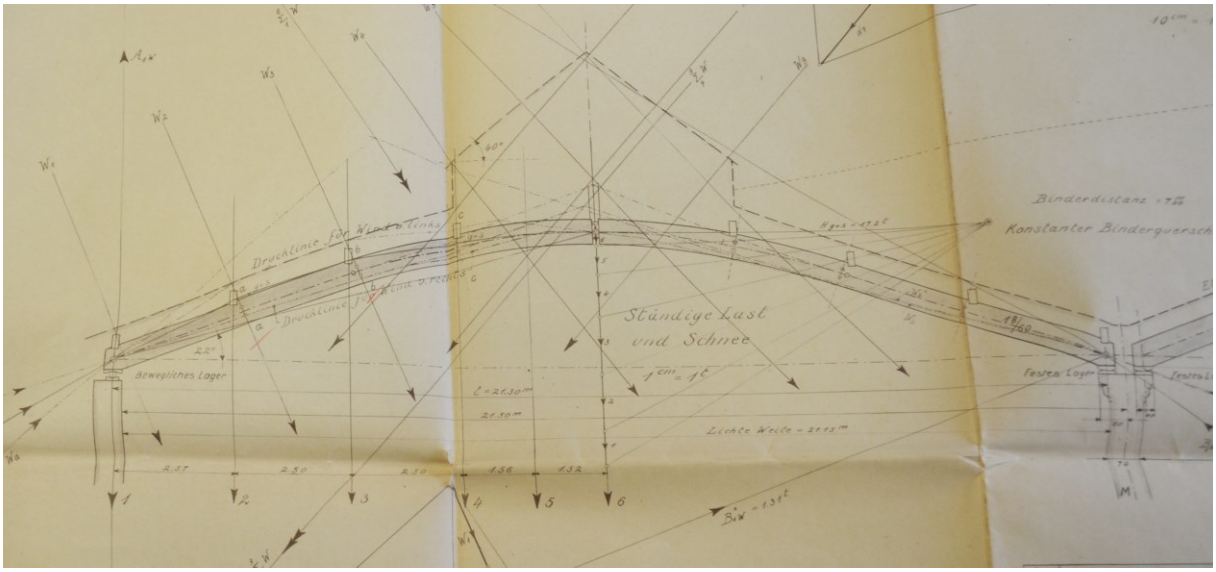


Fig. 35 Calculation based on graphic statics, Schweiz. A.G. für Hetzer'sche Holzkonstruktionen.

The calculations were done using graphic statics, similar to the case of the locomotive depot in Bern, discussed earlier. In the calculation, which measures the distance of the compression line of the arches from the central axis of the initial geometry in a few given points to determine the bending stresses, the maximum values turned out to be 94 kg/cm2 in compression and 56 kg/cm2 in tension for a constant cross-section of 18 by 60 cm. Since there was no existing code for timber construction before 1925, the stress limitation of 90 kg/cm2 for perpendicular and 110 kg/cm2 for skew forces was taken from the guidelines of the railway department. The purlins, which are not visible because of the wooden sheeting attached at them from below, are also made of glulam which allowed a span of 7 m measuring 15 by 32 cm.

The Swiss railway authorities, who had already gained experience with glulam with their different projects, reviewed the construction drawings and calculations from the engineers, submitted 31 August 1915. They required a specific arrangement in the lamination of the glulam arches. As the chief engineer Kiefer reported in his letter to the building authorities of the city of Basel, the three outermost lamellae at the bottom of the glulam arch had to be free from knots, with no joints in the lamellae in the half of the arch segment next to the support. The glulam arches had to be fabricated in such a way that they provided a camber of 3 cm when put in place. Furthermore, the authorities required information on the place and the time of the glulam fabrication to allow for their inspection. This detailed review process and the specific requirements demonstrate how limited was the trust in the technology.

3.4. The mechanical control of the structural performance

The thrust with a total of about 20 tons was to be taken by an iron rod with a diameter of 46mm which was connected with the glulam arch through an iron plate at the back side of the footing, just where the projected horizontal line of the iron rod met the thrust line of the glulam arch. What is particularly new in the constructional detailing of the Basle depot are the mechanical parts for the connection of the glulam arches, both the two halves with each other and to the supports. Not only is the shape of the glulam components themselves based on the regime of structural form ensuring maximum control of the internal forces. The iron bearings are borrowed from contemporary steel bridge design using the hinges from the three-hinged arch concept and, at the same time, specifically allowing the movement of the footing resulting from structural action of the components, i.e. the elongation of the rod, and to control where exactly the horizontal load should be transferred to the supporting structure. Accordingly, there are movable bearings on the exterior walls to only transfer vertical loads and fixed bearings on the interior concrete columns.

These bearings are designed to precisely control these movements in the most standard manner: the movable bearings consist of an upper plate (65mm thick) screwed to the bottom surface of the glulam arch, a lower plate (50 mm thick) fixed to the wall through a spike and a solid cylinder in between them, all of cast iron; the fixed bearings feature similar iron plates which are connected through a notch in the lower plate. (Fig. 36) The crown hinge is made of two iron plates, each inserted into the upper end of the glulam components and touching in their centre where a bolt transfers any vertical forces.

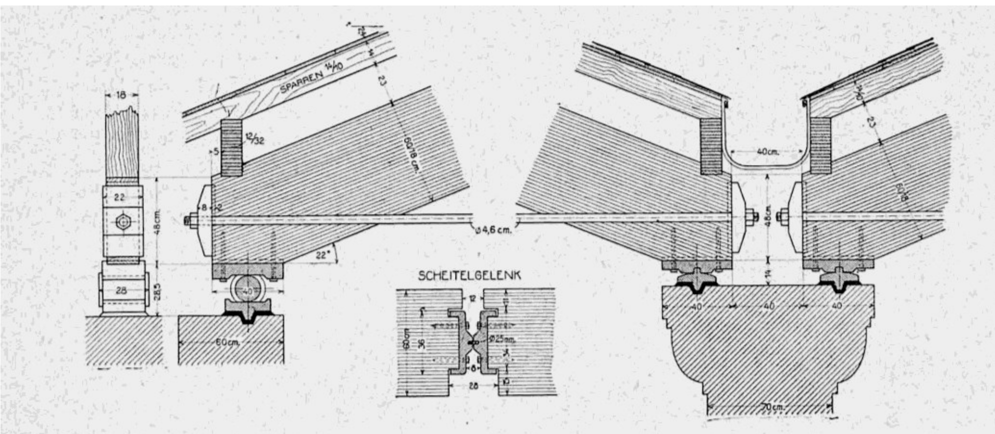


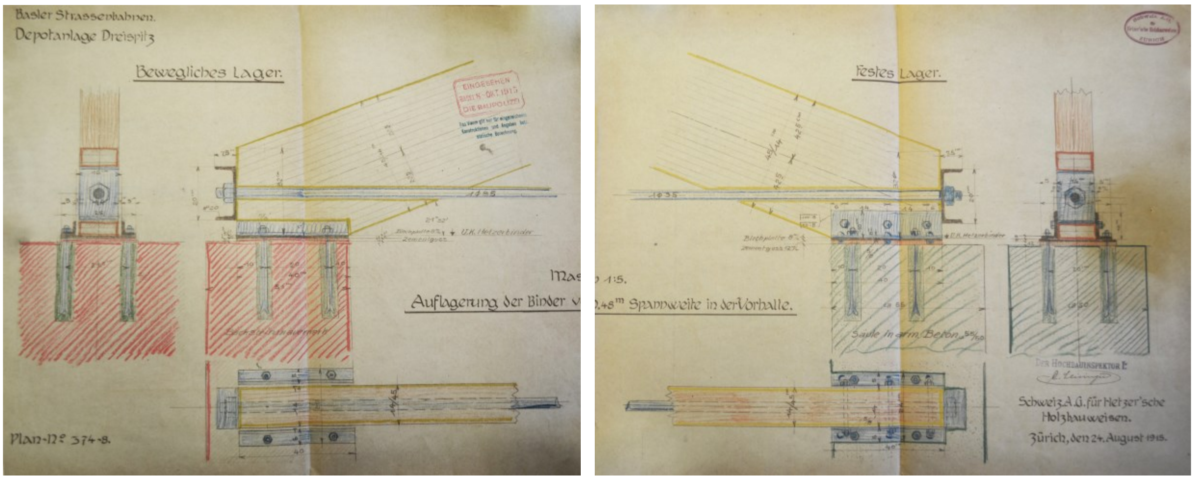
Fig. 36 Fixed and moveable bearings.

In this adoption of mechanical devices, such as conventional steel connections or bridge bearings, each has been used most directly and independently of each other. Although the iron hinges, both the roller and rocker bearings as well as the crown hinge, are consistent and refer to the same language and reflect the well-engineered precision and constructability of steel structures at that time, they are not including the connection of the iron rod to the footings of the glulam arches. The detailing of these connections, letting the iron rod go through the timber and have it pushed through an iron plate from the back, uses a common timber construction practice avoiding the introduction of concentrated tension forces by translating them into compression. The single disconnected measures, the tied arch footings using a horizontal iron rod and the iron bearings transferring the support forces to the members below and ensuring the defined boundary conditions of the system, thus refer to different constructional material worlds and refer to different times when they were introduced into the design of glulam structures. Iron rods had often been used many times before in the first design concepts of glulam structures, others were added later to improve the structural performance, such as for the riding all in St. Moritz where the iron rod was introduced a few years later. The bearings, however, are used here for the first time, and since they are borrowed from an existing construction practice and directly applied to the glulam structure, they have obviously not been modified to accommodate the existing practice of horizontal bracing for glulam arches.

What can also be observed in the project of the tram depot in Basel, is the different locations of the arch footings in relation to the overall interior space. Unlike previous glulam structures, the arches do not come down to the floor level of the building but rest on the walls and columns. Apart from architectural considerations, this might have been a consequence of damage observed in earlier structures where some of the footings were subject to decay, as was the case for both the riding arena in St. Moritz (1910) and the locomotive depot in Bern (1912). There seems to have been a tendency to lift the footings in subsequent projects.

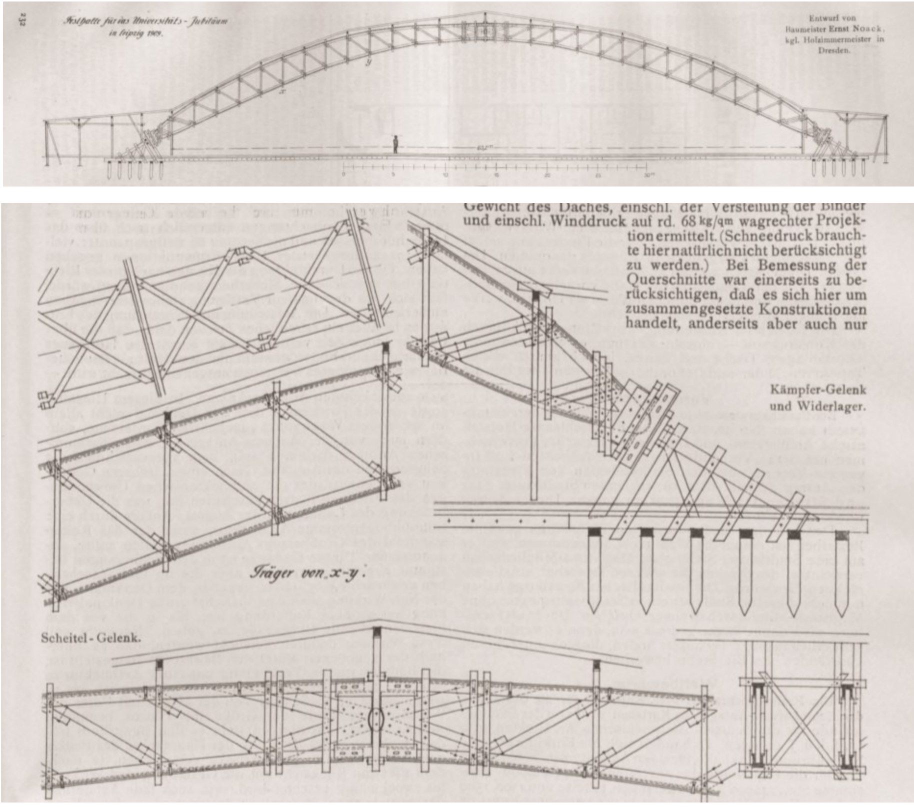
3.5. Alternative bearings for shorter spans

Although the building structure provides a great regularity, the use of elaborated iron bearings does not apply to the entire structure. For the shorter spans, such as for those in the narrow entrance area measuring only 10.48 m, which is half of the regular span, a different constructional concept was used for the bearings. Very similar to the standard connection details of earlier glulam projects, the glulam components are held in place by regular L-shaped steel profiles (50/ 100 mm); the iron rod is connected to a U-shaped profile (200/75 mm). For the movable bearing, an additional steel plate (8 mm) has been used between the support and the timber to allow free sliding. As a consequence, the fixed points of the supports are carried by reinforced concrete columns which are implemented in the brick walls. (Figs 37-38)



Figs 37-37 Fixed and movable bearings for shorter spans.

The Basel depot is a significant example of the early glulam development, not only in Switzerland but in general. Beyond its recognition as an extraordinary case of industrial architecture that has been published and celebrated nationally and internationally, it represents a turning point in the formation process of modern timber engineering, although the idea of the introduction of iron hinges into timber structures was not initiated by this project. From several examples of previous attempts, the project of the festival hall in Leipzig can be mentioned, although it was never built. To celebrate the university anniversary in 1909, a series of 3-hinged girders with a span of 68m was designed. The timber truss-girder was connected together and to the base of the arches by means of iron hinges. The project was designed by Ernst Noack, the Court Master Carpenter in Dresden (Figs 39-40).



Figs 39-40 The overall structure, and the details of the hinges at the base and at the apex.

Although there were some doubts over the “sufficient safety” that the formation of the joints in this way could offer, mainly due to the unclarity of path of the structural forces, the project was welcomed by the technical journals of the time, which encouraged the use of structural timber for long-span projects.[23]

The glulam structure of the tram depot in Basel addressed the raised doubts, and could propose a solution where the structure performed in a controlled and technically refined way.
While in the first glulam applications the design focussed on the precise articulation of the members making use of the new technology to variably adjusting the cross-section, the form decisions were driven by looking at the ideal path of the structural forces, i.e. the parabolic shape, which was then directly translated into glulam components with a regular cross-section. But not only is the shape of the glulam components themselves based on the regime of structural form ensuring maximum control of the internal forces but also there are iron devices used for each of the three hinges of the arch, borrowed from contemporary steel bridge design. This way, they control precisely which forces would be transferred to the supporting structure. What is thus entirely different from earlier glulam structures designed by Terner and Chopard, or the early glulam consortium respectively, is the constructional clarity. No site joints, no improvised footings, no integration of other functional elements in the structural system, such as the skylight. The tram depot in Basel from 1916 is a significant example for

[23] "Entwurf zu einem freitragenden Hallendach in Holzkonstruktion von rd. 68m Stützweite”. *Deutsche Bauzeitung,* vol. 43, no. 35, 1909, pp. 229-236.

consistent hybrid material use in glulam construction and for the mechanisation of constructional design.

Reflecting upon the design procedure including all documented steps in the calculation, the method used was a material independent, universal mechanical approach. It was a straight-forward design procedure used for wrought iron and steel structures throughout the late 19th century. Only in the moment when the stress limits were compared with the actual stresses, a specific construction material was chosen and glulam entered the equation. However, the calculations were based on the assumption of using a homogeneous, isotropic material since there was no allowance for the local directions of stresses in the material or such considerations as possible delamination effects where shear stresses occur or stress peaks in the area of the connections. It can be concluded, that the schematic structural system, comprising its geometry and boundary conditions, was used as a predominating construction idea, and the construction material glulam was projected onto this system by 'making the geometry', i.e. bringing its components into the given shape, and using the iron parts as mechanical devices to fulfil the boundary conditions.

4. On-site processes: limitations and opportunities

4.1. Practices and limits

Although glulam had a high standard of quality in its fabrication, there were hardly any standards or an established practice for its actual construction on site. Assembly and fastening, both in combination with other materials and between glulam and small-format timbers, had to be figured out in the first practical applications. Using the scale of steel girders handled by a traditionally run carpenter practice crossed lines of existing responsibilities and competences of various players, as it was discussed briefly at the end of the second chapter. The coexistence of timber technologies with different stages of industrialization brought new aspects of organisation in design and construction. The actual preparation, pre-fabrication, putting-in-place and on-site fabrication will now be discussed in following part. It will, therefore, first be looked at the construction practice and industrialized processes with large-scale structures and, subsequently, compare this practice with small-scale application in roof structures. Eventually, the discussed developments and tendencies will then be placed in a larger context. [24]

[24] This part of the chapter has been already partly published as Rinke, Mario, and Roshanak Haddadi. "Industrialising timber craftsmanship: Early glulam within the traditional timber construction in Switzerland". *History of Construction Cultures. Proceedings of the Seventh International Congress on Construction History, Lisbon, Portugal, 12–16 July 2021,* edited by Joao Mascarenhas-Mateus and Ana Paula Pires, Taylor & Francis, 2021, pp. 502-508.

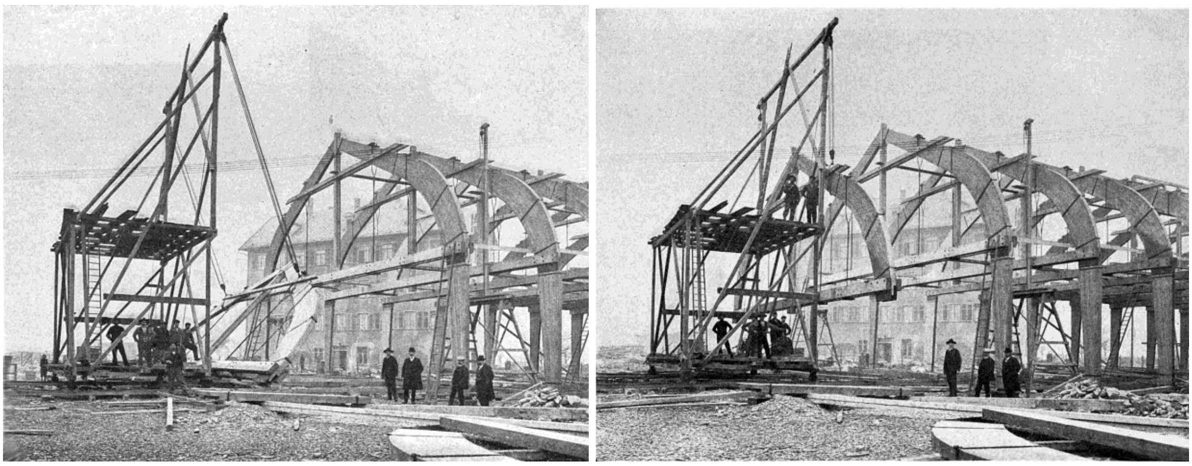
4.2. Constructing large-scale structures

Procedures for standard hall constructions

Most of the large-scale one-room structures were of the same type and were typically used for factories or warehouses. They consisted of two half-girders forming a three-hinged arch with one ‘hinge’ at each footing and one at the top where both parts met. Often, when the large half-girders exceeded regular transportation sizes, they were segmented and, consequently, featured a construction joint, in many cases below the highest curvature and just above the lower ‘straight’ part. But the size of these large structural elements also exceeded the manual handling capacities of the carpenters. For regular timber structures, construction wood was delivered and stored on site. It was then available in different dimensions as specified in the construction drawings of the architect, sometimes together with additional shop drawings from the contractor. The individual pieces were lengthened and prepared with all connections, then eventually placed in their definite location. Most of these regular construction members featured traditional wood working joints such as mortise and tenon or half lap joints. As the connection of the large glulam members, however, were also scaled, they were not fabricated on site but, together with the elements, prepared in the workshop.

As we saw in the previous case studies, the connection at the top between the two girder halves was almost always done by placing the elements against a central post using single step joints together with steel bands tying girder and post together.

The post, however, was not simply a remnant of traditional carpentry but was a key element to form, together with the tie beams, a stable triangular upper part of the girder for the erection process. On site, this part was prepared flat on the ground, as figures 41 & 42 show: the two upper segments of the girder halves, connected with the post at the top and connected through a tie beam (consisting of two flat timbers place on both sides of the glulam elements receiving the post at their centre.



Figs 41-42 Construction process of the girders of the Schweizerische Eternit-Werke in Niederurnen, ca 1912.

The tie beam was placed just above the girder joint, and sometimes a second tie beam was added just below the top hinge for extra stability. This upper tie beam also offered a practical suspension points for cables when this stable unit was then lifted up, either through tripods and hoists or a crane. As the upper part was lifted into its final position, the lower parts of the girders were added by slotting them in between the steel plates which were already attached to the upper segment before the lifting. Using this procedure, the carpenter only needed ladders to place the bolts into the connection steel plates and to add further timbers longitudinally to keep the girder in place.

Figures 49 & 50 show this erection process for the girders of a warehouse of the Swiss Eternit factories in Niederurnen. The contractor B. Zöllig from Arbon (Thurgau), developed a movable lifting device for the repetitive erection of the girders. They placed the purpose-built timber crane on rails and shifted along the central longitudinal axis of the building so that all girders could be swiftly placed without scaffolding and only very few skilled workers.

Responsibilities and competences

In 1913, Burkhard Zöllig was in charge of the building exhibiting the construction industry and designed by the well-known local architect Otto Ingold.[25] Apart from the extraordinary contractual agreement for the exhibition, according to which the contractor was the owner of the building renting it to the organizers for the period of the exhibition and was thus in charge of the dismantling and transport from the site, his engagement here offers an extraordinary insight into the daily organization of the construction. The daily reports from the site manager Hagen in Bern to Zöllig in Arbon allow a better understanding of the organisation and procedures behind the glulam practice. For Ingold's project Zöllig proposed a structure with eight glulam semi-circular arches and six half-arches for the ridges and the annexes, each half spanning 11.50 m with a rising height of 12.55 m. For the entire timber works, Zöllig deployed 11 workers, most of them carpenters of them permanent staff but also a few temporary local carpenters to support the works.[26]

The constructional detailing for the Bern girders was somewhat common but needed to be adapted. Again, for each half-arch a joint was used to its overall size and transportation constraints. These segments were first assembled on the ground and then lifted which is why the site joint between the two segments of each half-arch not only features a steel plate on each side but also steel u-profiles embracing both the top and bottom of the glulam section at this point.

Unlike the ordinary timbers the glulam segments could not be moved with the carpenters' hands alone. For the unloading of these heavy parts, they normally used mechanical devices but also for their relocation, as the site manager explains in his progress report:

> The girders could not be placed yet, because they have to be transported to the location where they will be placed. Tomorrow, Thursday morning, we will be able to start with this. We have taken care of unloading the girders ourselves, as we could not use the crane, which has an electric drive and was being repaired this morning (…) .[27]

[25] Ingold, Otto. *Vertrag über die Erstellung einer Halle, Halle 3, Swiss National Exhibition of Bern 1914, Otto Ingold and B. Zöllig, 15.5.1913*. Bern, Cantonal archives of Bern: SLAB 5102. 1913, (unpublished).

[26] Zöllig, Burkhard. *Offerte über Erstellung einer Halle für Hochbau, 20.4.1913*. Thurgau, Cantonal archives of Thurgau : 8'409-1-2. Thurgau (unpublished).

[27] Zöllig, Burkhard. *Report of the Swiss national exhibition for 1914, 6,7,16.8.1913.* Thurgau, Cantonal archives of Thurgau : 8'409-1-2.1. Thurgau (unpublished).

The most easily available lifting device was directly set up by the carpenters themselves, for the unloading but also for the lifting in general: “This morning we loaded up, unloaded at the exhibition site, set up the tripod, assembled the ridge girders and pulled them up." Eight days later, all girders have been placed, relying on 11 carpenters on site. As several lifting devices were already set up, they were used to construct the walls.

As the scale of the glulam parts exceeded the capacity of the workers and required a thorough mechanical approach with a coordinated use of machines, also the planning capacities of the contractor called for systematic approach. In general, the scope of the licensed contractors was clearly limited to the fabrication of the glulam parts and the constructional work on site. They were sometimes commissioned as general contractors of a building, but mostly they were responsible for all timber works of which the glulam elements were only a small but important part.

The design of the glulam structures fell to the license holder, in the beginning Terner & Chopard and later the glulam consortium. The contractors, with their growing experience and local networks, could propose a design, tender for projects or negotiate details alone; for large-scale projects where the structure was considered an essential part of the building early on glulam was often a construction option from the beginning. All technical specifications, however, together with the shop drawings for the fabrication of all glulam parts were given by the consortium (fig. 43). Interestingly, the design procedure was rather generic as the structural calculations or site specifications from the consortium (or Terner & Chopard) never considered the specific site conditions, circumstances of the construction process or the detailing of the site joints or the footings.

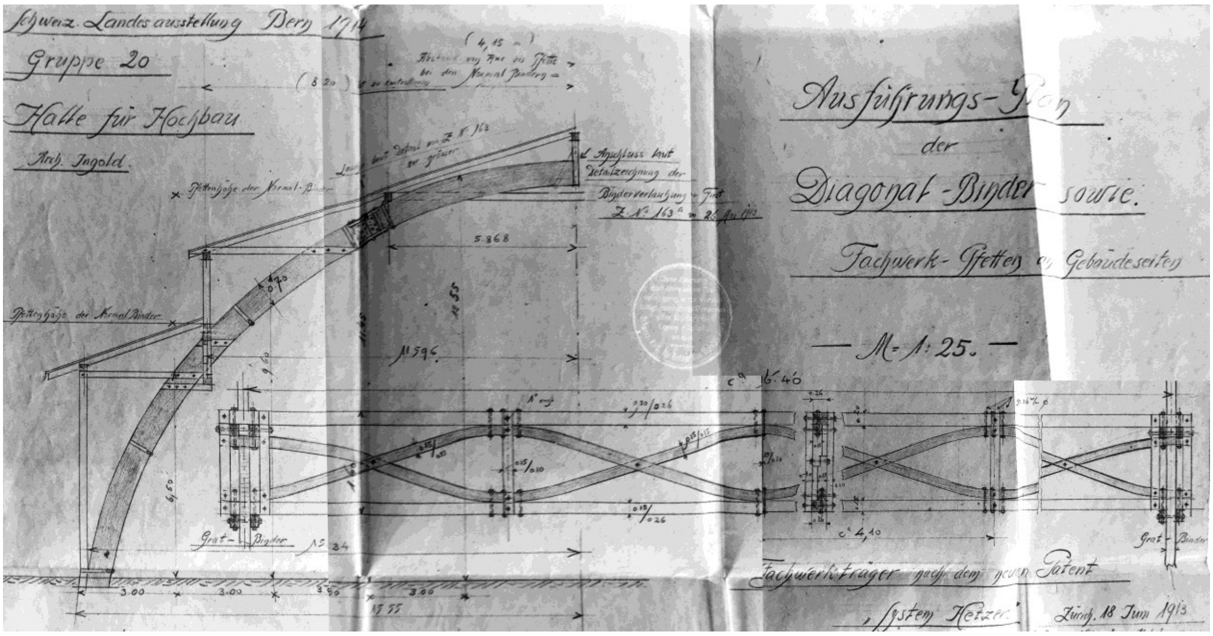


Fig 43 Workshop drawing for the glulam elements of the diagonal girders, hall 2, for the national exhibition in Bern1914.

4.3. Small-scale applications within mixed structures

Standardized girder application

An interesting example of for small-scale application of glulam within mixed structures (timber and glulam) is the roof structure of the Swiss hospital for crippled children in Zurich, built in 1913 (today university hospital Balgrist), and shown in figure 44. It was built by the contractor Fietz and Leuthold. The smaller building on the right has a roof of moderate size which does not need any girders in between gables. But to not require any posts or other structural members, both the ordinary ridge and intermediate purlin are replaced by massive glulam beams, curved and straight in detailed execution respectively.

On the left, the larger roof structure of the main building reveals a greater complexity. Probably due to time pressure, the brick walls were already up to the roof level when the carpenters erected the roof, which created a much denser working space for them. The backmost part of the building features a roof similar to the aforementioned one on the right: between two girders span curved purlins to receive the regular rafters. The major roof structure in front consists of massive glulam girders which are placed with slightly varying spacings. Their positioning clearly reacts to the functional space inside the roof, as the room dimensions determined the place of the adjacent girder. Consequently, the purlins which span in between them are adjusted according to their span and load: curved or straight respectively.

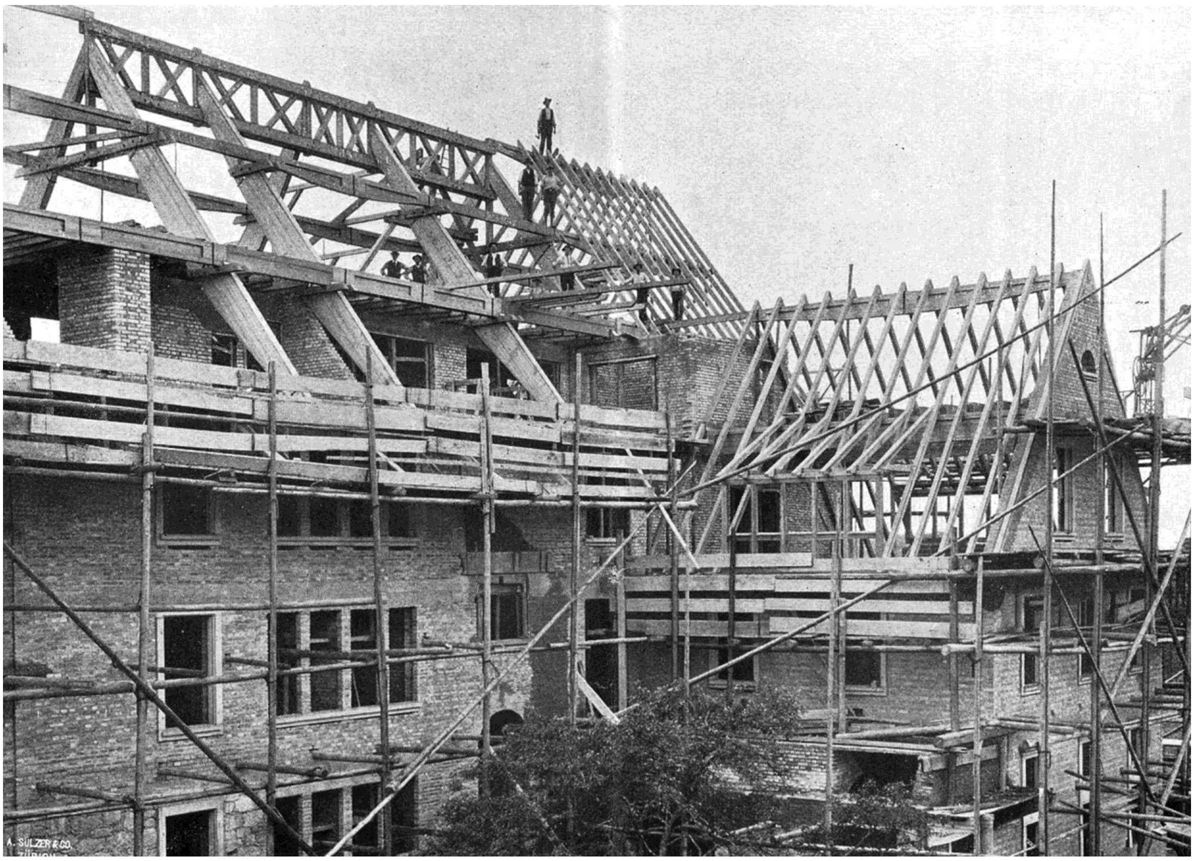


Fig. 44 Swiss hospital for crippled children in Zurich, 1913.

The erection of the wide girders in the roof, however, seems to have been a fundamental problem, especially given the density with of the given space. Based on the insights from the construction method of the repetitive girders from the larger one-room structures, such as the Eternit warehouse or the Bern exhibition, the actual procedure can be also traced for the given situation of the hospital roof in Zurich. Firstly, the complete closed girders are placed which consist of both halves and two pairs of tie beams connecting them together with the central post. They are most likely also first put flat on the ground of the roof level, put together and then lifted with tripod or with the crane which can be seen on the very right. Between these two closed girders, placed at each end of roof of this main part of the building, a long truss was then placed spanning the entire length. The halves of the intermediate girders were simply placed against this large-scale ridge beam from both sides resulting in girders which are open (without tie beams). The spatial complexity of manoeuvring full girder units was thus reduced through hierarchy using primary girders and larger purlins.

Another case exemplifies the application of girder units which was successfully used for the quick erection of repetitive girders in industrial buildings. Also, for the church in Romanshorn, glulam girders are used to simplify the roof construction, particularly for the given geometry of a raised and curved church ceiling that did not allow straight horizontal tie beams in between the girder footings.[28] Figure 45 shows the construction works of the glulam girders shortly after they were placed. Again, all girders are formed by a pair of two identical halves which are connected through a pair of tie beams and a short part at the very top, probably to hook the cables for the lifting. As there was no crane available on site, the carpenters used tripods which can be seen on the left of the photo with the ladder leaning against it.

Responsibilities and competences

The case of the roof construction for the catholic church in Romanshorn also gives insight into the actual demarcation of responsibilities between the actors. For roof structures of ordinary buildings, glulam came mostly only during the tendering process as one of the licensed contractors would proposed this as an alternative to the architects plans which was based on common timber roof typologies. Also here, architect Adolf Gaudy proposed a roof structure without glulam as it was open to all those contractors who were not licensed for the use of glulam. Gaudy was familiar with glulam constructions as he used it for several of his projects at that time.

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[28] Gaudy, Adolf. 1913. "Die neue katholische Kirche in Romanshorn".*Schweizerische Bauzeitung,* vol. 61/62, no. 16. Zurich, Jegher, 1913, pp. 220-221.

Fig. 45 Carpenters on the construction site of the catholic church in Romanshorn, 1911

Terner & Chopard were commissioned with the glulam girders that were the preferred option for the definite construction. Whether Gaudy reached out to them (the glulam consortium was only founded the following year) for a glulam option or they came up together with a contractor is not known because of missing planning documents. Eventually, the local contractor Wallisser from Romanshorn was chosen for the timber works which is unusual as they were not a licensed glulam contractor. According to their contract, Terner & Chopard was in charge of:

> delivery, preparation and erection of the standard girders "System Hetzer" over the nave and transept made of best, air-dry spruce wood, statically calculated (…) incl. all steel components such as tie rods, stirrups, screws, bolts, etc. as well as the associated timber parts such as central posts and all tie beams including all necessary scaffolding.[29]

Very likely they subcontracted Zöllig, the regional licensed contractor, who would have finished his work as it was documented by the client in the photo (fig. 45) so that contractor for the rest of the timber works could take over. For the Romanshorn church roof, the contractual practice was inversed: Whereas normally the timber contractor has a contractual relationship with the client and has then to reach out to Terner & Chopard, or later glulam consortium, the latter are here subcontracting their regional licensee.

4.4. Conclusions

Based on the rather generic design by the patent holders, engineers Terner & Chopard or later the glulam consortium, the licensed contractors developed construction methods for a secure, fast and flexible erection of the glulam parts. Key element was the development of a constructional unit, the

[29] Terner, Bernard, and Charles Chopard. *Werkvertrag Dachbinder, Romanshorn, 8.10.1910.* Romanshron, Romanshorn's Church archive: B17.2.04/8.

two girder halves with post and tie beams, that was fully joined flat on the ground and then, as an entity, lifted into place, using tripods or other movable lifting devices.
This process had to be strictly organised from off-site fabrication, delivery and positioning, since the scale and the uniqueness of the component did not see the worker on site as a constructing craftsman but a practical assembler: these large-scale timbers were not crafted and fitted but systematised and assembled according to the kit.
The constructional details grew with the scale but stayed in that period in between craftsmanship and mechanical steel parts like the bearings or the site joints. The putting-in-place was, like the connections, a convergence of tradition and technology: the material knowledge in the craftsmanship of the carpenters and a process-orientation through the fabrication regime of a new timber industry. However, the construction details and the erection of glulam parts on the construction site, were not only influenced by the scale and the function of the building. Sometimes, the fact that buildings were supposed to be standing for a limited period of time, entailed processes of dismantling, and in most cases, re-assembly. These conditions influenced the construction details, but also the dynamic between the engineers and the contractors in the design process. In the following part, some early temporary glulam structures will be case studied, to demonstrate how these structures pushed the industrialization of the design and construction process of early glulam structures.

5. Early temporary glulam structures

Among the very early projects within the first decade of their glulam works, there is a considerable number of temporary structures. These structures were built to meet the demand for temporary event spaces and were designed with the intention of being resold on a secondary market after their initial use. However, due to the temporary nature of these structures, most of them no longer exist in their original form. Although previous case studies have already cast light on the early developments of glulam projects in Switzerland and their underlying construction culture, the examination of the constructional practice for temporary structures provides a different perspective on the subject.[30]
Temporary structures and their different relation of constructional effort and the result defined by the design brief seem to enforce pragmatism. As a simple and repetitive construction procedure is desired for such structures, based on relatively light parts and reversible connections, either traditional multipartite timber in the form of trusses or industrial steel structures were the common choices for larger scales. Glulam, though, was quickly established in Switzerland as a reliable, readily available, and highly capable construction material appreciated and promoted by both engineers and craftsmen alike and also found early applications in temporary structures. The dynamic between architects,

[30] Early temporary glulam structures in Switzerland have been already published as Haddadi, Roshanak, and Mario Rinke. “Early glulam for temporary large-scale structures in Switzerland”. *Studies in the History of Services and Construction. Proceedings of the Seventh Conference of the Construction History Society,* edited by James Campbell et al., Cambridge, Construction History Society, 2020, pp. 477-488.

carpenters, and engineers was sometimes affected by the scale and the nature of the project. For example, the case of temporary structures was different from exhibition projects.

With glulam, the production time, a crucial factor for temporary structures is also reduced to a minimum: for the *Internationale Baufach-Ausstellung* 1913 in Leipzig, the production of the girders took 3 weeks in the factory from the order to the preparation, preparation for assembly took 3 days, and installation in site took 4 days. In total, only 4 weeks from the order till the use of the building.[31] Such a glulam hall can be erected much faster and the operations can be handed over than a hall of another construction type, iron requires long delivery times, reinforced concrete requires considerable time for the erection of the extensive formwork and scaffolding, as well as for hardening the concrete. Regarding the regular timber structure, the carpentry joints remained the Achilles heel, which necessitated long assembly and disassembly processes and site work.
There is a wide range of applications among the very early temporary glulam structures, reaching from festival halls, skating rinks, footbridges, and scaffoldings to manufacturing plants and exhibition halls. In some of those projects, glulam was chosen over steel mainly for economic reasons for its rapid assembly and disassembly process in comparison with regular timber truss structures. In some other projects, however, glulam was chosen to easily allow for shapeable structural elements which simultaneously delivered a modern character in contemporary timber structures.
The following examines early temporary large-span structures in glulam. Four case studies are chosen from the early examples of temporary glulam structures: a footbridge in Lausanne, a skating rink in Geneva, both from1910, a singing festival hall in Zurich from 1911 as well as an aeroplane hangar in Frauenfeld from 1913. Here it will be explained how the short lifespan influenced constructional strategies and detailing and how the overall constructability allowed for a secondary market of the components. Consequently, also, the effect of construction strategies of temporary structures on the ongoing industrialisation and mechanisation of glulam construction will be discussed.

5.1. Early exploration with available technologies

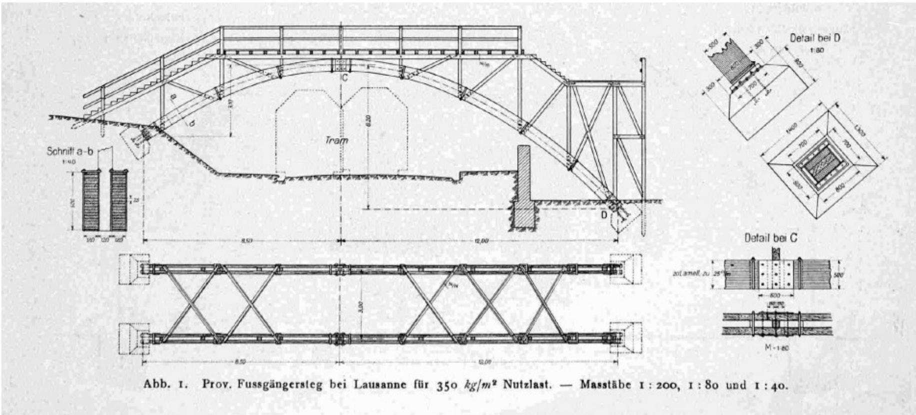
Footbridge, Lausanne, 1910 – Singing festival hall, Zurich, 1911

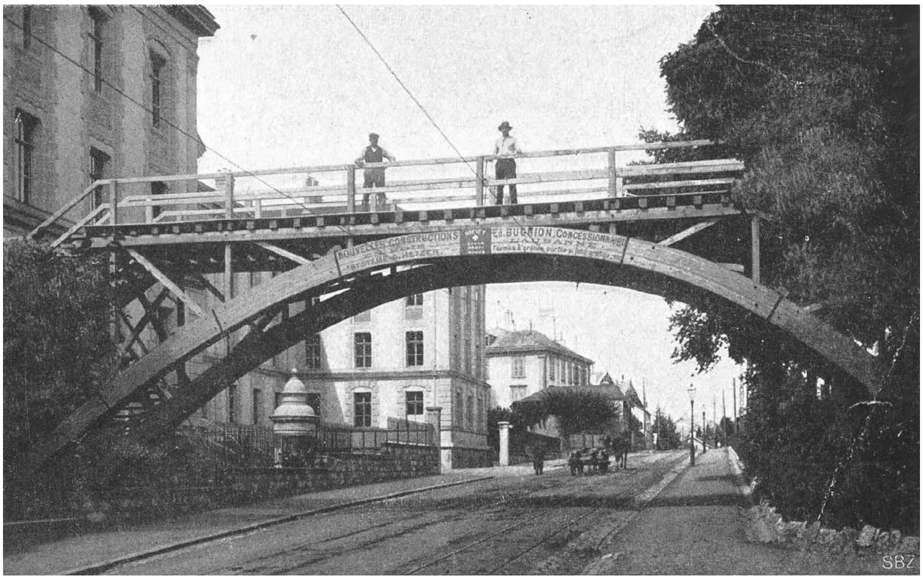
Constructed in 1910 the Lausanne footbridge is very probably the first glulam project in Switzerland. The 1910 Lausanne footbridge was temporarily erected on the occasion of the 8th Swiss Exposition of Agriculture,[32] held for 10 days in September 1910 in the Beaulieu area, Lausanne. Organised by the cantonal administration, the expo was to celebrate the art of agriculture and related products, but also the "rural youth, who, full of illusions, immigrated to the cities"[33]. Placed at the entrance of the expo

[31] Denkschrift über Hetzer's neue Holzbaiweisen, Verfasst im Auftrage des «Schutzverbandes für neue Holzbauweisen» von K. A. Urban, Grossherzoglicher Bauart in Weimar. p 25.
[32] *Illustrierte schweizerische Handwerker-Zeitung*, n° 26, 1910, p. 770, presents the singing festival hall in Zürich as the first glulam structure constructed in Switzerland.
[33] *Conteur Vaudois*, n° 36, Sept. 3rd. 1910, p. 3.

site the “very elegant”[34] glulam footbridge served as a connection between the city and the expo, spanning a public street together with two tramway lines. This way, the expo visitors could easily reach most directly the entrance of the expo.[35]

The bridge consisted of two pairs of parabolic glulam arches, one pair on each side of the 3m wide walkway. They have been developed as 3-hinged arches, “mimicking the curve of iron bridges”[36], spanning 20.5 m (Figs 46-47).





Figs 46-47 Temporary glulam bridge at the 8th Swiss Exposition of Agriculture, Lausanne. contractor: Ed. Bugnion, 1910.

Each glulam component was 12 cm wide and 50 cm deep, being composed of lamellas of 25mm thickness. Directly translating the model of the 3-hinged arch, each arch consists of 2 glulam components which meet precisely at the apex. Due to the asymmetric situation, the higher part spans 8.5 m while the lower part of the arch spans 12 m from the abutment to the apex. The connection details are kept as simple as possible. The pair of arches at each side follows a universal logic of timber construction and allows to receive all parts from above, posts and struts, in between the two

[34] *La Revue, Organe du Partie Démocratique et Fédéraliste Vaudois,* n° 201, Aug. 27th. 1910, p. 1.

[35] Tramways belonged to the Swiss Federal Railways. This company performed a load test on this bridge to ensure the stability of the structure erected over its tramways and the safety of its passengers. The national railway company becomes soon after one of the major clients of glulam structures.

[36] *La Revue*, (Note 4), p. 1.

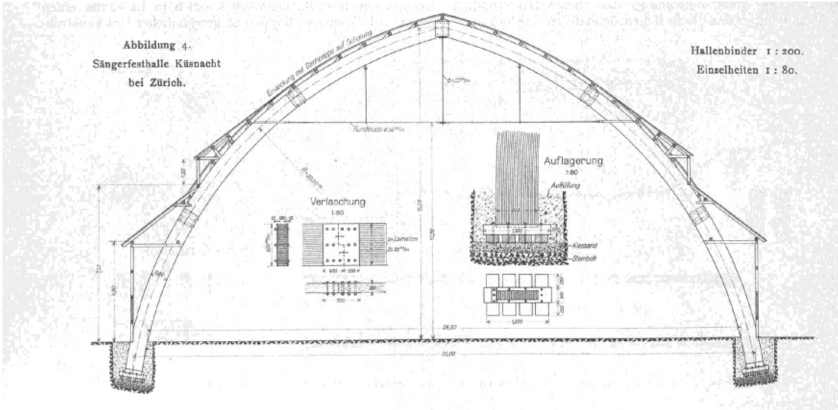
layers which simplify the load transfer immensely to a set of steel bolts. As the connections are reduced to only one type which can be easily put in place and also disconnected, they allow for both a fast construction process and reuse of the components in their almost unaltered shape. As this concerns the timber structure only, it can be assumed that set up was by the contractor, the licensed master carpenter Ed. Bugnion from Lausanne.

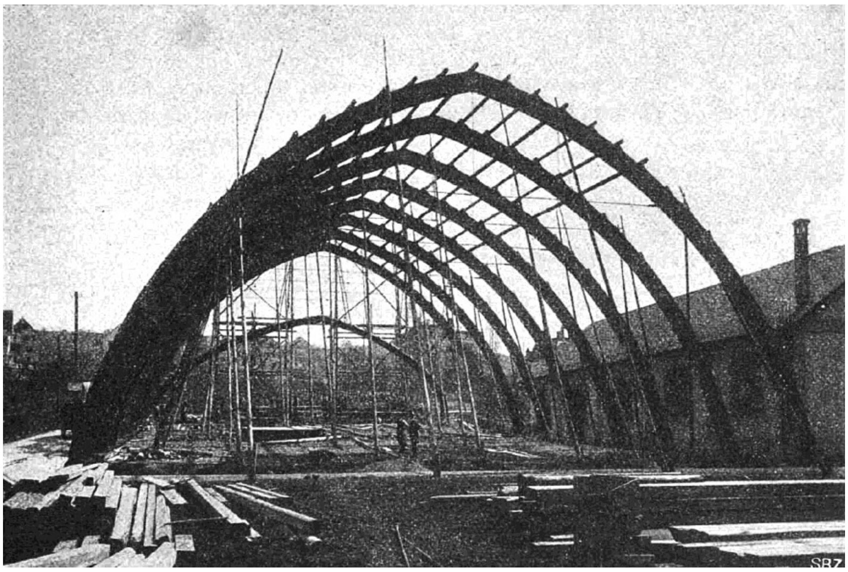
The details for the glulam parts, though, reflect the different scale of members: at the apex, steel plates are used on both sides of the arch components which are of the same height of the timbers, together with steel bolts. Technically, the connection over almost the full depth of the components eliminates the functioning of the hinge, as it is suggested with the choice of having the arch components meeting at this very point. This kind of joint usually is only used for site joints to enable a mechanically continuous solid component. Placing the joint in the apex also allows for the fabrication of components with similar curvature and thus a use of the same mould. The footings of the arches were carried out according to similar structures in steel, that was discussed in the previous case studies. Interestingly, these arch footings were buried in the soil of the surrounding landscape, so that these timber ends were permanently exposed to moisture and could, due to absence of any ventilation around them, barely dry. This was probably done in the knowledge of the short time of this situation and to keep the concrete foundation as small as possible, not being extended upwards to receive the arch above the ground.

One year later, another essential glulam structure was built, the singing festival hall in Zurich. The Swiss National Singing Festivals, held every 8 to 9 years at changing locations, were the most significant musical events of the country in the 19th century, keeping their importance throughout the 20th century. Zurich already hosted this event five years earlier, providing a large building roofed by steel trusses. The structure, though, was covered mainly with textile membranes with a central panoramic display of the city of Zurich. There was obviously a wish for separating the decorative interior space from the different technical structure around it. The “modern singing festival hall”[37] six years later, this time taking place in the Zurich suburb of Küsnacht, was constructed from glulam and allowed a step forward in different aspects. It not only enabled the harmony of the interior space by using a local, well-known material but also provided the Federal State with a project of advantageous costs, as well as a quick assembly and disassembly process compared to 1905.

The glulam hall, erected only for one week in June 1911, resulted from the collaboration of the engineers Terner & Chopard with the licensed contractor, Fietz and Leuthold from Zurich. Spanning 30 meters and with a height of 15 m, the hall structure consisted of 13 girders placed at intervals of 5 meter, covered by simple purlins and roof sheathing, roofed a surface of 1800 m^2. (Figs 48-49)

[37] Original text in German: “Die ganz originelle Anlage entspricht in allen Teilen den Anforderungen, welche an eine moderne Sängerfesthalle gestellt werden können.”Allgemeines Bauwesen”. *Illustrierte schweizerische Handwerker-Zeitung,* vol. 26, no. 49, p. 770.





Figs 48-49 Temporary hall for the Swiss singing festival, Kuesnach near Zurich. Contractor: Fietz and Leuthold, 1911.

All design decisions regarding the overall form and those of the components are driven by the leading idea of fast fabrication and construction. The girders were erected utilising mobile scaffolding and were, therefore, all identical. Unlike the structural members of the Lausanne footbridge, the girders here did not have a parabolic shape, which would reflect the ideal structural form to minimise the need for material. The choice for the Zurich girders, instead, was to be close to an optimal arch form but to use a constant curvature, so that all segments of the structure could be fabricated repeatedly using the same mould. Each girder consisted of two identical halves, with each half featuring the same constant curvature, meeting at the apex where they form a kink. Each half consisted of three identical segments, each of them 7.5 meters long featuring a constant cross-section of 18/80 cm. All segments were connected by using standard steel plates covering the full width of the girder elements which met in a step joint, and seven bolts on each side of the connection. The footings were carried out most simply: the ends of the girders were received by a larger wooden shoe which, together with four cross sleepers, distributed the load to a solid layer of gravel and stones.

This highly process and fabrication-based design approach exemplifies the shift from carpenter-centred to industry-based construction practice. In its pattern-like design scheme using identical components, the Zurich hall features the strong construction logic of a system whose parts can be combined, extended and reused. One of the critical features of the Zurich structure was described as the possibility of extending it to a span of 40 meters by adding further segments.[38]

This considerable advantage for reusable temporary structures explains the design strategy for having identical and interchangeable elements. This design approach can be followed in a subsequent project of such kind of festival halls. In a project for a transportable festival hall in 1913 in St. Gallen, another approach was presented following the guiding idea of modularity. (Fig. 50)

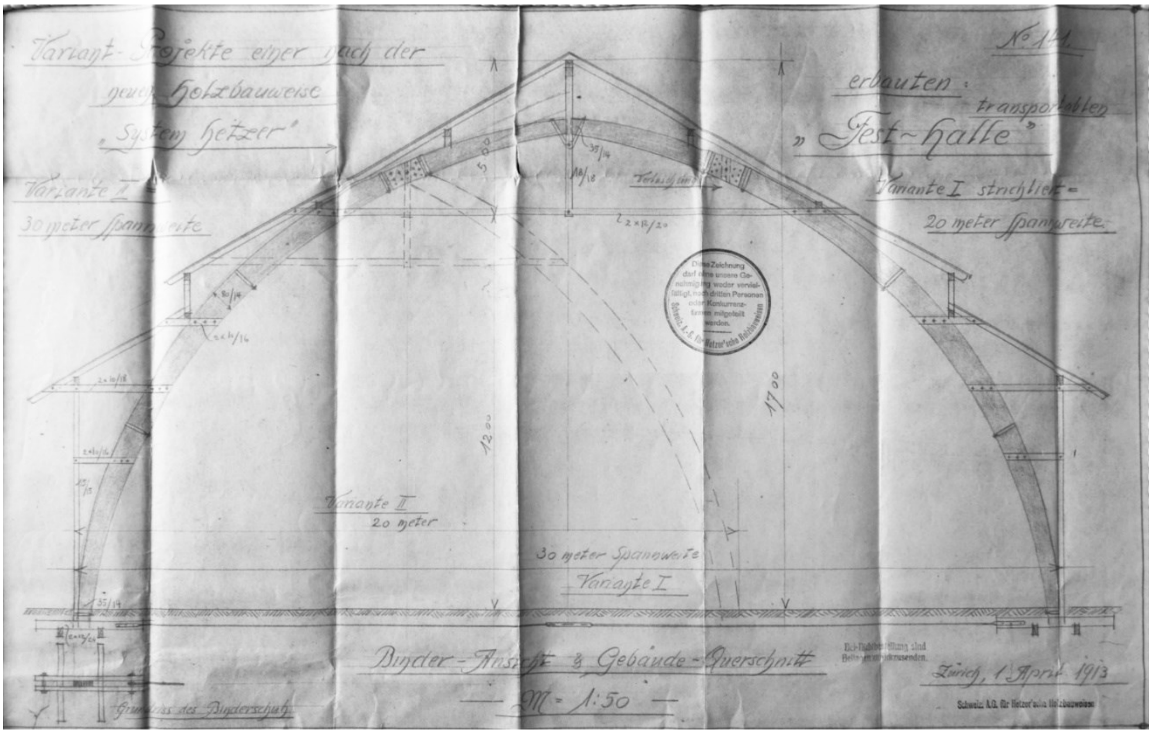


Fig. 50 Transportable festival hall, St. Gallen. Contractor: B. Zöllig, 1913.

Within one design proposal, the contractor B. Zöllig presented a structure which offered two options, a span of 20 or 30 m. Both options consisted of the same parts, the two lower segments, but the third segment at the apex is only used for the larger span. This different strategy of possible combinations required a different connection detail. The upper end of the lower segments is not a half lap cut but a straight vertical line allowing the direct connection of both with the lower segment on the opposite side or with the upper segment from the apex. Also, here, the steel fish plates at each of these joints made the girder basically always a 2-hinged arch system. The main focus of the refined glulam temporary halls is on the system of interchangeable components allowing the reuse and a flexible arrangement of the components.

These two projects show the main aspects of early temporary glulam projects focussing on a simple fabrication and construction process. Both the Lausanne footbridge and the Zurich hall sought to use elements of similar curvature while both festival halls also featured different arrangement through their versatile joints.

[38] "Die Hetzersche Holzbauweise". *Schweizerische Bauzeitung*, vol. 57/58, no. 16, 1911, p. 216.

5.2. Large span structures with particular shapes

In 1909 a Swiss group of sports enthusiasts living in London launched a project for a skating rink in Geneva, Switzerland. Following other big cities like London and Paris, they sought for a place for the "popular and hygienic sport" and demanded a "modern Skating rink". Part of the modern expression should have been expressed through striking features of the then-present state of the science of construction. With their wish for "a strong, solid and elegant construction" they also saw that "such a building can be used for many other purposes: exhibitions, parties, assemblies". The project was to be realised on a plot of land which was leased for five years but, eventually, was never built.
The first proposal, published in a journal in 1910 advertising glulam, consists of the central hall, 17 m wide, with adjacent servant spaces on both sides, each five meters wide (Fig. 51). This proposal was considered too expensive, and they asked the engineers to rework the project. [39]

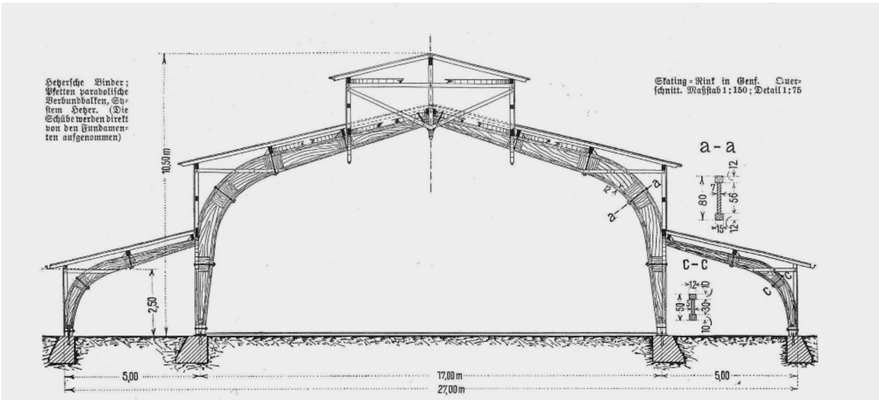


Fig. 51 First proposal for the Geneva Skating Rink project. Contractor: Ed. Bugnion, 1911.

As a result, two new projects were proposed: the first saw a parabolic arch spanning 32 meters, but much slenderer. However, in this single large space, it was probably difficult to integrate the serving spaces; this project was rejected. (Fig. 52)

[39] Steinman, M. "letter to the Conseil Administratif de la Ville de Genève". Archives de la Ville de Genève, 03. Dos. 255A, dated 19 March, 25 July, and 29 September 1910.

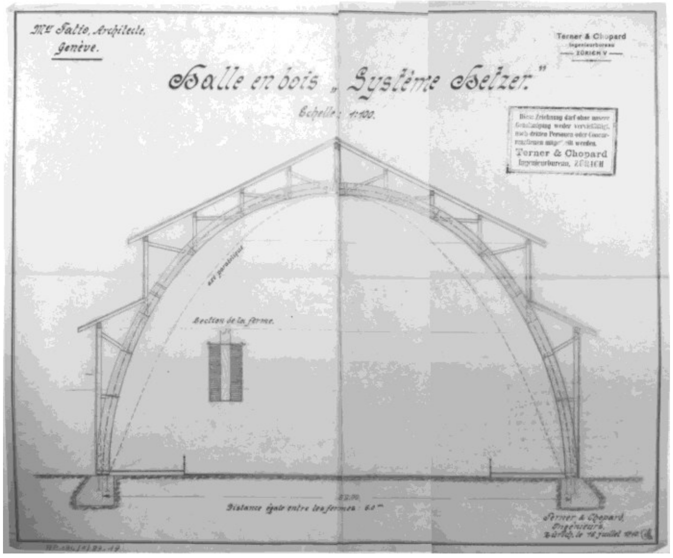


Fig. 52 Second proposal for the Geneva Skating Rink project. Contractor: Ed. Bugnion, 1911.

The other proposal was an extraordinary project: the engineers reduced the costs by simplifying the design of the glulam girder frames, using standardized timber trusses instead of custom-made glulam girders. To adjust the span to the irregularities of the site, a regular timber truss was inserted at each span the apex, connecting the lateral girders. This way, all the glulam girders of the whole structure could remain identical (Fig. 53).

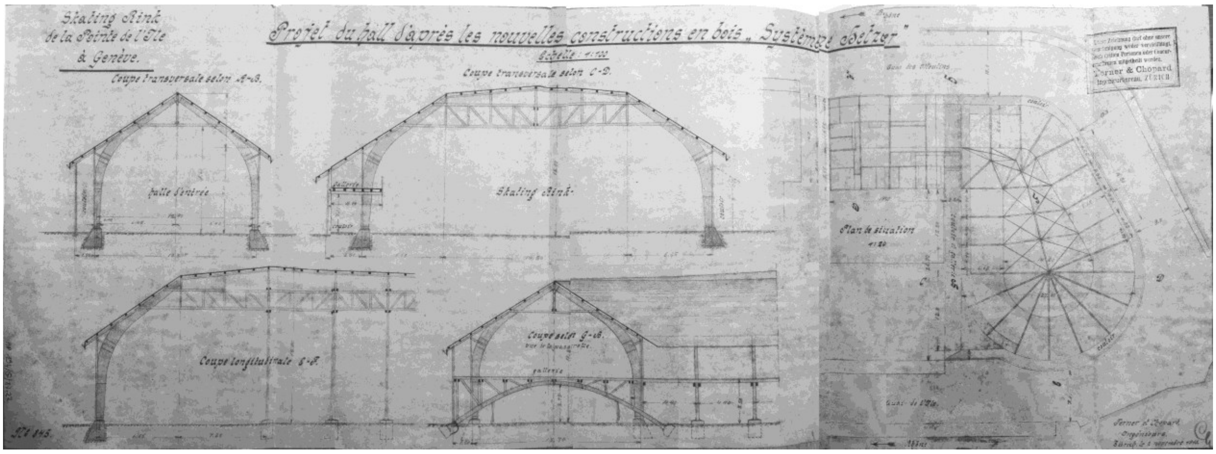


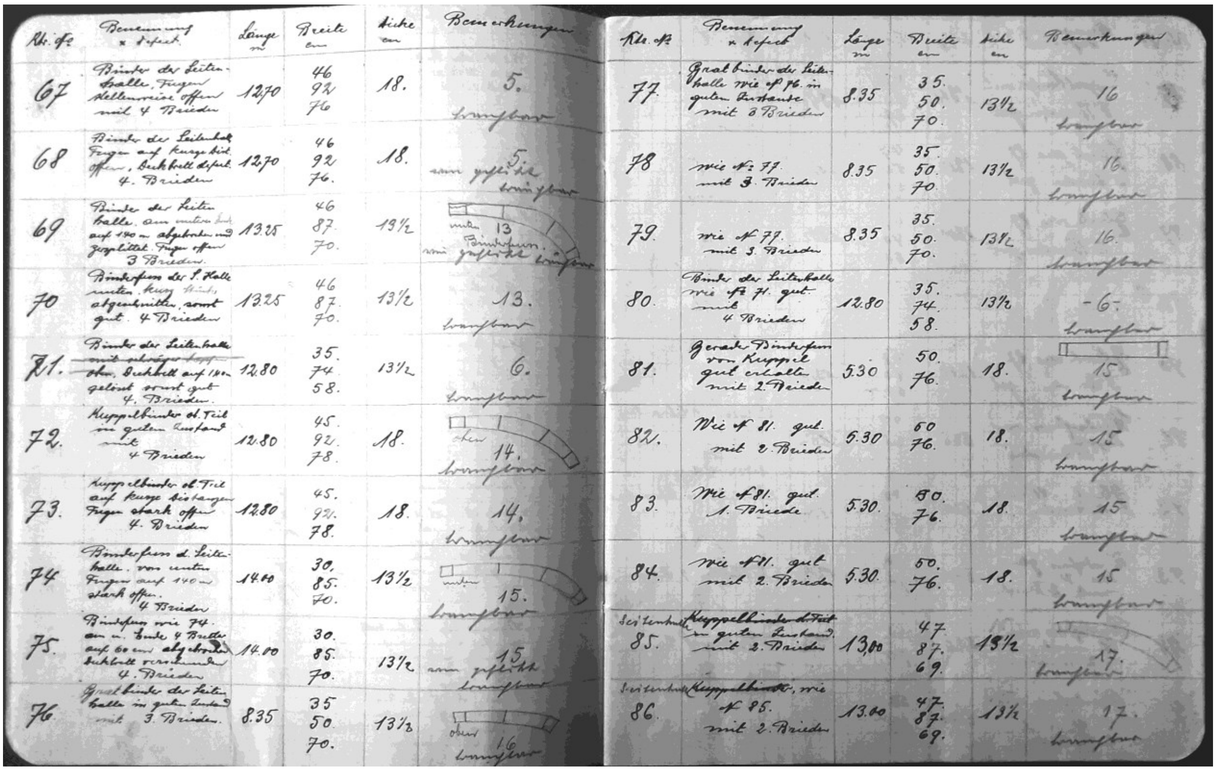
Fig. 53 Final proposal for the Geneva Skating Rink project, combination of two different material concepts: glulam and timber. Contractor: Ed. Bugnion, 1911.

Struggling with the tight budget, the concept thus combined two different structural typologies or, speaking about the material use, two different material concepts. Unlike the discussed festival halls, the proposed building here was, due to the plot, highly irregular in plan. Given the temporary nature of the structure, the new design avoided differently shaped glulam girders, instead, using identical components and mediate the span with the trusses in between. In the plan, they also very likely proposed the reuse of the temporary Lausanne footbridge, as can be seen in figures 45 and 46, featuring the very same geometry and dimensions and which was erected in the same year and fabricated by the same company.

5.3. The market and practice of glulam reuse

As demonstrated before, one of the frequently appearing features of the design of a temporary structure was the possibility of reuse. Apart from the influences on design and construction strategies, temporary structures also influenced the market. Glulam had considerable advantages to offer: first, a highly competitive price, particularly in comparison with steel. Second, traditional timber trusses with multiple members and rather complicated joints were not ideal for quick assembly and dismantling. Moreover, as the archival records demonstrate, sometimes it was challenging to sell an existing timber structure for the same use. For example, the structure of a pavilion for the National Exhibition in Bern from 1914, could not be sold for reuse but only to recycle the raw material.[40]

Archival materials show that glulam components were sold either as a package of the entire structure or as single components (or combination of them). The pricing for buying these existing components was usually based on the volume of material (wood) but could vary immensely among the different kind of components (Fig. 54).



Nr. No	Benennung & Defekt	Länge m	Breite cm	Dicke cm	Bemerkungen
67	Binder der Seitenhalle, Fugen stellenweise offen mit 4 Briden	12.70	46 92 76	18.	5. brauchbar
68	Binder der Seitenhalle Fugen auf kurze Dist. offen, Deckbrett defekt. 4. Briden	12.70	46 92 76.	18.	5. wenn geflickt brauchbar
69	Binder der Seitenhalle. am unteren End auf 140 cm abgebrochen und gesplittet. Fugen offen 3 Briden.	13.25	46 87. 70.	13½	unten 13 Binderform. wenn geflickt brauchbar
70	Binderform der S. Halle unten kurz [illegible] abgeschnitten, sonst gut. 4 Briden	13.25	46 87. 70.	13½	13. brauchbar
71.	Binder der Seitenhalle ~~mit schräger Kopf-~~ oben, Deckbrett auf 140 cm gelöst sonst gut 4. Briden.	12.80	35. 74. 58.	13½	6. brauchbar
72.	Kuppelbinder ob. Teil in guten Zustand mit 4 Briden	12.80	45. 92. 78.	18.	oben 14. brauchbar
73.	Kuppelbinder ob. Teil auf kurze Distanzen Fugen stark offen 4. Briden	12.80	45. 92. 78.	18.	14. brauchbar
74	Binderform d. Seitenhalle. von unten Fugen auf 140 cm stark offen. 4 Briden	14.00	30. 85. 70.	13½	unten 15. brauchbar
75.	Binderform wie 74. am u. Ende 4 Bretter auf 60 cm abgebrochen Deckbrett verschwunden 4. Briden	14.00	30. 85. 70.	13½	15. wenn geflickt brauchbar
76.	Gratbinder der Seitenhalle in guten Zustand mit 3. Briden.	8.35	35 50 70.	13½	oben 16 brauchbar
77.	Gratbinder der Seitenhalle wie No 76. in guten Zustande mit 3 Briden	8.35	35. 50. 70.	13½	16 brauchbar
78	wie No 77. mit 3. Briden	8.35	35. 50. 70.	13½	16. brauchbar
79.	wie No 77. mit 3. Briden	8.35	35. 50. 70.	13½	16. brauchbar
80.	Binder der Seitenhalle wie No 71. gut mit 4 Briden	12.80	35. 74. 58.	13½	-6- brauchbar
81.	Gerade Binderform von Kuppel gut erhalten mit 2. Briden	5.30	50. 76.	18.	15 brauchbar
82.	Wie No 81. gut mit 2. Briden	5.30	50 76.	18.	15 brauchbar
83.	Wie No 81. gut 1. Briede	5.30.	50. 76.	18.	15 brauchbar
84.	wie No 81. gut mit 2. Briden	5.30.	50. 76.	18.	15 brauchbar
Seitenhalle 85.	Kuppelbinder d. Teil in guten Zustand mit 2. Briden	13,00	47 87. 69.	13½	17. brauchbar
Seitenhalle 86.	Kuppelbinder, wie No 85. mit 2. Briden	13.00	47. 87. 69.	13½	17. brauchbar

Fig. 54 Inventory listing the glulam pieces of a pavilion at the Nation Swiss Exhibition in Bern (1914), established by the contractor B. Zöllig, 1914.

It shows that glulam was not considered to be reused as raw material, but always as a predefined technical object. There are some cases that show combinations of components from different buildings to create another structure.

[40] State Archives of Canton Bern: S. L. A. B. 5132 129: Verkauf der Festspielhalle, pp. 3-6, 15, 45-49, 71. Recycling the structural elements only as the raw material caused loss of an important part of the price. Regarding the mentioned project, the timber piece were sold for only one third of their initial price.

From the examples discussed above can be concluded that buildings were not only offered as systems for flexible use and reuse as the very same package of components. In some cases, the temporary buildings have been clearly designed for a secondary market. New projects, such as the later festival hall in Aarau from 1924, focus on the system and the designed components of old existing structures, such as festival hall in Zurich. It can be noted that temporary structures, however, sometimes end up to be used a considerably extended time period, occasionally up to decades. For example, the halls of the *Comptoir* in Lausanne, built in 1922 and intended to be in place for one week per year, was continuously used until 1937 eventually standing for 15 years. Glulam for temporary structures, altogether, allowed for the possibility of successive reuses of the components which turned out to be an economic advantage.

5.4. Designing the transportable kit of parts

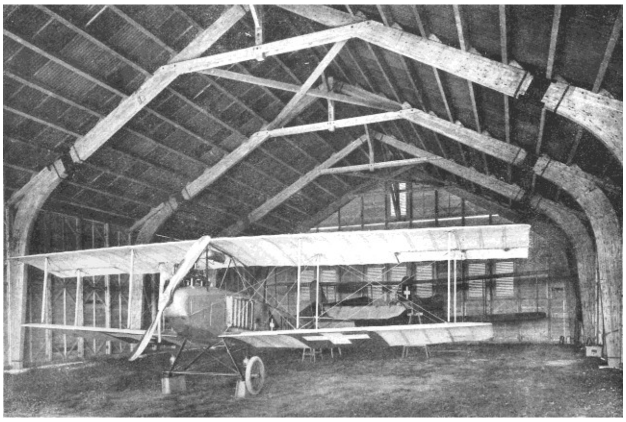
Aeroplane hangar, Frauenfeld, 1913

It's difficult to accurately assess the significance of the early temporary glulam structures market due to a lack of archived documents and the use of a single plan for multiple projects. For example, the project for an aeroplane hangar in Dübendorf built in 1917 was used as a model for 20 structures ordered for military use (Fig. 55). The archival documents demonstrate that prior to the war, the army has been client of this kind of structures for its aircrafts, for which the aeroplane hangar in Frauenfeld serves as example.

One of the first projects that were intended not only to be temporary but also reused at a different location and thus transportable is an aeroplane hangar in Frauenfeld.

The glulam consortium sent a letter to all its contractors informing them about the intention of the air force to build hangars for its aeroplane equipment in different parts of the country. As part of the brief, the structural components should be transportable with the wagons of the Swiss Federal Railways. Also, the air force would be the owner of these structures. Thus, the army personnel, who were neither carpenters nor craftsmen, were to be in charge of assembly and dismantling of the structures. Consequently, the required timber structure was required to be “solid, but also light, and easily dismountable and transportable”, with the minimum number of pieces possible and straightforward joints. As all holes for the bolt connections in the construction parts had to be burned out to avoid splitting of the wood after repeated assembly and to keep the number of bolts minimal. Seeking the monopoly for army hangars, the contractors were asked to recognise the high importance of the matter and provide active support for the most economical construction.

The proposed structure features familiar details of temporarily used systems for easy assembly and dismantling. The footings are using timber shoes together with sleepers and piles, similar to the Zurich festival hall. The apex, however, uses a post where the girders’ halves meet. (Fig. 56)



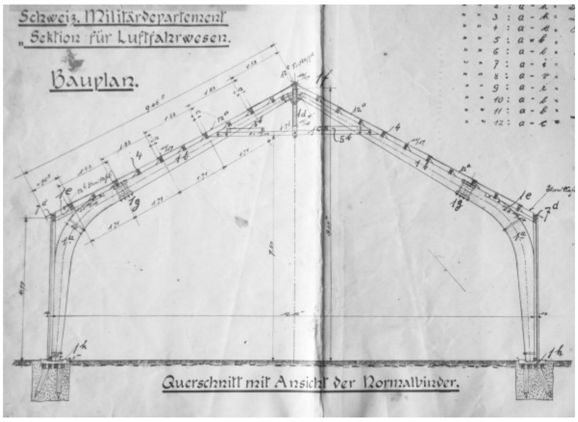


Fig. 55 Transportable aeroplane hangar and balloon shed in Dübendorf. Contractor: B. Zöllig, 1913.
Fig. 56 Detail of the apex. Excerpt from the plan of the aeroplane hangar in Frauenfeld. Contractor: B. Zöllig, 1913.

This rather traditional timber connection resembles many early glulam projects but is unlike all temporary structures discussed above. It was probably used to increase the stiffness of the slender girder together with the horizontal tie beam. This was probably necessary for the construction process: the lifting up of the assembled flat girders on the ground needed extra stiffness.

The design focus was on the simple but highly effective connections to reduce the number of elements. When the contractor Zöllig, for example, asked if the wind bracings would be enough, the consortium replied that they would not increase the number of pieces, "the rigid connections of the purlins to the girders, will greatly contribute to the stiffness of the structure".

The details of these elaborated connections demonstrate the integrated design approach bringing together the reduction of complexity, simplicity of installation and great robustness of its functioning. The purlin is not bolted to the girder but instead locked into it through an additional key fixed onto the girder omitting any extra penetrating metal connectors (Fig. 57), a feature that was used as well for the project of the Dübendorf hangar, that can be recognized in the photo (Fig. 55).

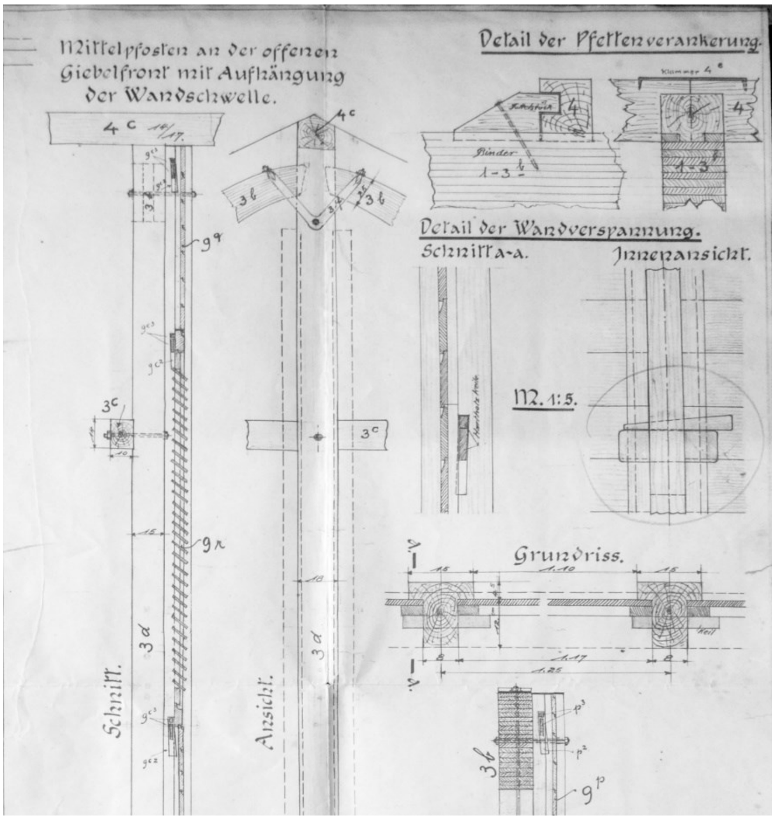


Fig. 57 Detail of the connection of the girders at the apex, detail of the connection of the purlins to the girders (top right). Excerpt from the plan of the aeroplane hangar in Frauenfeld. Contractor: B. Zöllig, 1913.

At the apex, the upper girder ends are designed to be curved downwards which allowed a much smoother process of sliding them in. They were eventually fixed with a standard steel hook at the post. This assembly-focused connection design was especially crucial for the overall simplicity and sequence of the assembly of the structure. The photos show that they assembled each girder on the ground and then lifted it up into the vertical position. Having these details developed as a primary standard ought to be applied for many following cases, the glulam contractors moved quickly to thorough industrialization of joint production.

The analysis of some early temporary glulam structures elaborated on the hypothesis, that based on the circumstances of the short life span of the structure and the reuse of parts of the structural components, considering the extended redistribution of design, detailing, and construction tasks among engineers and contractors, temporary glulam structures intensified and accelerated the influences of industrial processes, namely simple fabrication and construction process, on the very nature of standard glulam construction. These temporary structures were offered as systems for flexible use and reuse. Bringing together the simplicity of installation and the reduction of complexity, the design approach for temporary structures generated the possibility of successive reuses of the components with the least sacrifice of labour and material for other purposes, in further reuses, which turned out to be an economic advantage.

6. Conclusion

The design and construction process of early glulam projects, as the case studies of this chapter demonstrated, have been developed at the intersection of the design practices, models, and standards typical for timber and steel structures. A hybrid use of structural timber and glulam within a structure, or the hybrid use of the construction logic related to these two materials, resulted in construction details that do not appear to be based on consistent design practice. A combination of craft-design and engineering-design of the connection details can be observed in the early projects.

This hybrid reference from timber and steel structures, and the hybrid use of timber and glulam within a structure, present challenges when it comes to defining the roles and responsibilities of engineers and contractors. The case studies show that sometimes design was left entirely in the hands of the craftsman (for example in the case of temporary structures), or could be carried out entirely by the engineers (such as the case of the tram depot in Basel, where the design method used was a material independent, universal mechanical approach), or by a combination of them both. Most often it has been the latter with the technical issues decided by the craftsman.

Appendix 4.1

Although site joints and specifying their location on the girders following the static calculations can be seen in many structures, it is however not a universal approach. For example, when the fabrication of the glulam girders was done near the construction site; in that case, the contractors would have probably avoided the site joint, if the transport of the whole girder has been possible. This would have greatly reduced the assembly time.

Here the example of the glulam structure of workshops of the *Aluminium Schweisswerk AG* can be mentioned, where the overall structure and the detailing is quite similar to the locomotive depot in Bern, except the site joints (Fig. 58). The structure has been located in Schlieren and built most probably by one of the Zurich-based glulam licensees. The same goes for the warehouse of the company Francillon & Co., in Renens near Lausanne, which has been constructed by the contractor Gribi in Lausanne. (Fig. 59)

Fig. 58 Glulam structure of the workshop of the *Aluminium Schweisswerk AG* in Schlieren

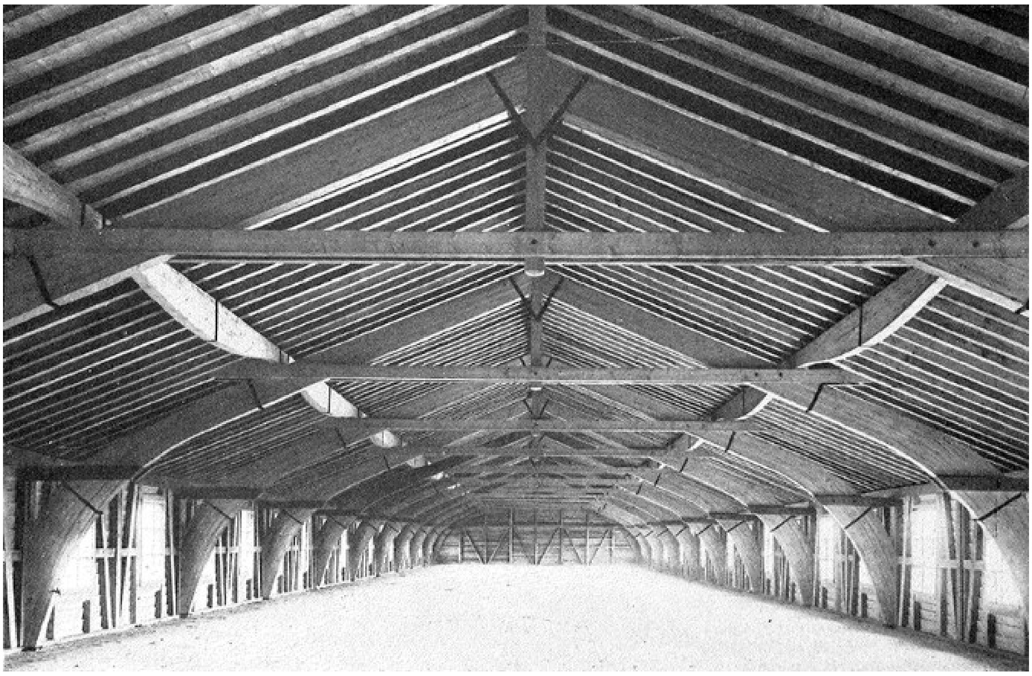


Fig. 59 Glulam structure of the warehouse of the company Francillon & Co., in Renens near Lausanne

In another case, the location of the site joint has been set according to the secondary structure, like the slab of the second story of the building (Fig 60).

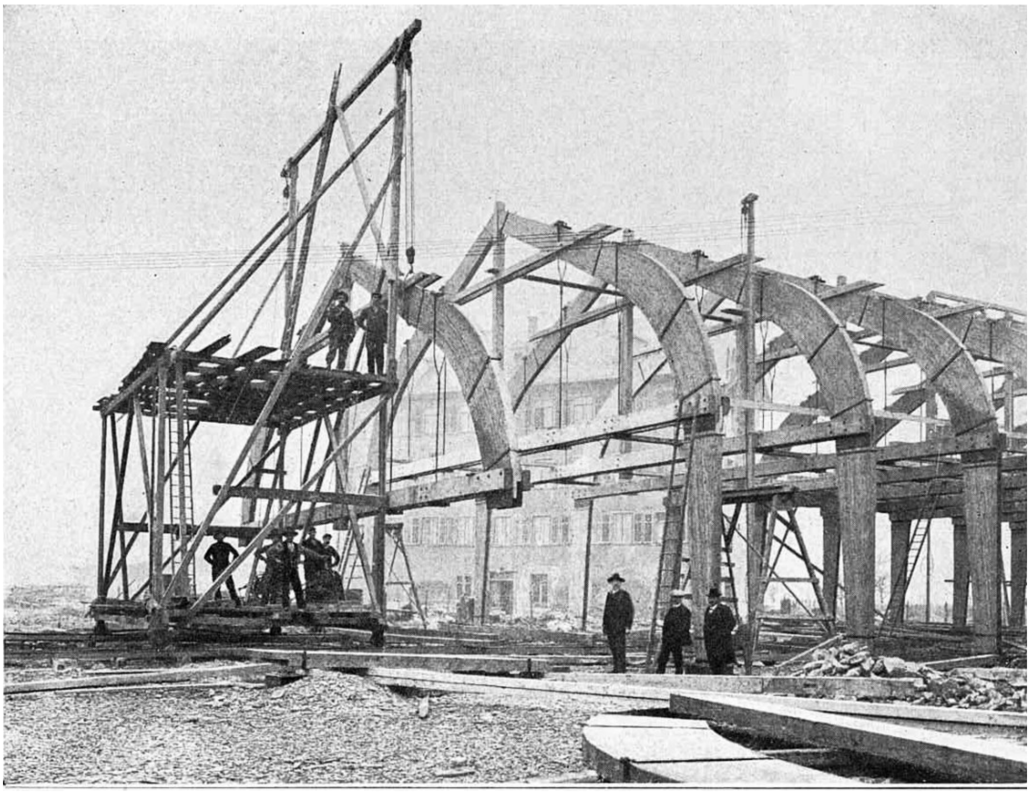


Fig. 60 Assembly of the glulam structure. Warehouse of the Schweiz. Eternitwerke AG in Niederurnen (Glarus), 1912.

Chapter five

Hybrid material nature

timber and glue

Glulam and other similar glue-wood composite materials have generally been identified with timber, the material that constitutes the appearance of the composite material. Almost all the properties that can be measured by human sensory organs support the timberness of glulam.

In a promotional catalogue of the company Nielson-Bohny & Cie., the company proposed to its client a project "*en bois*" (in timber), in the Hetzer system (Fig. 1). In his meticulously researched PhD thesis, Eric Schatzberg similarly identifies Howard Hughes' Spruce Goose as a wooden aeroplane, while, it has in fact been made of plywood, a composite of which wood is but one component.[1]

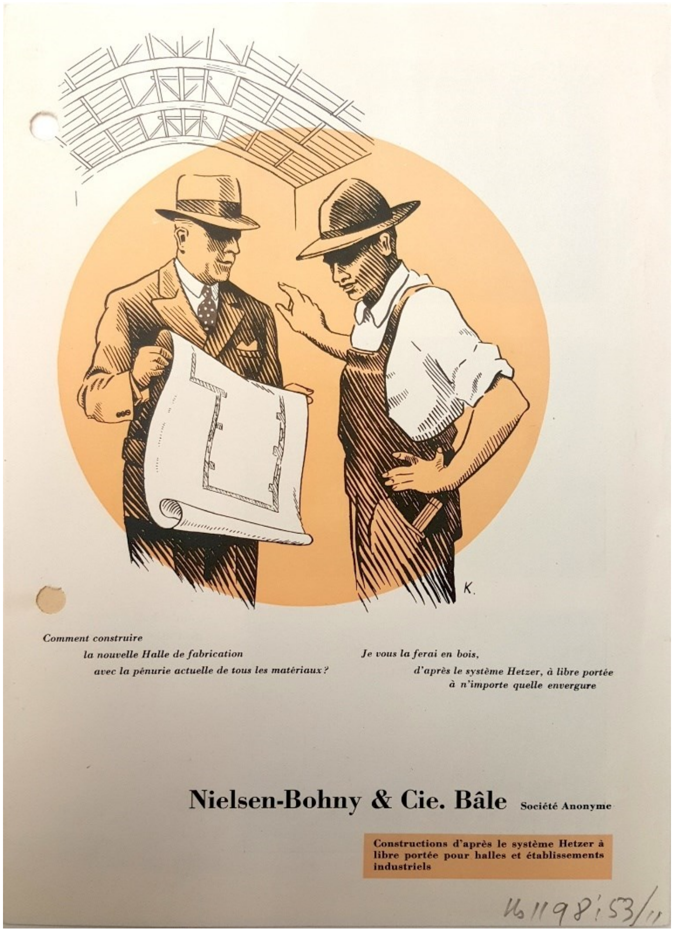


Fig. 1. The carpenter proposes to the client: "*I will build it in timber, according to the Hetzer system, at any span length*.". Glulam is not considered a new material, but a construction system.

In the early decades of the development of glulam, an important turning point for the diffusion of the technology was the transition from organic chemistry (casein glue with natural components) to synthetic one.[2] The transformation from natural to synthetic was not only affecting the performance of the material itself but the involved parties, the production chain, and the workshop layouts as well. Although primary sources describing the early glue-laminating process according to the patented

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[1] Schatzberg, Eric. *Wings of Wood, Wings of Metal: Culture and Technical Choice in American Airplane Materials, 1914-1945*, Princeton, New Jersey, Princeton University Press, 1999, p. 3. Of course, one reason for it, is that glulam was in fact presented as an improved version of natural wood. That's why it was mainly associated with timber rather than glue.

[2] Casein glue has been used for hundreds of years, in different industries. See "Tausend Jahre Käseleim". *Die tierischen Leime: Geschichte, Herstellung, Untersuchung, Verwendung, Patentübersicht*, edited by Josef Maria Greber et al. Hannover, Schäfer, 2003, pp. 44-45. (originally published in 1950).

technology are rare, the secondary sources related to the Swiss context however describe conditions in which the gluing task was performed in the early days of this technology. The technical journal *Hoch- und Tiefbau*, which became in 1907 the official organ of the master carpenters' association as well (the latter being presided then by Emil Fietz, the first licensed contractor for the production of glulam in Switzerland), explained in 1910 that the glue-laminating process had to take place in a protected room where the air temperature did not have to drop below 40 ° C, since the setting time and hardening of the adhesive primarily depended on the prevailing temperature.[3] Moreover, it should be noted that the actual performance of the natural glue showed deviations from performance expectations that arose from the claims of Hetzer in his patent, guaranteeing waterproof behaviour. It was vulnerable to mould, insects, alternate wetting and drying, etc., which affected seriously some of the early glulam structures (see Appendix 3.1).

Moreover, varying characteristics of natural raw material, was a major obstacle to reach a consistent level of quality standard, knowing that guaranteeing fixed care during the manufacturing process was almost impossible. Spreading the glue was done manually by the workers, with different speeds and pressure of the brush, and judging the quality of the glue and its application was subjective. Synthetization of glue and the industrialization of its production aiming at constant quality, ease of application, and better performance when exposed to the open air, appeared then to be crucial steps towards its standardization.[4]

One reason that glulam, among several alternatives, became the engineered timber structure of the 20th century, was the particular role of the hidden substance, the glue, and especially the synthetic glue. Scholars have already devoted considerable attention to the development of glue from a variety of viewpoints, and much valuable research has been accomplished many times over and successfully. Among the primary sources, the reports published by the EMPA and the SVMT should be cited, which provide us with an overview of the development path of glues in their transition from natural to synthetic. [5]Among the most relevant research on the early glue used in glulam, the dissertations of Christian Müller, Matthias Seraphin, and Emil Brockstedt should be cited.[6] To this can be added

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[3] "Neu Holzbauweisen, system Hetzer". *Hoch- und Tiefbau, Schweizerische Baumeister- und Zimmermeister-Zeitung*, Zurich, Arnold Bopp, 1910, pp. 146-149. (citation on page 149)

[4] In the guidelines for the production of glulam elements proposed by the SBB in 1943, it is noted that the use of casein glue should be avoided for uncovered wooden structures that are exposed to the weather. *Bestimmungen für geleimte Holzkonstruktionen*, Lucern, Swiss Federal Railways, 1943.

[5] *Die Melocol-Leime der CIBA Aktiengesellschaft Basel*. EMPA, Zürich, 1945. Roš, Mirko. *Le progrès dans le domaine des constructions en bois collé en Suisse*. EMPA, Zurich, 1946. *Verleimtechnik mit Knochen- und Lederleim, Spannungsfrei Holztrocknung*. SVMT (Discussion report no. 30/ EMPA's report no. 28), Zürich, 1934. Also, as a secondary source see: Kühn, Helmut. "Die Kunstharz-Melocol-Leime". *Schweizerische Bauzeitung*, vol. 127/128, no. 4, 1946, pp. 46-47.

[6] Brockstedt, Emil. *Die Entwicklung des Ingenieurholzbaus am Beispiel der hölzernen Brücken im Zeitraum von 1800-1940*. Dissertation, TU Braunschweig, 1994– Müller, Christian. *Die Entwicklung des Holzleimbaues unter besonder Berücksichtigung der Erfindungen Otto Hetzer- ein Beitrag zu Geschichte der Bautechnik*. Dissertation, Bauhaus-Universität Weimar, 1998, particularly pp. 111-116. – Seraphin, Mathias. *Zur Entstehung des Ingenieurholzbaus - eine Entwicklungsgeschichte*. Dissertation, TU Munich, 2003, particularly pp. 103-105.

research on the development of glue and their classification from the perspective of today's knowledge, which contextualizes the early developments of glue in the broader historical context.[7]

Moreover, the functionality of glue used in the very early glulam structures has been subject of scientific studies, among which the tests performed by prof. Wolfgang Rug should be cited.[8] Beyond the German-Swiss circles, researchers from abroad mainly the Americans T.R.C. Wilson and Max Steinhaus and the British W. A. Chugg, left valuable information about glue and glue-laminating techniques in Switzerland. These engineers visited (in 1936, around 1965, and in 1961 respectively) the earlier generations of Swiss glulam workshops as well as glulam projects and investigated the performance of early glulam structures of continental Europe, and very particularly those of Switzerland where they had (mainly Max Steinhaus) the opportunity to meet the early pioneers of glulam and discuss their questions with them. These reports provide us as well with valuable information about the early problems with the natural glue and the proposed solutions.[9]

Moreover, the aircraft industry provides us with valuable information about the development of glue. Placing much higher demands on strength, moisture resistance, and fatigue resistance, the aircraft industry played particularly an important role on pushing the synthetization of glue, which has been subject of some excellent studies. The dissertation of Eric Schatzberg should be mentioned here, to cite only one example.[10]

Here the excuse for this further study lies in fact in the lack of insight in the role played by glue in promoting glulam as "the" engineered timber structure of the 20th century. Being centred on non-technical factors, this account takes a different perspective on the transition from natural to synthetic glue from those narratives that explain this shift merely as a technical progress. This thesis's account studies the impact of the background forces that used to define, in the early 20th century, the synthetization of the built environment as a pattern for progress. One of these accounts that has remained until now relatively unexplored, is the role that glulam as a less anisotropic and less natural material played in pushing the process of standardization of structural timber, where natural timber as

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[7] For the development of the casein glue see: Brockmann Walter, et al. *Klebtechnik, Klebstoffe, Anwendungen und Verfahren*. Wiley-VCH., Weinheim, 2005. – For a historical overview see: Scherer, Robert. *Casein: Its Preparation and Technical Utilization*. London, Scott Greenwood & Sons, 1911. – Brockmann, Walter, et al. *Klebtechnik, Klebstoffe, Anwendungen und Verfahren*. Wiley-VCH., Weinheim, 2005.

[8] Rug, Wolfgang, et al. "Untersuchungen Zur Festigkeit Der Klebefugen von Historischem Brettschichtholz." *Bautechnik Zeitschrift für den gesamten Ingenieurbau,* vol. 90, no. 10, 2013, pp. 651–659.

[9] Steinhaus, Max. Archiv schweizerischer, europäischer und arnerikanischer Holzbau- und Holzleimtechnologie; Autographen und Dokumentation meist aus den Jahren 1940 – 1970. ETH Zürich, Handschriften und Autographen der ETH-Bibliothek, 1987. – Wilson, T.R.C. *The Glued Laminated Wooden Arch*. Technical Bulletin no. 691, United States Department of Agriculture, Washington D.C. 1939. – Chugg, W.A. *Report on a visit to Switzerland to inspect glued laminated timber structures over ten years old.* Timber Research and Development Association, High Wycombe, Information Bulletin E/IB/7, 1962.

[10] Schatzberg, Eric. *Wings of Wood, Wings of Metal: Culture and Technical Choice in American Airplane Materials, 1914-1945*. Princeton, New Jersey, Princeton University Press, 1999. pp. 175-192. – In this regard, see as well: Wilk, Christopher, and Elizabeth Bisley. *Plywood: a Material Story*. London, Thames & Hudson, 2017, pp. 72-103. Moreover, the early natural glue, especially the casein glue, converged the interest of not only the timber industry and particularly the aircraft industry, but also it was used in the textile industry. see: Brockmann Walter, et al. (see note 7 above). – Scherer, Robert. (see note 7 above).

a “heterogeneous and unreliable natural materials” faced many obstacles.[11] In the following, the process of standardization of structural timber in Germany and in Switzerland will be briefly compared. This comparison demonstrates how this process, commonly considered an objective process driven by technical factors, is itself a socio-cultural construct, and how it affects the development of technologies in different places.

1. Challenges of standardization

Standardization, by maximizing compatibility, repeatability, safety, and quality of a material is an important milestone in its development and its broad and rapid taken up by the industry. Standardization of natural materials, however, faces more obstacles compared to industrially composed ones. In the case of timber, the natural variability, the variation in strength properties, and the effect of the flaws and defects have always been obstacles for engineers in the process of standardization. Subdividing wood into a considerable number of separate elements “lamellae”, removing strength-reducing natural defects, restructuring the order of the lamellas with the help of glue, and transforming the material into a more homogenous composite, have all been in favour of standardization.

It is interesting to note that although the phenomenon of engineered timber structures – which pushed the general research on structural timber – originated basically in Germany, it was however in Switzerland where the first building codes for this material were established. It would be therefore interesting to know if the contribution of Switzerland was particular in this field, and where appropriate, how the Swiss approach to standardization was different from its northern neighbour. This chapter will supplement the first three chapters of the thesis, where the differences of the approaches of these two countries to the development of glulam were discussed within the business spaces. The present part will be centered on the institutional spaces.

As with glulam, the elaboration and implementation of standards, here building codes, in some cases are initiated and developed by heterogenous group of actors, who have at times shared interest in the act of standardization and the testing methods. Unshared interests, however, would trigger conflicts among the parties involved in or affected by the process. An example of this could be the situation of unequal power relations that threatens the interests of particular groups, as it is the case when the process is initiated or supported by government action. This setup could give rise to conflicts between manufacturers, users, interest groups, standards organizations, and the governing body. To this, it should be added that the by-product of any standardization act, is the introduction of non-standards.

[11] The way Le Corbusier described wood, in Le Corbusier-Saugnier, “l’esthétique de l’ingénieur : maison en série”. *Nouvelle Esprit,* no. 13, 1921, p. 1530.

Those actors related to the latter group have essentially disinterest in the methods and the processes that categorized their products or services as non-standard.

From the very early days of the standardization in the building industry (regulation of the execution of structures as well as standardization of materials), concerns arose regarding the degree of objectivity in different aspects of a standardization process, since it was clear that despite all the care taken to proceed objectively, it would be “inevitable” that “the special interests […] would prevail".[12]

The mindset of standardization is principally associated with the concept of decontextualization and universality. Standardization in modem economic production, similar to the standardization in science, aims at ensuring an agreed-on performance of the economic medium (product, process, service, etc.), regardless of the context. Although the decontextualization of a medium involves a high degree of objectivity, it should however be noted that the standardization process itself should not be perceived as a neutral process for resolving technical issues, developed through an unbiased data-based process. Establishing building codes for structural timber in Germany and Switzerland, demonstrate that the process is shaped by different configurations of local and national economic forces, power relations, and cultural agendas, highly influenced by non-technical factors.

In order to be coherent with other chapters, the study will be comparative, considering the circumstances of the standardization process both in Germany and in Switzerland, emphasizing mainly the points of divergence, in order to, among others, understand the particularities of the Swiss approach. The other reason to follow this process in these two countries is that in the process of standardization of glulam, and in a broader context of research on structural timber in the Interwar period, there was a vivid exchange of information and experiences between these countries, and disentangling the contribution of these two countries would be difficult, if not impossible.[13]

Standardization of glulam, in both countries, was in the continuity of the efforts for establishing standards for structural timber. Although safety factors and hazard prevention are known to be among the most important reasons, if not the principal ones, pushing the standardizations and establishing building codes (like the two well-known collapses of a wrought-iron bridge in Münchenstein in 1891, and the collapse of a reinforced-concrete building in Basel in 1901 which had major influences on the development of new norms related to these materials),[14] in the case of timber structures, these were not the initial reasons. Unlike concrete and steel with almost no tradition (in the industrial scale) in

[12] Resolutions of the conferences in Munich on 22.-24. September 1884 and Dresden on September 20th and 21st, 1886 on uniform examination methods when testing building and construction materials for their mechanical properties. Munich 1887 (As cited in Seraphin, Mathias. *Zur Entstehung des Ingenieurholzbaus - eine Entwicklungsgeschichte*. Dissertation, TU Munich, 2003, p. 178).

[13] In 1921 for instance, Stuttgart based timber expert Alfred Jackson gave several talks at the meetings of the Swiss architects’ and engineers’ association. Moreover, the research on the development of the synthetic glue, as we will see further in this chapter, was carried out in close collaboration of both countries.

[14] For the train accident over the bridge in Münchenstein see: Weinmann, Karin, et al. *Beyond Materials: a Brief History of Empa*. Dübendorf, EMPA, 2020. For the collapse of the concrete building see Nichols, Sarah. *Opération Béton - Constructing Concrete in Switzerland*. PhD dissertation, ETH Zürich, 2020.

their construction practice, structural timber had hundreds of years *de facto* standards followed by informal convention and dominant usage. Here, this question could be asked that which background forces pushed the establishment of *de jure* standards, part of legally binding contracts and regulations, similar to the established norms for steel and reinforced concrete.

In the following, the process leading to the establishment of the first building codes for structural timber in Switzerland and in Germany are discussed.

Switzerland

Standardization of structural timber in Switzerland was developed on the consensus of different parties that included the federal and national institutions, as well as those whose professions were influenced by the implemented standards, either promoting their product or threatening its market.

The founding or institutionalized expansion of materials testing institutes is a development that characterizes the second half of the 19th century. The initial steps towards the establishment of standards regarding structural timber were taken in 1883, on the occasion of the acquisition of a material testing machine, in the context of the Swiss National Exhibition of Zürich, which was as well the starting point for the early tests on different materials, including timber. A universal testing machine was bought in the 1860s on the initiation of the ETH professors, with the sponsorship of several railway companies. This machine was transferred, in 1879 to the material testing institute affiliated with the polytechnic school of Zurich.[15] Based on the tests performed in this institute, the SIA released in 1883, norms for cement, issued "Classification of iron and steel" and "Normal conditions for bridge and railway material", and established a standardized format for brick (250*120*60 mm).[16]

It was thanks to the initiation and the efforts of the chief of the experts of Group 18 (Building Materials) of the Swiss National Exhibition of 1883 in Zurich,[17] Colonel Ulrich Meister (1838-1919), that material testing institute, affiliated with the polytechnic school (the forerunner of the EMPA) was able to lay the bases for an in-depth examination of the structural timber of Swiss origin, beside stone and concrete and cement. A report entitled “Buckling strength of construction timber” was the result of the first series of tests. As explained by prof. Tetmajer, on the occasion of the expo Geneva of 1893, a considerable amount of wood of Swiss origin was available, which opened the possibility of using them for further tests at the EMPA.[18]

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[15] Gugerli, David, et al. *Transforming the Future: ETH Zurich and the Construction of Modern Switzerland 1855-2005*. Zurich, Chronos, 2010, pp. 82-83.
[16] Rebsamen, Hanspeter, et al. “Zurich”. *INSA: Inventar der neueren Schweizer Architektur, 1850-1920.* Zürich, Bern, Orell Füssli, Gesellschaft für schweizerische Kunstgeschichte, p. 204.
[17] Tetmajer, Ludiwig. “Die Knickungsfestigkeit der Bauhölzer”. *Schweizerische Bauzeitung,* vol. 1/2, no. 22, 1883, p. 141.
[18] Tetmajer, Ludiwig. *Landesaüsstellungs-Ausgabe 1896, Methoden und Resultate der Prüfung der schweiz. Bauhölzer (Foreword to the first edition)*, EMPA Report, Zurich, 1896.

Here it should be remembered that in those years, as mentioned in the second chapter, in a petition sent by the *Schweiz. Holzindustrie-Verein* (Swiss Wood Industry Association) to the Federal authorities in 1886, this association outlined the frustrating situation of the export of timbre, and alarmed over "the complete ruin of the Swiss timber export industry in a very short space of time".[19] This association being just founded during the same year as the petition was not the only effort of the forestry sector to enhance the economic interest of timber as a major national commodity. In its previous year, in 1885, a centre for experimental forestry had been affiliated with the polytechnic school. The forestry centre was "intended not for educational purposes but to directly serve the economic interests of the country in the areas of construction, forestry, and agriculture."[20] Concentrating on the domestic market and promoting the use of timber of Swiss origin, was in fact in line with the efforts of Ulrich Meister to encourage standardizing structural timber.

One of the early and fundamental problems with standardization was then how to set the criteria for defining the standard and therefore, the non-standard.

Although the process of standardization was principally in favour of the designer of the structures, who could work with more "reliable" material, it could however threaten the benefits of the forestry sector, if the criteria set by the standard program would identify a larger amount of their products as non-standard. The program provisions for the testing of Swiss timber, driven by economic necessities, have been established with regard both to structural and forestry interests of timber, to bring the interested and the affected parties simultaneously involved in the process of the development of standards. In order to promote mutual gains by making mutually consistent decisions, the drafting of the program for the testing of Swiss timber of 1882, was submitted to the board of the Forest School of the Polytechnic School of Zurich (ETH), which was then one of the first six faculties of the school, "in order to avoid any one-sidedness and to take due account of the special needs of foresters".[21] The cornerstone for the standardization of structural timber was therefore laid at the intersection of the interest of different trades.

Besides, it should be pointed out that Colonel Meister who initiated this process, was the head forester of the City of Zurich (1875-1914), while he was as well a member of the Parliament of Canton Zurich.[22] Moreover, he was a National Councillor, promoted to the position of the presidency of the

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[19] *Eingabe Schweizer. Holzindustrie-Vereins an den Hohen Bundesrath zu geehrten Handen der Tit. Bundesversammlung*, 1886, Basel, Schweizerisches Wirtschaftsarchiv, B. Verb./Bc 156, p. 2. Original citation "bei solchem Forschreiten des Ausfalls der vollständige Ruin der Schweizer. Holzexportindustrie in kürzester Frist als geschehene Thatsache konstatiert warden müsste."

[20] Gugerli, David, et al. *Transforming the Future: ETH Zurich and the Construction of Modern Switzerland 1855-2005*. Zurich, Chronos, 2010, p. 83.

[21] Tetmajer, Ludiwig. *Landesaüsstellungs-Ausgabe 1896, Methoden und Resultate der Prüfung der schweiz. Bauhölzer (Foreword to the first edition)*, EMPA Report, Zurich, 1896.

[22] These tests were the starting point of the collaboration between the EMPA and one of the glulam licensees and early glulam consortium member. Within the test program, the impregnation tests of Swiss structural timber, with Chlorzink was performed in collaboration with the company Gribi & Cie. in Burgdorf. Colonel Meister and the directors of Gribi & Cie., (who served both as major in the army) had a close collaboration in this regard. Tetmajer, Ludiwig. *Landesaüsstellungs-*

Swiss National Council in 1902. He was as well a co-founder of the FDP (Liberal political party. 1892-1911 he was the national councillor of the Liberals), actively involved in public relations (from 1873 he was a member of the board of directors of the NZZ, promoted in 1883 to the chairman, and from 1911 active in the board of directors of the news service *Schweizerische Depeschen-Agentur*), and as well affiliated to several higher-educational and academic associations of the canton of Zurich.[23] Ulrich Meister, a political and economic elite with several pivotal roles at the cantonal and national levels, besides being a high-ranked army officer, promoted timber in the intersection of politics, the economic associations, and aimed at an updated and modernized image of timber, by affiliating it very early with the ETH, the institution shaping the scientific and technical infrastructure of the government.[24]

The early steps and setup for the standardization of structural timber in Germany showed nonetheless major differences with the path forged in Switzerland.

Germany

In the German Empire, as Wolfgang Rug explains, until the first world war, the building codes varied depending on the region. In 1909 there were "*six different permissible stresses for welded iron in 37 large cities*". The situation, still according to Rug, was not better for concrete. To this, it should be added that the regulations applied in the same country for private and public buildings were different, which led to considerable deviations in the permissible load of the same components.[25]

In Germany an early considerable role and interest of the government in standardization can be recognized, which was well different in Switzerland, where, as we saw previously, it was mainly driven by the economic interests of the trades.[26] The reason that *"German Institute for Standardization" (DIN),* which was founded in 1918 by various Reich authorities, concentrated on setting building codes for structural timber, was related to the economic emergency of the immediate years to come after the first World War and the role of structural timber at the time of great housing shortage. The energy-intensive building material, like steel and concrete, had to be then substituted by timber. It is therefore not surprising that the first DIN standards were not concentrated on steel or reinforced concrete, but on timber. The DIN-104 for "Timber beams for small houses", in a rudimentary way defined the material-saving cross-sections and load-bearing tables.[27]

Ausgabe 1896, Methoden und Resultate der Prüfung der schweiz. Bauhölzer (Foreword to the first edition), EMPA Report, Zurich, 1896.

[23] Hürlimann, Katja. "Meister, Ulrich". *Historical Encyclopedia of Switzerland (HLS)*, Online: https://hls-dhs-dss.ch/, consulted on August 27, 2022.

[24] For more about this particular role of the ETH see: Gugerli, David, et al. *Transforming the Future: ETH Zurich and the Construction of Modern Switzerland 1855-2005*. Zurich, Chronos, 2010. (particulalrly p. 45)

[25] Rug, Wolfgang. "100 Jahre Forschung für den Holzbau". *Deutsche Gesellschaft für Holzforschung,* no. 95, 2006.

[26] Welder, Bernhard. "Fortschritte des bauingenieurwesens im neuen Deutschland 1933 bis 1943. Entwicklung der technischen Baupolizeibestimmungen seit 1933". *Die Bautechnik,* vol. 22, no. 1/4, 1944, pp. 10-13.

[27] Rug, Wolfgang. "100 Jahre Forschung für den Holzbau". *Deutsche Gesellschaft für Holzforschung,* no. 95, 2006.

Publication of these mandatory standards however caused growing discontent within the German timber construction industry and gave rise to serious concerns about its adversarial economic consequences. The director of the *Deutscher Holzbau-Verein* (German timber construction association), voiced his disagreement concerning the building codes, by stating that by standardizing a commodity, one cannot be "indifferent to economic life if". He believed that at a time of great housing shortage due to the scarcity and the high prices of all building materials, introducing those building norms has been in fact "shackling" the timber, and restricting its use.[28] The new decree was anticipated to increase the price of all wooden construction buildings for the consumer by 25%, as stated in the article.[29]

In Stuttgart, the Government architect, Jackson, formulated his objections about the permissible stresses published by the norms, in an article illustrated with glulam structures (both Swiss and German examples), in the journal "der Holzbau":

> In my opinion, the stress diagrams given for wood only apply to carpenter's constructions; there would be special provisions for modern large-span wooden constructions, in which only selected wood is used to set up.[30]

Jackson's misbelief in the standards for structural timber concerned mainly the fact that the degree of the natural defects and variability of the strength of the material cannot be fully assessed. So, in order to "get rid of the erroneous concept of viewing wood as a homogeneous body", Jackson voiced "the wish of all wood constructors", for standards for modern engineered timber constructions.

This brief comparison shows that the foundation of standardization of structural timber was differently laid in Switzerland and in Germany. The cornerstone of the process in Switzerland was identifying common ground among involved parties (both interested and affected ones). Standardization of structural timber was in line with the policies of the forestry industry for implementing a scientific outlook on the development of this commodity.

1.1. First timber norms

The debates following the first attempts towards standardization of structural timber in Germany in 1918, demonstrate that besides the bitter disappointment regarding the proposed norms by the government, there was a hopeful optimism about the role that engineered timber could play in

[28] Original text in German: "[…] Es kann für das wirtschaftliche Leben nicht gleichgültig sein, wenn in einer Zeit größter Wohnungsnot infolge des Mangels und der hohen Preise aller Baustoffe demjenigen Baustoff, der im gegenwärtigen Augenblick noch auf dem Markt ist, Fesseln angelegt werden, die er in wirtschaftlich günstigen Zeiten nicht zu tragen brauchte.". Jackson, A. "Uber die Grösse der zulässigen Beanspruchungen des Holzes im Ingenieurbau, vor allem für freitragende Holzkonstruktionen". *Der Holzbau (Deutsche Bauzeitung),* no. 3&4, 1920, pp. 9-13.
[29] Mylius. "Der neue preußische Ministerialerlass über die zulässige Beanspruchung des Bauholzes". *Der Holzbau (Deutsche Bauzeitung),* no. 3&4, 1920, p. 9.
[30] Orinignal text in German: "gelten meines Erachtens die für Holz angeführten Beanspruchungsziffem nur für Zimmermanns-Konstruktionen; es wären für die neuzeitlichen freitragenden Holzkonstruktionen, bei denen nur ausgelesenes Holz zur Verwendung kommt, besondere Bestimmungen aufzustellen". Jackson, A. (see note 28 above), p.10.

achieving an agreement for standards for structural timber. Similar concerns arose as well in the early discussions about the official timber code in Switzerland in 1925.

Engineered timber, by using basically smaller pieces of wood (regardless of the type of connections, either mechanical fastening or adhesives), entailed the possibilities of more selective use of the raw materials, increasing the chance to employ clear timber free of knots for high-stressed parts of the structure, but also to use of the lower-graded timber in the less-stressed parts of the structural member. Engineered timber appeared to be a solution against the unfortunate and simplified dichotomy of standard and non-standard material, suggested by the early norms.

A commission appointed by the SIA in September 1925 in Zurich, was assigned to prepare a first draft for the Swiss timber code. For this purpose, strength tests had been carried out at the EMPA with structural timber, in the years 1924/25. The committee to discuss the results consisted of, among others, the representatives of the polytechnic schools of Zurich and Lausanne,[31] representatives of the Swiss Federal Railways and those of Federal Railways Department[32] including Ing. Fritz Hübner, under whose supervision loading tests on early glulam structures were performed, as well as three representatives of the construction industry, including Charles Chopard and Ed. Locher, both members of the early glulam consortium.

This session was followed by wide-ranging discussions. Besides the in-depth exchange of views of the experts on the results of the tests, one of the controversial points was the question whether the norms for timber structures should become mandatory, or rather to be “subjected to an intelligent use”.[33] The reason for such a question was both economic and technical. Eng. Robert Maillart (1872-1940), a pioneer engineer in reinforced-concrete structural design, expressed his “sceptical” attitude towards the mandatory nature of the standards for timber constructions,[34] wishing that “the standards be regarded at most as a very general guide, but not as mandatory”:

> The difficulties involved in timber construction are greater than those of iron and reinforced concrete, both in terms of quality and in terms of use. Since iron and cement products are available and their production can always be arranged in such a way that quality standards can be met, their feasibility is out of the question: the contractor is required to comply with these standards, and he does so by demanding standardised goods from the supplier and obtaining them without difficulty. Timber, on the other hand, is a natural product, and I do not believe that it will be possible to get the suppliers or producers to guarantee the strength of the standards, i.e. to take back timber that does not comply with the standards and replace it. If the quality standards are demanded in building contracts, the contractor faces a significant risk due to the lack of coverage by the supplier, not only because of the lack of use of rejected timber, but also because of the loss of time caused by subsequent deliveries and new samples. The way out, that the timber can still be used under lower stresses, is not always feasible, as often ready-cut beams and boards arrive at the construction site, which cannot simply be reinforced. In any

[31] In 1925, it was École d’ingénieurs de l’Université de Lausanne. In 1944 it became École Polytechnique de l’Université de Lausanne, and in 1969 École Polytechnique Fédérale de Lausanne.
[32] The complete name was since 1879, “Post- und Eisenbahndepartement”, which actually is “Eidgenössisches Departement für Umwelt, Verkehr, Energie und Kommunikation”.
[33] Stated by prof. A. Paris, from the École d’ingénieurs de l’Université de Lausanne.
[34] He started his speech with the sentence “Verbindlichen Normen für Holzbauten stehe ich skeptisch gegenüber.“

case, last-minute project changes would result in additional dimensions and delays, thus making construction more expensive and more difficult. [35]

These tests carried out at EMPA under the direction of Prof. Roš, considering as well all the tests performed by prof. Tetmajer from in the 1880s resulted in the publication of the SIA-Norm 111 «Normen über Holzbauten» in 1926. During the same year, the first "Preliminary Specifications on Timber Constructions" was issued by the *Reichsbahn* (German Railways), which was followed in 1930 by DIN-1074 "Bridges in Wood", and eventually in 1933 by DIN-1052 "Construction in Wood".[36]

The study of the process of standardization of structural timber in Germany and in Switzerland reveals some other differences between these two countries.

When Hetzer started with testing glulam girders for its early projects, different loading tests were carried out in different institutions. His first glulam beam was tested at the Royal Material Testing Office in Groß-Lichterfelde (Prussian government district of Potsdam, now part of the Berlin district of Lichterfelde), and later tests were performed at the Technical University of Munich.[37] Moreover, other tests were conducted by prof. Gustav Lang (1850-1915) in Hannover, who was the first to do scientific experiments on wood as a construction material, before the first DIN norms for "Timber beams for small houses" was published by the Prussian Ministers of Public Works in Berlin. Eventually in 1926, the first preliminary regulations for timber structures was issued by the German Railways, in collaboration with the Material Testing Institute associated with the Stuttgart Technical University under the supervision of prof. Otto Graf (1881-1956).[38] In comparison with Switzerland, where the polytechnic school of Zurich, to which very early EMPA got affiliated and acted as the core of the scientific and technical infrastructure of the federal government, the research on structural timber in Germany was affiliated with different universities and institutions. Interestingly, it can be observed that in Switzerland, similar to the business space developed for the very early glulam, in which only few selected people but with multiple and cumulated roles in different politico-economic circles promoted this technology, the research on timber and as we will later on glulam, was pushed from the very early, into the centralized federal research and development infrastructure of the country, the ETH Zurich and the EMPA. Major overlaps between these two spheres, (by the personalities like Charles Chopard, both Ed. & F. Locher, one involved in establishing timber code, and one involved in the development of early synthetic glue, as we will see in the following part,

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35 "Zum Schluss möchte ich also wünschen, dass einerseits Holzversuche – an Material und Verbindungen – mehr als bis jetzt gepflegt werden möchten, dass je doch die Normen höchstens als ganz allgemeine Wegleitung, nicht aber als verbindlich angesehen werden möchten." (translated from Germany by the author). Roš, Mirko. *S.I.A. Normen für Holzbauten. Ergebnisse der Festigkeitsuntersuchengen an der E.M.P.A. mit bauhölzern, in den Jahren 1924&1925 als Grundlage für die Normen des S.I.A.* Zürich, EMPA, report no. 5, 1925, pp. 13-14.

36 For more about the development of Germany's timber norms see Seraphin, Mathias. "On the origin of modern timber engineering". *Proceedings of the First International Congress on Construction History: Madrid, 20th-24th January 2003, in Madrid,* edited by S. Huerta, Madrid, Instituto Juan de Herrera, ETSAM, 2003, pp. 1845-1854.

37 Adams. "Neuere Holzbauweisen". *Zentralblatt der Bauverwaltung*, no. 21, 1907, pp. 147-148.

38 For a complete list of the involved universities and institutions see Rug, Wolfgang. "100 Jahre Forschung für den Holzbau". *Deutsche Gesellschaft für Holzforschung,* no. 95, 2006, pp. 33-50.

Ulrich Meister, etc.), resulted in a parallel and reciprocal development of the early technology in these two spheres.

Until the early 1930s, individuals and institutions endeavoured to research and test structural timber more intensively, and other engineered timber structures like nail and ring dowel constructions were in practice and in research.[39] It was principally by the industrialization of the natural glue, and afterwards its synthetization, that glulam became eventually in the late 1930s and the early 1940s, the dominant engineered timber construction of the market, and the standardized and industrialized version of natural timber.

1.2. The Chemical Age

The first world war demonstrated that the chemical industry was in fact the cornerstone and the basic component of military and state power, and the need for strong national chemical industries became evident.[40] "The chemists' war" of 1914_1918,[41] brought together the university chemists, professional chemical institutions, the manufacturers and the government chemistry and acted as a catalyst in the development of chemical know-how.[42] It had also a decisive role on the international relations. To illustrate this situation, the example of the relation between America and Germany can be used, that was marked with considerable tensions. Despite many diplomatic relations between these two countries, a hostile attitude particularly towards the German chemical industry could be then recognized. Regarding the chemical plants of Germany as espionage stations, the project of "De-Prussianization of the Chemical Industry" in America was launched right after the war.[43] The fight of

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[39] Nail and ring dowel constructions were everywhere. The joining techniques were also researched and tests began on entire building components. In Switzerland, to a lesser extent than in Germany, tests on mechanical fastenings, particularly ring dowels were performed. See Schaechterle, K. "Die VorIaufigen Bestimmungen fiir Holztragwerke (BH)" der Deutschen Reichsbahn-Gesellschaft". D*ie Bautechnik*, vol. 5, no. 2, 1927, pp. 21-23, 84-87. – Schaechterle, K., „Bauholz Verbindungen". *Der Holzbau*, no. 23, 1920, pp. 89-92. – Schaechterle, K., „Bauholz Verbindungen". *Der Holzbau*, no. 24, 1920, pp. 93-96. Lewe. "Die Berechnung des gesechtlitzten Ringdübels". *Der Holzbau*. No. 20, 1920, pp. 77-80. For the Swiss case see: Chopard, Charles. "Festigkeits-Versuche an Holzverbindungen mit abgestuften, geschlossenen Ringbündeln". *Schweizerische Bauzeitung,* vol. 95/96, no. 8, 1930, pp. 99-103, 117-120.Terner and Chopard as well registered a patent "*Knotenpunktverbindung für Holzkonstruktionen*", which was in fact a variant of ring dowel connections. These tests were mainly promoted by the owner of the patents of engineered timbered structured, in order to, among other scientific reasons, advertise effectively their product in the technical journals. Terner & Chopard. *Knotenpunktverbindung für Holzkonstruktionen*. patent no. 106496, CH, 17.09.1923.

[40] *Determinants in the Evolution of the European Chemical Industry, 1900-1939: New Technologies, Political Frameworks, Markets and Companies*, edited by Anthony S. Travis et al. Dordrecht, Springer Netherlands, vol 16, 1998, pp. xi-xii.

[41] Pilcher, Richard. "Chemistry in Wartime". *The Journal of Industrial and Engineering Chemistry*, no. 9, 1917. Richard Pilcher, registrar and secretary of the Royal Institute of Chemistry of England, used the phrase, 'the chemists' war' to describe the First World War.

[42] MacLeod, R.M. "Chemistry for King and Kaiser: Revisiting Chemical Enterprise and the European War". (see note 40 above) pp. 25-50. Citation on page p. 27. Nevertheless, it should be emphasized that the chemical industry was not bigger in the interwar period, only its significance was substantially different. During the interwar period, market growth in chemical product was even much slower than before 1914.

[43] Garvan, Francis P. "Report of the Alien Property Custodian. Review of the Report, with a Summary of the Enterprises in the Field Taken Over by the Government- The De-Prussianization of the Chemical Industry". *Chemical Age*, vol. 1, no. 1, 1919, p. 11.

the supremacy over the chemical industry, marked the interwar decades with considerable international tensions.

In this context, by sharing common bonds of language, backed with a historical tradition in university exchange between the Southern Germany and the German speaking part of Switzerland, particularly the strong historical connection in the subject of material research, these two countries collaborated closely, particularly in the 1930s, in the process of development of chemical products, including the synthetic adhesives. Early systematic and academic research in the chemical fields, similar to the timber engineering (discussed in the first chapter), was a German and Swiss affaire. (see Appendix 5.1).[44]

Before discussing the role of synthetic glue in promoting glulam, a brief overview of its previous natural alternatives will be discussed. The description of the patent provided by Otto Hetzer while submitting his patent for glulam in Great Britain in 1906 did not include technical information about the ingredients of the glue, neither its production process:[45]

> […] the surfaces intended to adhere to each other having been coated with a mastic for producing intimate adhesion and which when dry is impervious to and unaffected by moisture or atmospheric influences; this mastic consists of one part of milk of lime well mixed with about ten parts of albumen or cheese which has been compound elements thus produced will when the mastic is dry and after removal from the mold retain their curvature and shape without warping while the adhesion of their constituent parts is secured. In many cases the element is composed partly of beech and partly of pine pieces. [46]

However, it is known that "the purchase of the license included a two-month course at the Hetzer factory in Weimar, and a set of detailed technical instructions for all production aspects, including the recipe for the glue".[47] The patent, however, made a big claim about the glue, "complete resistance to atmospheric influences",[48] and indeed opened the way to such early large-span glulam structures. Initially it was indeed believed that the early glue was "water-proof", otherwise it can hardly be explained that an uncovered bridge with a span of 33 m, as one of the earliest glulam projects in

[44] For this relation see: Tanner, Jackob "The Swiss pharmaceutical industry: the impact of industrial property rights and trust in the laboratory, 1907-1939", in *Determinants in the Evolution of the European Chemical Industry 1900–1939,* edited by Anthony S. Travis et al. Dordrecht, Springer Netherlands, vol 16, 1998, pp. 257-271.

[45] The amount of information and details given in the patents registered in different countries, differed considerably. In the patent registered in Switzerland and in Germany, there is no detail about the glue, except that it is waterproof. The patents registered in France and in Great Britain, give more detailed information about the ingredients of the glue.

[46] Hetzer, Otto. *Improvements in Composite Wooden Structural Elements applicable for Roofs, Barns, Ladders, Lattice Work, Furniture and other Structures*. Patent no. 20,684. Great Britain. Date of Application 18th Sept., 1906.

[47] Rusak, Mariya. FACTORY-MADE: the everyday Architeture of Moelven Brug, 1955-1973. PhD dissertation, The Oslo School of Architecture and Design, 2022, p. 46.

[48] vollkommene Wiederstandsfähigkeit gegen atmosphärische Einflüsse. *Neue Holzbauweisen, system Hetzer*, Hoch- und Tiefbau, schweizerische Baumeister und Zimmermeister Zeitung,1910, pp. 146-147.

Switzerland, was built as early as 1911 (Fig. 2).[49]

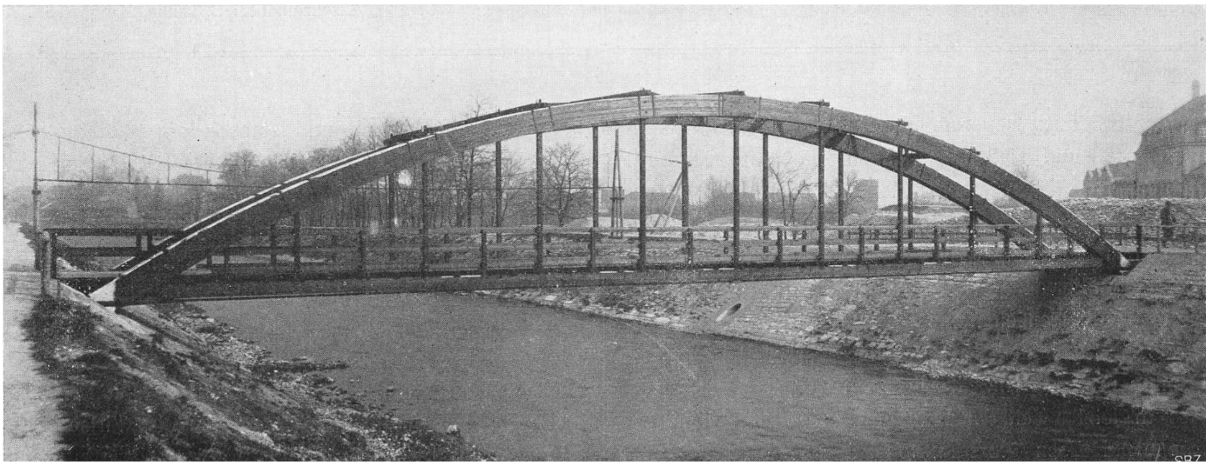

Fig. 2 Glulam footbridge in Wiese near Basel, contractor: Riesterer-Asmus, 1911.

The early glue used for the production of glulam was casein glue.[50] Its industrial production in Switzerland dates back to 1915, when the trademark "Certus", was registered by the company "Kaltleim-Fabrik O. Messmer", founded in Basel in 1913.[51] The cold-glue product of the company introduced under the name "Certus Normal", with a simple production recipe of "1 kilo of powder, for two litres of water" once prepared, could be used within 12-14 hours which did not need to be warmed before application, and it could be applied at open-air on the construction site, as claimed in the sales brochure of the company.[52] The significance and success of this product can be understood better when we consider that the first cross-Atlantic non-stop flight in 1919 was completed by flying an airplane whose composite-wooden part was made with Certus glue (Fig. 3).[53]

Until the introduction of synthetic glue in the late 1930s, no significant development in industrially produced casein glue can be observed (see Appendix 5.2).

[49] Between 1908 and 1919, casein glue was used in the construction of Schütte-Lanz's airships. Brockmann Walter, et al. *Klebtechnik, Klebstoffe, Anwendungen und Verfahren*. Wiley-VCH., Weinheim, 2005.
[50] Kühne, Helmut. "70 Jahre geleimte Holz-Tragwerke in der Schweiz". *Schweizer Ingenieur und Architekt*, vol. 97, no. 32-33, pp. 577-593, particularly page 577.
[51] Gribi & Cie., in a letter explains to Max Steinhaus that "at the end of Casein period, the most of this glue was manufactured by Geistlich, Wolhusen. Max Steinhaus archives (see note 9 above), Hs 1198.54. See as well: Schumacher, Hans, et al. *Hundert Jahre Ed. Geistlich Söhne AG für chemische Industrie, 1851-1951 : [Jubiläumsschrift]*. [Ed. Geistlich Söhne AG], 1951, pp. 32-34.
[52] Certus' company catalogue, Emil Birkhäuser & Cie., Basel (no publication year). (catalogue can be found in the Max Steinhaus archive, Hs 1198.54).
[53] For the broad use of this glue in the aeroplane industry see: Boulton, B. C. "the manufacture and use of glues in aeroplane construction", *Aerial Age Weekly,* 1919, pp. 452-453.

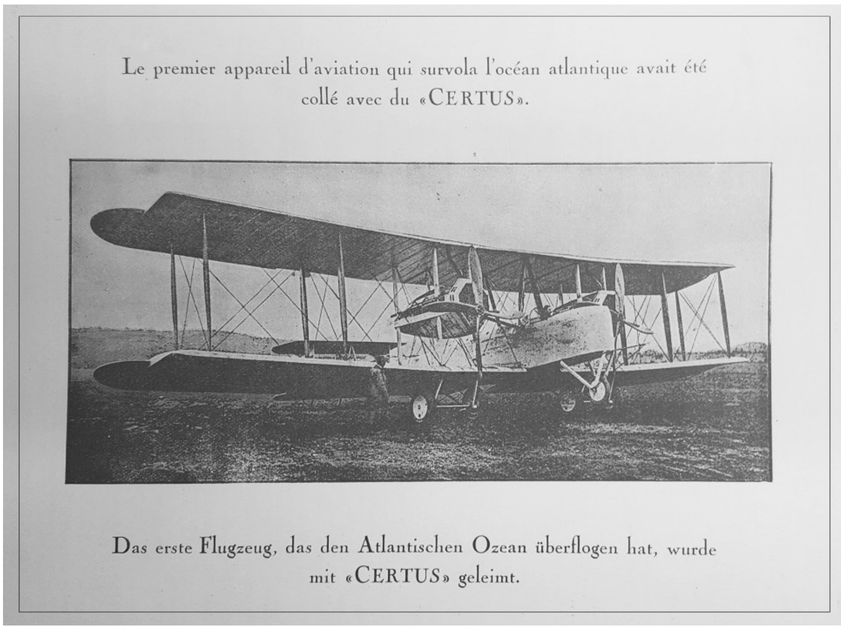

Fig. 3 Advertisement of the "Certus" glue, illustrated with the first airplane crossing Atlantic non-stop fly in 1919.

1.3. Glue and timber: crossed paths

Leading figures of different trades related to wood, for several reasons had to gather, in the 1930s, in order to find a solution to promote the use of wood in construction which was experiencing then a strong decline. This decline was partly due to the global economic crisis of the interwar period, particularly the Great Depression of 1928, which lowered the construction industry in general. As a consequence, the activity of the timber workshops, glulam manufacturers, forestry workers, and all the professions linked to wood calmed down, compared to the stormy days before the war. The activities of the EMPA demonstrate that the interest in research on structural timber followed the same trend as in the market.[54] The need and hardship of the forestry and timber industry at this time triggered courageous steps towards self-help, resulting in the establishment of an interest group called Lignum in 1931.[55] The organization's goal was to promote wood sales, in all relevant branches of the industry, through advertising, consulting, technical documentation, and public relations.

This hard time for timber either in the market or in the research laboratories coincided with the growing interest in the synthetic chemicals that shaped the 1930s as the most important decade in the composites industry. Until then it was almost clear that the use of natural glue could not go beyond indoor uses, and for sure not in civil projects in open spaces or demanding environments. As an

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[54] Number of clients who commissioned EMPA for tests on structural timber in 1925, was only 25%, 10% and 13 % of the number of clients for Hydraulic binders (cement and mortar), brick and chemical analysis respectively. This amount reduced to 2%, 4%, and 5% in 1926. See: Roš, Mirko. „Tätigkeit der Eidgen. Materialprüfungsanstalt an der E.T.H. in Zürich 1926", *Schweizerische Bauzeitung,* vol. 89/90, no. 24, 1927, p. 319. This trend is not limited to Switzerland. In the International Congress of the IVMT (International Association for Material Testing in Technology) held in 1927, there were three sections: 1. Metals, 2. Cement, stone and Beton 3. Diverse. And in this group called diverse, wood is studied besides other chemicals such as oils and anti-rusts.

[55] Tromp, Hermann. *Lignum 1931-1981: ein Bericht der Lignum, Schweizerische Arbeitsgemeinschaft für das Holz: wie die Lignum entstanden ist und wer sie geprägt hat; ihre Tätigkeiten gestern, heute und auch morgen*. Zürich, 1981.

example, surviving archival documents demonstrate the interest of the Swiss army in the glulam structure for its bridges exposed to the water, however, the low-quality glue dissuaded the army from this project. In 1931, the War Technology Department of the Swiss Federal Military Department, conducted a water test on a glulam piece that was supposed to be used for a bridge project. The results were not satisfying at all: "after only one month, however, the individual lamellae that had been glued together became detached from each other […].", the army stated in its letter to the contractor. In order to prepare the glulam sample provided by Nielson Bohny & Co. for the test, the army decided to cut it in two pieces, during which they realised that the lamellas have been nailed together, which, according to the letter could "give rise to misconceptions about the durability of the gluing". The army apparently was not aware of the existence of these nails. They got aware of "this unprofessional work", while cutting the sample in two pieces, where subsequently "a whole number of cutters were ruined by the nails".[56] Development in the quality or the composition of glue therefore seemed necessary in order to promote glulam as a reliable choice, regardless of the environment conditions to which the structures were to be exposed.

Chemistry was central to Nazi endeavours. With the depleted reserves of raw materials, chemists played a major role in developing and improving techniques for producing synthetic alternatives for many materials, even for petrol and coffee. The same applied to the casein glue which was largely used, among others, in the aircraft industry. Besides its poor performance in demanding environments (both in aviation and building industries), the fact that acquiring raw material for the industrial-scale production of casein glue was problematic, pushed the laboratory-based production of a synthetized substitute for natural glue.[57] Moreover, as Straumann and Wildmann demonstrate in their study on the *Swiss Chemical Enterprises in the «Third Reich»*, during the Nazi period, Germany represented an increasingly important and lucrative market for Swiss firms, including the *Gesellschaft für Chemische Industrie Basel* Ciba AG, (Swiss Society of Chemical Industries), the main developer of synthetic adhesives in Switzerland.[58]

In various respects, 1939 was a decisive point in glulam and generally in wood-composite construction. The common research of Switzerland and Germany on glue and timber, got intensified by the outbreak of the second world war. At this time (from 1918 to1951), Ciba and the two other key chemical companies Geigy and Sandoz formed the so-called *Basler Interessengemeinschaft* (Basel Common Interest Group), which developed into a very far-reaching cartel.[59] The research conducted by an Independent Commission of Expert, examining the links between the Swiss chemical industry

[56] Eid. Militärdepartement, Krigstechnische Abteilung. "Hetzerkonstruktion, Ausführung Nielsen Bohny & Co." 20 June 1930. Schweizerisches Bundesarchiv. Dossier E5480A #1970/325#3332* (*Festigkeitsproben mit Hetzer Ganzschwellen*)
[57] The shortage of milk in post-WWI Germany had a significant impact on the production of casein glue. This have been reported as a contributing factor in Hetzer's decision to exit the glulam business in 1926. Rusak, Mariya. *FACTORY-MADE: the everyday Architeture of Moelven Brug,1955-1973*. PhD dissertation, The Oslo School of Architecture and Design, p. 307.
[58] Straumann, Lukas, and Daniel Wildmann. *Swiss Chemical Enterprises in the «Third Reich»*. Independent Commission of Experts Switzerland – Second World War (ICE), Zürich, Chronos, 2001.
[59] Degen, Bernard,"Ciba", *Historisches Lexikon der Schweiz*. Schwabe, Basel, 2004.

and the Third Reich, demonstrate that these companies were "the only major non-German dye- and pharmaceutical-producing companies to own factories and operate in National Socialist Germany between 1933 and 1945".[60] As shown earlier, the research collaboration in material research in general, and specifically in the adhesive field was as well strongly followed in form of collaboration between the two countries.

The Wood Department of EMPA was founded in 1942.[61] Besides the main focus on the most important strength parameters of local timber, fundamental studies were carried out on the gluing of load-bearing components with synthetic glues.[62] In the years 1943-1945, EMPA, being commissioned by Ciba, carried out different tests on the Melocol glue that was then approved by the timber industry as the synthetic glue used for glulam.[63] As demonstrated in the third chapter, the SBB engineers developed the first guideline for the fabrication of glue-laminated timber structures. Published as a formal institutional publication (*SBB Bestimmungen für geleimte Holzkonstruktionen*), their guidelines were complemented and enriched by the tests performed by the EMPA in 1943-1945 and was eventually published in 1945, as *EMPA Rechtlinien für geleimte Holzkonstruktionen*.

The timing of the development of synthetic glue was favorable to the timber industry, inasmuch as relevant interest groups, as discussed earlier, were already successful in rising the status of structural timber, promoting its use and the research on it in the 1930s. Following the development of glue mainly for military purposes, glulam revealed great potentials for development, and therefore intensive public-relations effort and marketing campaigns were organized towards the use of timber as structural material and promoting glulam as the state-of-the-art engineered timber (Fig. 4).[64]

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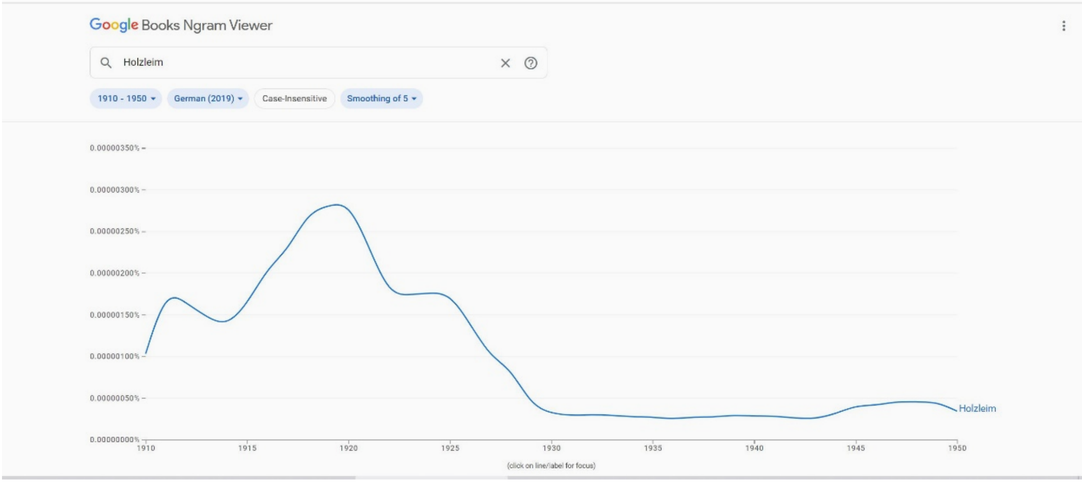
[60] Straumann, Lukas, and Daniel Wildmann. *Swiss Chemical Enterprises in the «Third Reich»*. Independent Commission of Experts Switzerland – Second World War (ICE), Zürich, Chronos, 2001.
[61] Jürgen, Sell, and Erwin Graf. "Forschung und Weiterbildung für die Holzwirtschaft : Aktivitäten der EMPA Dübendorf und St. Gallen". *Schweizerische Zeitschrift für Forstwesen*, vol. 140, no. 10, 1989.
[62]Jürgen, Sell, and Ulrich Meierhofer. "50 Jahre EMPA-Abteilung Holz - 50 Jahre für das Holz". *Schweizer Ingenieur und Architekt,* vol. 105, no. 14, 1987, p. 351.
[63] Kühne, Helmut. "Die Kunstharz-Melocol-Leime". *Schweizerische Bauzeitung*, vol. 127/128, no. 4, 1946, pp. 46-47.
[64] In 1933, Lignum in collaboration with the SVMT *(Schweiz. Verband für die Materialprüfungen der Technik)* under the presidency of Mirko Roš, organized at the ETH Zürich a conference, named "Wood conference", in "an effort to promoting the rational use of glue in the timber industry", the organisers, give opportunity to different research and professors from Switzerland and Germany, to discuss their latest findings in the reals of glue-laminating. Structural timber, after a quasi-absence of almost half a century from academia, started to appear in the building material courses as a "progressive" material. The doctoral thesis of Emil Staudacher "*Der Baustoff Holz*", done at ETH Zurich in 1936 under the supervision of Mirko Roš, was one of the early fundamental research appearing in academia in this field. In the same year, Staudacher leaded a program at the EMPA with the task of designing and carrying out a comprehensive programme to research the properties of Swiss construction timber.

Fig.4 Advertisement for the synthetic glues developed by CIBA, appearing on the cover page of the Association of Swiss Mastercarpenters' journal. This glue was used for the glulam structure of the building of the Trade Fair of Basel in 1943.

The significant role of glue in the promotion of glulam in the 1940s, when synthetic glue replaced to a large extent the natural one, can be partly understood by the shift in the terminology used to describe glulam, where glue was celebrated as the representative material of glulam, outshining the timberness of this composite material.

In his speech entitled "*die Bedeutung der geleimten Bauweise […]* (the significance of glued structures […])" held in 1945 at SVMT, Mirko Roš (President of the EMPA 1937-1949, and the SVMT 1926-1949), discussed the importance of glulam structures by referring to "glued structures". In the *Holzbau Taschenbuch* (timber construction pocket guide) of 1948, the chapter dedicated to glulam is entitled *Leimbauweisen* (glued structures).

According to the Google Ngram Viewer charting the frequencies of the use of the terms *Holzleim* and *Leimbauweisen* in the period 1910 to 1950, it can be demonstrated that from the early 1940s, the word glue dominated the term designating glulam structures, at the expense of timber, in *Holzleim*.



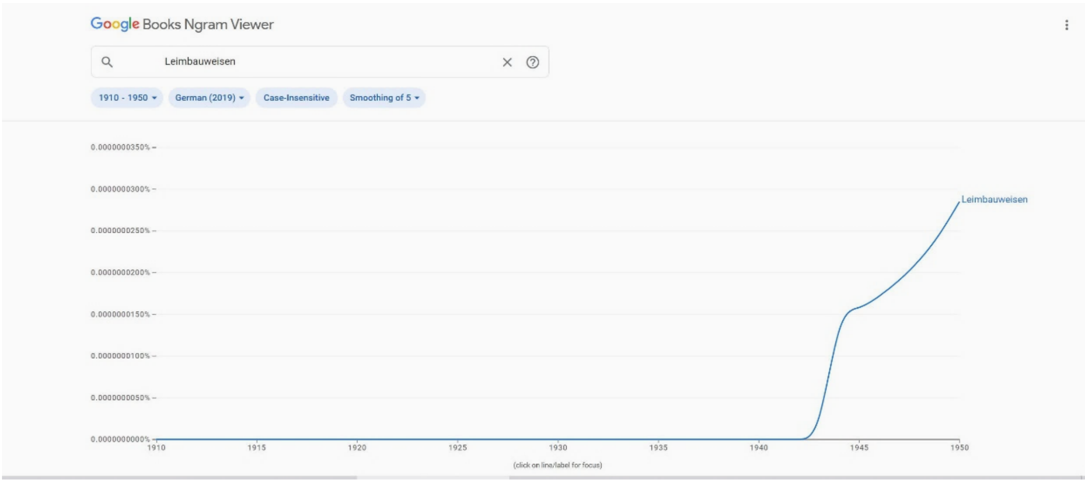


Diagram 5.1 Google Ngram Viewer, frequency of the use of *Holzleim* in German literature, period 1910-1950.
Diagram 5.2 Google Ngram Viewer, frequency of the use of *Leimbauweisen* in German literature, period 1910-1950.

Here a word should be said about the development of the early licensed glulam contractors, parallel to the development of the glue. The general contractors, namely Fietz & Leuthold and Locher & Cie. continued using glulam in their projects (more intensely after the introduction of the synthetic glue). The other contractors, as we saw in the third chapter, either disappeared during the economic recessions of mid-1970s and early 1990s, or were taken over by the company Häring. It is interesting to note that the surviving carpenter-contractors of the Hetzer consortium founded by Terner and Chopard (namely Zöllig and Gribi & Cie.), were acquired towards the end of the 20th century, by a company based in Basel, the canton hosting and representing the chemical industry in Switzerland.[65] Glulam, starting from carpentry workshops with their long and rich tradition in craftsmanship, moved towards the vicinity of the chemical plants, and the producers of glue.

The carpentry shop Häring & Co. of the master carpenter Christian Häring (Born 1842) was established in 1877 in Pratteln near Basel. Being located near the industrial area Schweizerhalle, the carpentry shop could benefit from the regular orders of the chemical plants for new industrial

[65] At that time the Ciba company was located in the canton Basel-Stadt and the Häring company was located in the canton Basel-Land. In the years 2011-2012 this company was transferred from Canton Basel-Land (Pratteln) to the Canton Aargau (Eiken). The debates behind this move, can be traced in the journals, among others, Basler Zeitung and Basellandschaftliche Zeitung, years 2011-2012.

buildings. Moreover, based on the dairies of Christian Häring, the developer of the synthetic glue, colonel Karl Frey at Ciba AG, and Christian Häring met each other in the army, when the latter returned to active service in 1941 as a young lieutenant and had as his supervisor, Karl Frey.[66] It was at this time, that it was decided to open up the company, through glulam, to new areas of activity.[67]

1.4. Ersatz or Heimstoff?

Although from the early years and for several reasons discussed in the previous chapters, glulam has been mainly used as an alternative mainly for steel, it was however, thanks to the introduction of the synthetic glue, that glulam was officially advertised as a high-performance composite material, an equivalent substitute to steel.[68]

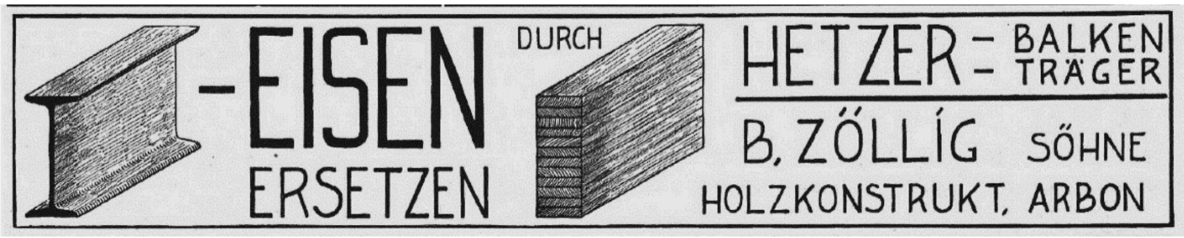


Fig. 5 Zöllig's company advertisement for glulam, 1942.

In an advertisement published by the company of Zöllig in 1942 (Fig. 5), two portions of beams one in iron and one in timber are compared. The same height, width and the same perspective to depict these beams, reinforced the attempts to promote glulam as equivalent material to iron (steel) with all the advantages that it offered as a robust and "fixed" material, over timber as a natural and "variable" one. The advertisement reads "Eisen durch Hetzer Balken ersetzen" (Substitute iron with Hetzer beams).

The German word *ersatz* was commonly used, particularly during the second world war, to refer to an "artificial and inferior substitute or imitation".[69] The use of the word *Ersatz* to describe a material during the Third Reich such as in *Ersatzkaffee, Ersatzbenzin*, etc., as the historian Helmut Maier explains,[70] was banned, because of its negative connotation as an inferior material. Several of these Ersatz materials, according to Maier, were banned to be called so, during the Nazi government. The list of banned words to be distinguished as Ersatz, included aluminium, and some other alloys, but also

[66] The project of development of the synthetic glue during the second world war (1943-1945) at the EMPA and in collaboration with Ciba, was conducted under the leadership of Colonel Karl Frey (1900-1974). Doing his PhD thesis, jointly between ETH Zurich and the University of Freiburg am Breisgau, Karl Frey collaborated closely in these two cities with the Nobel Prize winner Professor Hermann Staudinger and took part in his basic research in the field of plastics as his assistant. He entered the service of Ciba AG, Basel, in 1927, at the plastics department, where he became later the director in 1955. *Basel-Stadt* journal, Oct. 1974.

[67] https://www.haring.ch/assets/Downloads/Web-Haering-Buch.pdf

[68] For timber as a surrogate material see Rinke, Mario. "Konstruktive Metamorphosen-Holz als immerwährendes Surrogat". *Holz: Stoff oder Form.Transformationen einer Konstruktionslogik,* edited by Mario Rinke and Joseph Schwartz. Sulgen, Niggli, pp. 263-277.

[69] Merriam-Webster dictionary, "Ersatz".

[70] Maier, Helmut. *Forschung als Waffe : Rüstungsforschung in der Kaiser-Wilhelm-Gesellschaft und das Kaiser-Wilhelm-Institut für Metallforschung 1900-1945/48*. Göttingen, Wallstein-Verlag, 2007, pp. 365-368. - Maier, Helmut. "New Age Metal" or „Ersatz? Technological Uncertainties and Ideological Implications of Aluminum up to the 1930s". *ICON 3*, 1997, pp. 181-201.

plywood glued with synthetic resin. The word *Heimstoff* was suggested, and used thereafter to described the domestic produced materials.

The synthetic glue, and hence glulam, benefited from a historical context in Germany and Switzerland, where the use of this material, was promoted as both *Ersatz* and *Heimstoff*. It was definitely an Ersatz, to replace steel in the wartime scarcity of iron and a *Heimstoff*, where the synthetic glue and timber were both local materials processed with the local knowledge both in timber construction and in the chemical industry.

2. Synthetization, a paradigm

For a better understanding of the significance of synthetization of glulam in its rapid development in the early 20th century, it is essential to study glulam in the wider historical context of the principal techno-economic commodities that shaped our built environment. This study helps to explain why the chemicalization of the early glulam was an important step towards the spread of the technology, compensating the prejudices and misconceptions that created a distorted image of timber as a structural material.

The concept of techno-economic paradigms, as background forces that define technological opportunities and possible ways to exploit them, as well as the notion of paradigm changes have been subject of broad studies, developed in the 1980s by Giovanni Dosi,[71] Carlotta Perez, and Christopher Freeman.[72] The below table which is developed by the two latter scholars, demonstrates how different commodities dominated, guided, and shaped different periods of modern history, until the new millennium, where timber stands again as "the construction material of the 21st century".[73] It also serves to explain in the latter part of this chapter, the transformation of attitudes towards both glue and timber in the recent decades, to shed light on the state-of-the-art today, and also to discuss possible alternatives for the future of glulam.[74]

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[71] Dosi, Giovanni, "The Nature of the Innovation Process". *Technical Change and Economic Theory*, edited by Giovanni Dosi et al, London, Pinter, 1988, pp. 221-238.

[72] The origin apparently dates back to a paper co-authored by Freeman Christopher and Carlota Perez, presented at the conference on Innovation diffusion, held in Venice in 1896, entitled "The diffusion of technical innovation and changes of technological paradigm". Not having access to this paper, this thesis is based on the further publications of Perez, particularly on those mentioned in the footnote below.

[73] Natterer, Julius. "Naturel et construit, le bois cumule les vertus." *Ingénieurs et architectes suisses*, vol. 128, no. 12, 2002, p. 26–31.

[74] These background forces that set the pattern for paradigms, is closely linked to the concept and notion of progress ideology developed by Schatzberg, Eric. *Wings of Wood, Wings of Metal: Culture and Technical Choice in American Airplane Materials, 1914-1945*. Princeton, New Jersey, Princeton University Press, 1999.

Techno-economic paradigms	
Eras	Key commodities
Pre-industrial society	Wood
The industrial revolution	Iron
Age of steam and railways	Iron, coal
Age of steel, electricity, and heavy engineering	Copper
Age of oil, automobile and mass production	Oil
Age of ICT (Information and communication technology)	Oil, data
Industry 4.0 (Fourth Industrial Revolution)	Data, renewables

Table 5.1 Techno-economic paradigms shaping different periods of the modern history[75]

As summarised in this table, before the industrial age, timber has been the structural and engineering material, for building and machine making, an era with "decidedly wooden character".[76] The contribution of wood to human history has been so fundamental, that the German historian Joachim Radkau, by referring to the "wooden basis of human history", narrates indeed an early history of civilization through this material.[77] Followed by the Industrial Revolution and later the age of steam and railways, iron and coal replaced wood. Coal, initially being used as fuel, revealed new potentials. Coal-tar, once the "unfortunate refuse" and a by-product of the processed coal, could be used for the production of a host of new medicines, dyes, resins", etc. The importance of this discovery promoted then chemistry to the "basic industry of civilization".[78] This transition, from the age of coal to chemicals, played a substantial role in setting the patterns for technological developments. The early development of glulam coincides then with the arrival of the chemical age.

Assisting the transition from the organic to synthetic chemistry, oil then led the way towards the age of mass production, until the 1970s where a turning point in the technological paradigms happened: the oil crises of 1970s, inspired the first waves of environmental awareness and advocacy, giving rise to a suspicious sensation toward oil as the main commodity, which resulted in the following decade in the concept of sustainable development. From the end of the 20th century, driven by a growing concern in CO_2 emissions, but also new hopes and opportunities brought about by the introduction of the computers in the 1980s in the interest of the sawing industry, a new wave of revival of structural timber was triggered. Articles such as "Das Holz hat Zukunft",[79] "optimism is justified",[80]to mention only a few, demonstrate the cultivation of an optimistic attitude towards this commodity. Wood since

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[75] The table is developed based on Perez, Carlota. "Technological revolutions and techno-economic paradigms". *Cambridge Journal of Economics,* 2010, vol. 34, no. 1, pp. 185–202. This table has been further developed by the author, by adding the first raw "Pre-industrial society", and by adding the last raw "Industry 4.0", according to Schwab, Klaus. *The Fourth Industrial Revolution*. Portfolio Penguin, London, 2017. With the same approach, Lewis Mumford has also classified in *Technics and Civilizations* the civilization eras, according to their states of technics.
[76] Sombart, Werner. *Der moderne Kapitalismus; historisch-systematische Darstellung des gesamteuropäischen Wirtschaftslebens von seinen Anfängen bis zur Gegenwart*. München, Duncker & Humblot, 1919, Vol. 2, p. 1138. Original citation in German: "daß die Kultur vor dem 19. Jahrhundert ein ausgesprochen hölzernes Gepräge trägt".
[77] Radkau, Joachim. *Holz Wie ein Naturstoff Geschichte schreibt.* Munchen, oekom verlag, 2018, p. 19. Original citation in German: "hölzerne Grundlage der Menschheitsgeschichte".
[78] "Chemical age". New York, Western Editor, 1919, v.1 no.1, voreword.
[79] "Das Holz hat Zukunft". An event organized on the occasion of the 100th jubilee of the Schweizerische Sägerei- und Holzindustrie-Verband. Thurgauer Zeitung, Frauenfeld, no. 243, 18 oct. 1994.
[80] "optimism is justified". *Der Bund*, Bern, no. 239, 13 oct 1986.

has regained an important place in building construction, until now that timber construction (principally in form of glulam, despite rising concerns about the environmental considerations of glue), is experiencing a new heyday and the 21st century is a new century of timber construction.

This rapid historical overview of the commodities that shaped our technological landscape and built environment, demonstrates a whole century absence of timber among the main commodities. The reason for its revival, however, is linked to the way that glulam contributed to putting forward a new perception and a new identity for structural timber.

The identity of glulam in its historical context is complex and multi-layered with notions of nature, composite, technology, modernity, culture, craft, or industry. These notions signify a hybrid nature of the material: embodying both natural and synthetic features at the same time. The synthetization, however never influenced the early perception of the material, whose popular image always stood for timber. This was indeed a reason for its early acceptance from its early days. Glulam appeared at the time when all the fundamental arguments for and against the use of iron and concrete in architecture were deployed.[81] Unlike these materials that have been subject of intense, critical, and passionate debates, mainly over their architectural and representative use, glulam did not raise critical arguments, and the public hardly ever maintained an air of reserve toward glulam as new material.[82] Although being understood as new and modern material and a replacement for iron, glulam always enjoyed an aesthetic sense conditioned by the centuries-old natural timber. This early acceptance of the new material has been one of the main reasons why glulam could readily get established within the construction culture of the time.

The synthetization, not only did not perpetuated the early acceptance of the material, but also it did have a decisive role in sustaining an operating network of interested parties in glulam. When timberness became a barrier, the synthetic component became a driver. The center of interest being shifted from timber to glue, glulam could get linked to the chemical age and benefit from all the infrastructures, perspectives and pattern for development, knowledge, (but also shared misinformation and prejudices), shared set of premises and assumptions, mass of lobbies and propaganda campaigns, shared norms and governmental policies, and shared potential clients that altogether shaped this age. The same agendas, half a century later, started to question the legacy of the chemical age.

This conclusion reveals another understanding of the relation between the material-technology and its drivers. Similar to the final discussions of the second chapter, on the impact of the nature of the material on transforming the very relation between the material and the workers, resulting in the rapid

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[81] Examples for concrete: Mecenseffy, Emil von. *Die künstlerische Gestaltung der Eisenbetonbauten : Ergänzungsband 1.*, Berlin, Ernst, 1911. For iron: Perception of iron as a structural material: Lux_Ingenieur-Aesthetik_1910.

[82] Gottfried Semper, Der Stil in den technischen und tektonischen Künsten oder praktische Ästhetik. 2 vols. Frankfurt am Main: Verlag fur Kunst und Wissenschaft, 1860. This was not the case for iron for example. Semper had a negative attitude toward the extensive architectural use of iron. He was considering it as a dangerous idea to apply iron construction to monumental buildings.

taken up by the capitalist production system, once again it can be seen that the material itself played a decisive role in its development by influencing the involved parties. The composite nature of the material, standing both for chemical and natural, oriented the identification of the material towards one of these poles that set the paradigms and aesthetic and ethic canon for technological development.

2.1. the outdated modern

Collective concerns about the synthetized materiality of our environment in the second half of the 20th century, influenced consequently the attitudes towards glulam as a partly-synthetic composite material. At the same time, glulam was merely the only existing format of structural timber for large-scale structures, and almost the only candidate for pioneering building material for the project of decarbonization of the world. Environmental awareness affected both components of glulam, not only glue but also timber. Regarding glue, it was mainly the material itself, which became the subject of debate on its impact on the human body and on the environment, and its end-of-life disposal, reusability, recyclability and overall sustainability. Regarding timber, however, it was our understanding and our attitude toward the material and its manipulation, that faced new interpretations.

2.2. Glue

The researchers responded to the rising concerns about synthetic glue by following approaches:

1. Reducing the poisonous ingredients of glue or replacing the synthetic glue with natural ones, influenced by the bio-sources chemistry;[83]
2. Promoting adhesive-free laminated timber, using mechanical fasteners, such as dowel laminated timber;[84]
3. Eliminating the adhesive by the transformation of lignin, rendering it as an adhesive itself, like wood-welding.[85]

Research on this area is well-established, and possible alternatives to the actual glue are being investigated.

2.3. Timber

Contrary to glue that has been much debated and criticized by scholars, the perceptual change and the attitude shift regarding the other component of glulam, namely timber, have been less academically formulated and debated.[86] Although the current discourses related to both materials are mainly centered on the relationship between human and nature, the perspective towards this relation are however different. If in the case of glue, it is mainly the impact of the synthetic glue on human and

[83] For a summery see: Raydan, Nidal Del Valle, et al. "Recent Advances on the Development of Protein-Based Adhesives for Wood Composite Materials-A Review." Molecules (Basel, Switzerland), vol. 26, no. 24, 2021, p. 7617– also see: Pizzi, A. "Recent Developments in Eco-Efficient Bio-Based Adhesives for Wood Bonding: Opportunities and Issues." *Journal of Adhesion Science and Technology*, vol. 20, no. 8, 2006, pp. 829–846.
[84] Sotayo, Adeayo, et al. "Development and Structural Behaviour of Adhesive Free Laminated Timber Beams and Cross Laminated Panels." *Construction & Building Materials*, vol. 259, 2020.
[85] See Stamm, Bernhard. *Development of Friction Welding of Wood : Physical, Mechanical and Chemical Studies*. Dissertation, EPF Lausanne, no 3396, 2006.
[86] As a recent example of research on this topic see: Rinke, Mario, and Joseph Schwartz. "Das Holz in der Zwickmühle seiner Identitäten und Möglichkeiten". *Holz: Stoff oder Form.Transformationen einer Konstruktionslogik,* edited by Mario Rinke and Joseph Schwartz. Sulgen, Niggli, pp. 11-13.

nature that is problematic, in the case of timber, it is the reflections on the act of engineering, the intervention as a mediator between human and nature that provoked considerable criticism, particularly towards the way human positions him/herself in the world, in relation to nature.

At the foundation of modern engineering science, this relation was based on a sharp dichotomy between human and nature, as subject and object, based on the idea of the human domination and "mastery of nature".[87] Glulam, celebrated as the result of engineering work was understood in this sense.

Mirko Rôs in a report on modern timber constructions entitled "*le progrès dans le domaine des constructoins en bois collé"*(Progress in the field of glulam constructions), published in 1946, praised the then-recent developments in the glulam technology as:

> Nature gives, the engineer creates and shapes. He returns matter ennobled to nature and puts his work at the service of culture, progress and social good.[88]

By this perception of the relationship between human/culture and nature, Roš contributed to the rhetoric of progress in technology development discourse, constructing a narrative in which glulam is understood as a gradual directional change embodying the improvement of timber; by ennobling nature. The latter provides the basic and primitive, and human processes it.

With the paradigm shift in the philosophy of the western world, new canons of ethics for the new millennium have been forged. Distancing from the dichotomy of human-nature, or subject-object, criticizing the "deluded [and] dangerous orientation towards the world",[89] and questioning whether the assumed distinction really existed and could lead to true reasoning and true knowledge,[90] the concept of engineering (and design in a wider sense) as a mediator between human and nature underwent major transformations. This paradigm shift is still under debate in academic circles, and its impact on practice can be also traced.

The novel perspectives gave rise to new dialogues between the so-called subject and object, designer and material, in which, beyond the human-centred view and one-way relationship between designer and material, these two can indeed reciprocally inform each other. The material can even "advice" the designer, by revealing its nature and its characteristics, as "a source of inspiration" to him/her.[91] Peter

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[87] In the American journal the "Chemical Age", appeared in 1919, the editorial team in the foreword, talks about the growing "mastery of nature" which qualifies, according to them, the Chemical Age: *"Today, with scientific attainment and growing mastery of nature in every field, man lives in an age which can be distinguished without qualification as the "chemical age".*

[88] Original text in French : « *La nature donne, l'ingénieur crée et façonne. Il rend la matière ennoblie à la nature et met son œuvre au service de la culture, du progrès et du bien social »*

[89] Fox, Warwick. *Toward a Transpersonal Ecology. Developing New Foundations for Environmentalism*. Boston & London, Shambhala, 1990, p. 13.

[90] Descartes, René. *Discours de la methode.* Paris, Gallimard, 1953, p. 168.

[91] From a famous conversation between Louis Kahn (1901-1974) and his students: "*'If you think of Brick, you say to Brick, 'What do you want, Brick?' And Brick says to you, 'I like an Arch.'." [....] Even a brick wants to be something*." Transcribed from the 2003 documentary 'My Architect: A Son's Journey by Nathaniel Kahn'. Master class at Penn, 1971.

Zumthor, explains in 1998 this situation by redefining the role of the architect as "generat[ing] a meaningful situation" for the material, in order to "bring out the specific meanings" of them.[92]

This significant shift, from the dichotomy of human and nature, with the domination and mastery of the latter by human, interpreted as “opposed systems” by Herzog-de Meuron, can be traced in the discourses and projects of these architects. In a speech, entitled “Poesis-Production” given by Jacques Herzog in a conference in Barcelona in 1993, the architect questioned the *““heroic” form of dialectical thinking, which denies any link between seemingly opposed systems”,* such as “*nature and society, nature and the city*”.[93]

The 1990s witnessed intense debates on this new approach, stressing that the modern society has never functioned on the basis of this artificial division that typified modernity, and concluded that in this respect, indeed “We have never been modern”.[94]

In the past century, the “lack of homogeneity”, was considered as “the worst disadvantage of wood”, and “a fundamental drawback” of the material, since the human demand was set for homogeneity, and the engineer and designer could not “base any reliable stress calculation on such an uncertain foundation”.[95]Timber, with its centuries-old construction traditions, was regarded then as an “unreliable natural material”.[96]

The new approach, spinning off from a paradigm shift in the relation between human and nature, invites to rethink the history of the development of architectural materials, that “has been guided by a hostility toward the natural tendencies of materials as found in nature”.[97] In this new approach, interestingly, what was once the “limitations of organic”, from which the material had to be “emancipated” with the intervention of the engineer, was then celebrated and the engineers were pushed to take advantage of its inherent properties, such as anisotropy and directional strength.

This new approach gave rise to new notions and new terminologies, such as the state of being “naturally engineered”. In a project of a timber pavilion accomplished in MIT, by taking advantage of “non-uniform natural characteristics” of naturally grown trees, “irregular sections such as knots and forks” (Fig. 6), have been chosen as joint to connect timber elements, as the leader of the project announced in March 2022, in order to use the "naturally engineered structural connections".[98] The

[92] Peter Zumthor, *A way of looking at things*, lecture given at SCI-ARC in Santa Monica, 1988. Published in “thinking architecture, Birkhäuser, Basel, 1999, P.11
[93] The speech is published on the website of the architects: https://www.herzogdemeuron.com/index/projects/writings/essays/poesis-production.html.
[94] Challenging the dichotomy of subject object, is the main topic of Latour, Bruno. *Nous n’avons jamais été modernes: essai d’anthropologie symétrique*. Paris, La Découverte, 2010. (originally published in 1991)
[95] Brenner, I.P. "Wood as a Homogeneous Material: Part I—A Method of Improving Wood for Structural Purposes", *Aircraft Engineering and Aerospace Technology*, Vol. 10, No. 5, 1938, pp. 129-134.
[96] Le Corbusier, (see note 11 above).
[97] Weston, Mark. “Anisotropic Operations.” *International Journal of Architectural Computing*, vol. 10, no. 1, Mar. 2012, pp. 105–119.
[98] Caitlin Mueller, in MIT news, published on their website: https://news.mit.edu/2022/using-natures-structures-wooden-buildings-0309. Published on March 9, 2022.

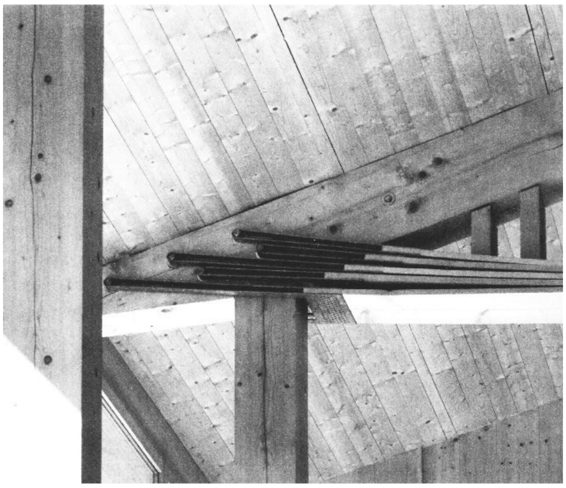
juxtaposition of these two words “natural” and “engineered” could have sounded paradoxical if not meaningless in 1946, when Roš, opposed these two concepts, nature and the engineered work, and defined the transition from the former to the latter as progress.

Regardless of the result of the project of the timber pavilion at MIT (Fig. 7), regardless of the fact that what has been claimed “new approach” has long tradition in shipbuilding, and regardless of the fact that a considerable amount of steel has been used in its joints, it can be however demonstrated that the new trend to celebrate the natural characteristic of structural timber (which basically should be based on understanding the material) is already expanded.

Figs 6-7 Project for building a pavilion by “using nature’s structures in wooden buildings”, MIT, Massachusetts, 2022.

Beside the trends, there are however fundamental research and projects that investigate genuine solutions which benefit from the properties of natural timber in structural design.

To cite only one example, in the project of architect Gion Caminada and engineer Jürg Conzett for a gym building in Vrin, Switzerland, constructed in 1996 (Fig. 8), the designers avoided using glue in the bottom chord, in order to visualize how the planks, transfer the tensile forces to the support, evoking the fibrous strands of cellulose in wood, that provide tensile strength in the direction of the trunk, here the boards (Fig. 9).



Figs 8-9 Gion Caminada and Jürg Conzett, gym building in Vrin, Switzerland, 1996.

Other research is running aiming at improving our understanding from natural timber in order to benefit from its natural properties for a more intelligent use in glulam structures:[99] an approach almost totally neglected in the whole 20th century.

[99] For one of the most recent study in this domain see: Tanadini, Davide. *Limit analysis and timber plasticity - Plastic design of interlocking timber-to-timber connections*. PhD dissertation, ETH Zurich, 2023.

3. "The shock of the old?"[100]

The agenda for discussing the future development of glulam, are basically set by two factors: the material, including both timber and glue, and the way glulam elements are designed in their structural role.

Regarding glue, as discussed earlier in this chapter, a tendency to reduce or to eliminate the synthetic glue is clearly apparent. Being replaced, as one of the alternatives, by more natural glues, almost the same question with which Terner and Chopard and in general the generation of early glulam constructors faced, should be tackled now.

Regarding timber, as demonstrated in the previous part, this material is experiencing a new heyday, it is "à la mode", particularly its use is pushed for the tall buildings.[101] The current private, public, and governmental campaigns promoting the use of timber in the building industry, pose however a considerable threat to available timber resources. To this it should be added, that the climate change causes (and has already caused) a modification of the potential distribution ranges of tree species in a given environment. As regards the Central Europe, it can be observed that the supply of hardwood resources is constantly growing.[102] This also means that by the decrease in the supply of softwood resources such as spruce and larch – currently being largely used for the production of glulam – new areas of use of hardwood, such as beech wood as a local resource should be investigated more intensely. Beyond its current use mainly in furniture and interior furnishing, hardwood like beech, is finding the areas of use in the building industry for the structural purposes.[103] The search for new application of hardwood, particularly beech, would surprisingly remind us of the efforts of Hetzer at the beginning of the 20th century, and the core idea of his successive patents, in order to expand the use of German red beech wood. (This subject was extensively discussed in the second chapter). So, it seems that the actual questions driving the development of glue and timber in glulam, do not differ much with the questions faced by the generation of early glulam constructors, in the early years of the 20th century.

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[100] *The Shock of the Old Technology and Global History Since 1900* is a book written by the British historian David Edgerton and published in 2006.
[101] Frey, Pierre. "Bois Naturel et Préjugés Artificiels. A propos du bois dans l'industrie du bâtiment". *Tracés : bulletin technique de la Suisse romande.* No. 8, 2017, pp. 6-9.
[102] Udo Thönnissen, in the inauguration of the exhibition "Potential Laubholz-Neue Wege im Holzbau", Zürich Hönggerberg, ETH Material Hub, 17. Nov. 2022.
[103] There are several products in the market now available, such as BauBuche, beams made of beech laminated veneer lumber. For an overview see: Hassan, Jan, and Matthias Eisele. "BauBuche - Der Nachhaltige Hochleistungswerkstoff." *Bautechnik Zeitschrift für den gesamten Ingenieurbau,* vol. 92, no. 1, 2015, pp.40-45.

Fig. 10 Poster of the exhibition Potential Laubholz (potential hardwood), ETH Zurich, 11.2022 – 02.2023.

Regarding the design of structural elements: efforts have been made for several years in order to increase bending and axial stiffness and ultimate load of glulam beam through reinforcement. To this goal, Fibre-Reinforced Plastics as a tensile reinforcement were used. Fibres used were glass fibres, aramid fibres and carbon fibres (Fig. 11).

This approach is as well astonishingly similar to the efforts of Hetzer, who patented in 1905 (Figs 12-13) his idea for reinforced timber beams, with the help of stronger woods embedded in the timber beam, functioning as reinforcement. The idea behind the innovation, as Hetzer claims in his patent, has been "the use of weak woods, which are brought to static interaction by a water-safe adhesive, similar to concrete structures in terms of concrete and iron. […] The insert can consist of just one board or of several boards of the same or different types of wood […] of greater strength".

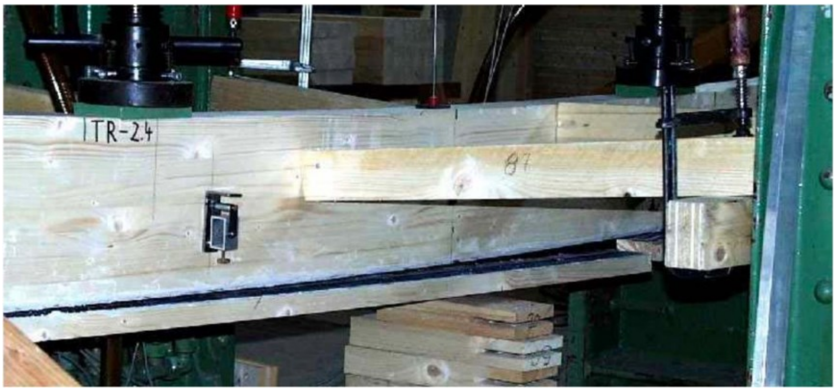
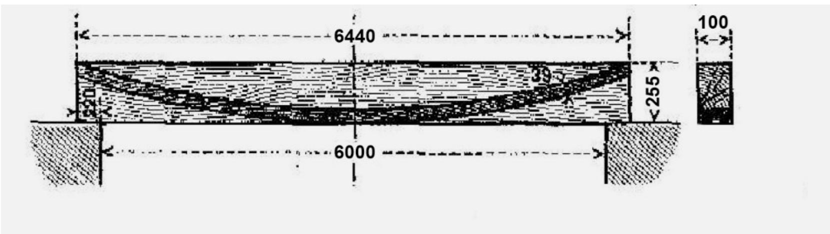
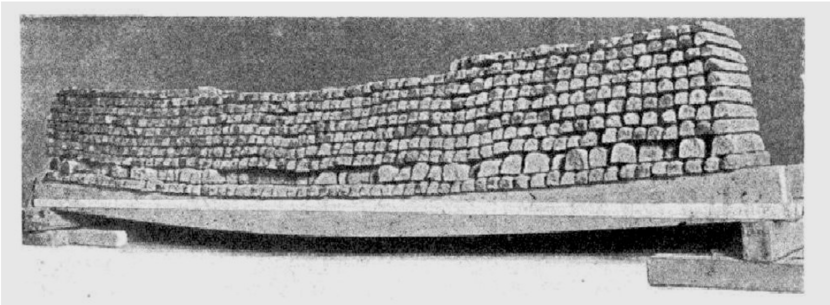


Fig. 11 Reinforced glulam beam, under loading test at University of Karlsruhe (TH). Thin carbon FRP and aramid FRP were used as reinforcements.[104]

[104] Blass. H.J., and M. Romani. Reinforcement of glulam beams with FRP reinforcement. Research at the University of Karlsruhe. (https://holz.vaka.kit.edu/public/23.pdf)





Figs 12-13 Hetzer's concept of reinforced beam and the result of the test performed on it, by using two different types of wood.

In describing his concept, Hetzer stressed that "in addition, the principle of using the right material in the right place, which is so important and creative for concrete construction, should be applied to wooden composites".[105] It has been in this regard that he proposed the use of different kinds of wood with different properties, in a composite beam. Interestingly, the efforts now are directed as well toward this concept to apply the principles of reinforced concrete to composite timber beams (Fig. 14).

Fig. 14 Glued laminated timber beams reinforced with strands. A research project between different universities in Latvia, 2017.[106]

[105] "Ausserdem müsste auf die Holzverbände der für den Betonbau so wichtige und schöpferisch wirkende Grundsatz der Verwendung des richtigen Materials an der richtigen Stelle angewendet werden."
[106] Sardiko, R., et al. "Analysis of the stiffness and load-bearing capacity of glued laminated timber beams reinforced with strands". Proceedings Journal of Physics: Conference series Materials Science and Engineering, vol. 251, 2017. "https://iopscience.iop.org/article/10.1088/1757-899X/251/1/012104/pdf

Some other recent research has been done to develop cross sections following two criteria of reducing the weight (the amount of material) and increasing the load-bearing capacity. These innovative solutions (Fig. 15), however can be compared to similar ideas which dates back as early as 1910, when Hetzer was granted a patent for his idea for a truss-girder with glulam elements (Fig. 16), and applied this idea in several projects. In Switzerland, the chemical factory of Ed. Geistlich, was built in Wolhusen in 1923 by using glulam truss girders (Fig. 17).

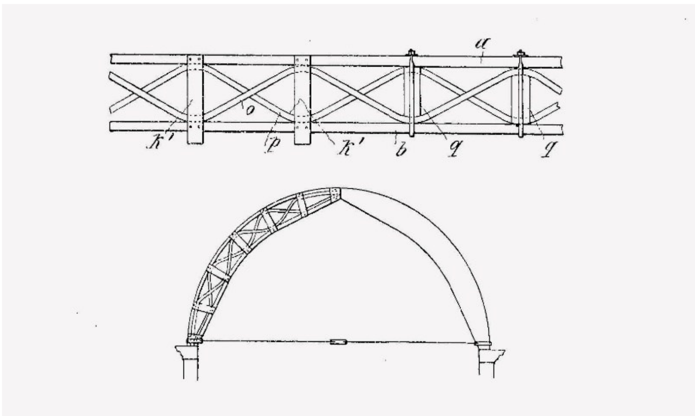


Fig. 15 Lightweight profile, glulam with hardwood. Research project, Technical University of Graz, 2014. This item was show cased at the exhibition Potential Laubholz, ETH Zurich, 11.2022 – 02.2023.
Fig. 16 Hetzer, Otto. *Fachwerkträger aus Holz*, patent no. 50660, CH, 12.03.1910.
Fig. 17 Glulam structure of the chemical factory of Geistlich, built in 1923 in Wolhusen.

The brief overview of the current research related to glulam, demonstrates however that the fundamental questions related to the development of this technology, which basically investigate compromises between available resources and the economic benefit, have principally not changed much in comparison with the questions of the early generation of glulam constructors for the development of the technology.

Few examples discussed here, however, represent only a part of the efforts of the timber industry and academia in order to find variants of glulam based on the local available resources of timber, more sustainable glue, and higher performance of the structural element. These efforts, in a broader context, had already contributed to a large degree to supporting and promoting the use of wood, through glulam, in building construction of any type, including tall building, an area where timber was previously hardly ever considered as a structural material. To this should be added huge amount of research carried out on glulam-composite structural members, in composition either with steel or with concrete, that pushed back the boundaries of the use of glulam in demanding structural conditions.[107] If the use of early glulam was mainly concentrated on long-span, single story structures, used for halls and factories in the industrial areas or for temporary structures, the development of the technology has opened new areas of use, such as residential and commercial towers, that directly transform the urban environment and influence the everyday life. Glulam, hence had an undeniable role in guiding the course of history in building construction.

[107] As example, several currently running research projects of the chair of "Holzbau/Timber structures" of prof. Dr. Andrea Frangi at the Institute of Structural Engineering (IBK), at ETH Zurich, can be cited here: Biaxial timber-concrete composite slabs made of beech laminated veneer lumber. – Reliable timber and innovative wood products for structures - Plate-type structural elements made of LVL beech wood.

Appendix 5.1

The collaboration of Germany in Switzerland for a systematic research in material testing can be traced back to the 1880s.

The first International Association for Material Testing in Technology was co-founded by the ETH professor of Structural Mechanics and founding director of EMPA Ludwig von Tetmajer in 1895.[108] This association was preceded by an international association for the agreement of uniform testing methods for building and construction materials *(Internationale Vereinigung für die Vereinbarung einheitlicher Prüfungsmethoden von Bau- und Konstruktionsmaterialien)*, presided by prof. Johann Bauschinger, professor of technical mechanics at the Munich Polytechnic. The "Mechanical-Technical Laboratory" began work under his direction in 1870. After his death, prof. Tetmajer was nominated as the president, and the name of the institution changed to *Internationaler Verband für die Materialprüfungen der Technik: IVMT.*

The IVMT was presided by Tetmajer until his death in 1905. Beside him, the Swiss engineer Bruno Zschokke (1860-1926) served as the secretary of the Association. Zschokke was trained as an engineer-chemist at ETH in Zurich from 1879 to 1882, where he became a professor of metallurgy. The collaboration of Zschokke and Tetmajer, was decisive at an international level (at the IVMT), as well as in Switzerland (at the EMPA and ETH). The first congress of IVMT was clearly dominated by German speakers. More than 25% of the participants were from Germany.[109] This association at the beginning consisted of mainly the European members, which, at the beginning of the 20th century, saw an increase in the members, mainly by joining of the American member.

> The foundation of the SVMT by Prof. Roš was primarily based on the idea of creating a forum for the exchange of ideas on an unofficial but nevertheless neutral basis in order to broaden and deepen our knowledge of the properties and behaviour of the materials used in construction, industry and trade and, on the basis of the knowledge gained, to promote the technically correct and at the same time economical use of the materials, to improve the quality of the products, to open up new fields of work, to permit higher stresses and to ensure better use of the products without compromising public safety. It is obvious that the founder of the association, as a civil engineer, dealt primarily with problems of civil engineering.[110]

The general purpose of the association was "testing of new technical processes, in so far as these are of general importance and open up possibilities for fundamentally new building materials, new

[108] Zschokke, Bruno. *Der vierte Kongress des internationalen Verbandes für die Materialprüfungen der Technik in Brüssel, 3.-9.Sept. 1906*. Stuttgart, Stähle & Friedel,1906.
[109] With the participation of about 350 members from 14 different European countries and the United States of America. The largest number of participants, 93, was from Germany, followed by Sweden with 51 and France with 38 members. Switzerland was represented at the congress by 10 participants and mainly by the following members: Prof. L. Tetmajer, Ing. Zschokke.
[110] Schläpfer, P. "Über die Beziehungen zwischen dem SVMT, der EMPA und den Fachvereinen". *Schweizerische Bauzeitung*, vol. 81, no. 46, 1963, p. 811.

applications of known materials, etc;" and "cooperation in the establishment of standards and guidelines in the field of materials testing".

With the post-war territorial settlement and the rise of new nation-states in Europe, a new (which title was later omitted) international association was founded in 1926, here again, by the direct influence of Switzerland. Under the initiative of the Swiss and Austro-Hungarian scholar, Mirko Roš,[111] the same institution in a national level (*Schweiz. Verband für die Materialprüfungen der Technik*: SVMT) was founded.

[111] Roš, Mirko, Gottfried Robin. *Dem Schweiz. Verband für die Materialprüfungen der Technik zum 25 jährigen Festtag seiner Gründung in hoher Wertschätzung und Verbundenheit zugedacht : [Festschrift]*. Solothurn, Vogt-Schild, 1952.

Appendix 5.2

The company of Otto Messmer, producer of industrial casein glue, was dissolved following the death of the owner in 1920. The reputation of its adhesive products in building, aeroplane and boatbuilding industries on the international scene,[112] encouraged the investors to establish a new company and to take over the glue-production plant of O. Messmer. This way the joint-stock company "Futurum AG" came to existence in Dornach, with international members in its board of directors, from France, Austria, Norway, and Switzerland. With the shift from natural to synthetic, the research and development of glue also was transferred from Futurum AG to Ciba AG.

Although the first industrialized casein glue was produced by the company Otto Messmer, Gribi & Cie., in a letter explained to Max Steinhaus that "at the end of Casein period, the most of this glue was manufactured by the chemical plant Geistlich in Wolhusen.[113]

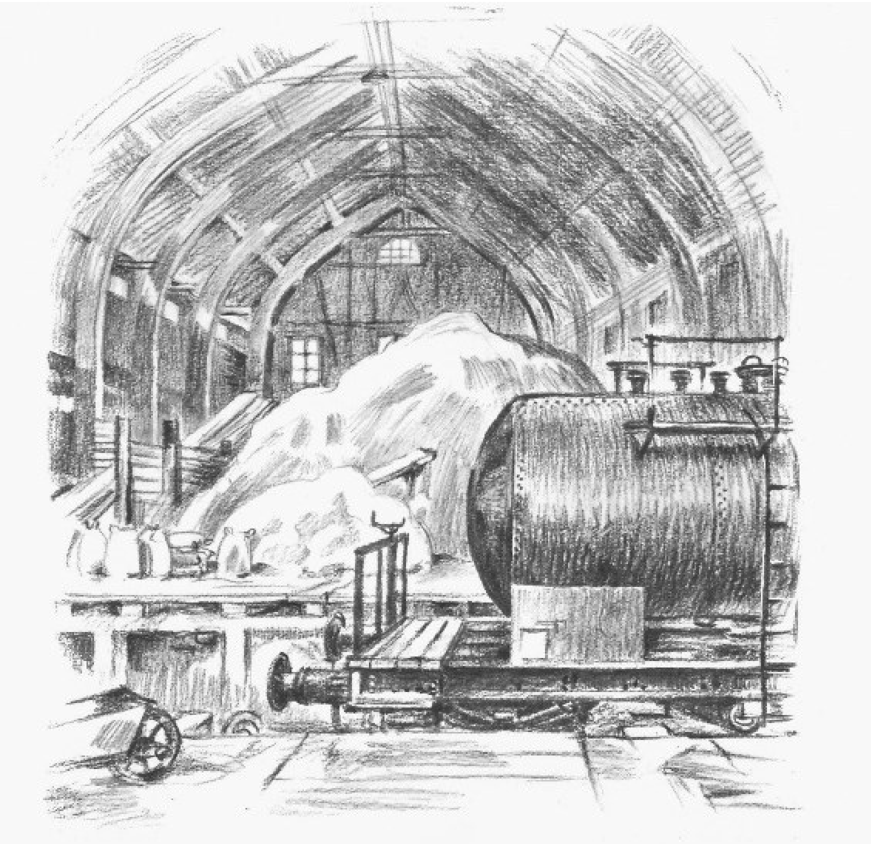


Fig. 18 Storage hall of fertilizer of the company Geistlich with glulam structure.

[112] This glue contributed as well to the boatbuilding industry. See: Mansfield, Kathleen. "Mc Gruer & Co., A century of boatbuilding - Wooden boat 1996", *WoodenBoat,* 1996, pp. 47-57.

[113] In 1851 Heinrich Geistlich founded the 'Lymhütte', a manufacturer of bone glue, in Zurich. The company Geistlich in its anniversary volume for the 100-year-old of activity, states that "Various types of cold glue based on casein have been developed for special purposes, which are particularly suitable for water-sensitive exterior constructions. Schumacher, Hans, et al. *Hundert Jahre Ed. Geistlich Söhne AG für chemische Industrie, 1851-1951: [Jubiläumsschrift]*. [Ed. Geistlich Söhne AG], 1951, pp. 32-34.

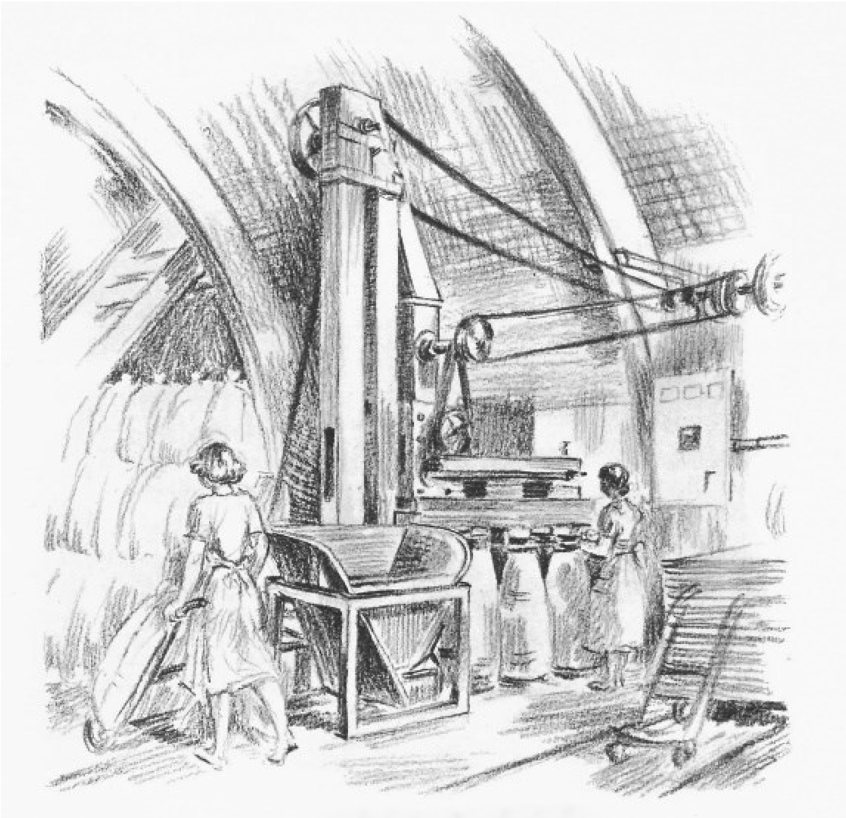


Fig. 19 Women workers screening and bagging the glue powder, in the factory Geistlich, in a hall with a glulam structure. For the storage of the chemical plants, timber was an ideal material, remaining almost intact under the influence of the chemical materials and the smoke of the engines. Glulam, offering a clear space in comparison to traditional timber structures, found very soon its place in this market. The archival documents regarding these buildings are very rare to find (in comparison to the public buildings like schools and gymnasiums, riding halls, etc.). That's why estimating the number of early glulam buildings is not easily possible. Moreover, these buildings were regularly damaged or collapsed in fire accidents. For example, in the Geistlich plant, fires were reported in 1902, 1917, 1919, 1951, 1972, and 1976 when an explosion and a subsequent fire destroyed several halls of this factory. [114]

[114] Schumacher, Hans, et al. *Hundert Jahre Ed. Geistlich Söhne AG für chemische Industrie, 1851-1951 : [Jubiläumsschrift]*. [Ed. Geistlich Söhne AG], 1951.

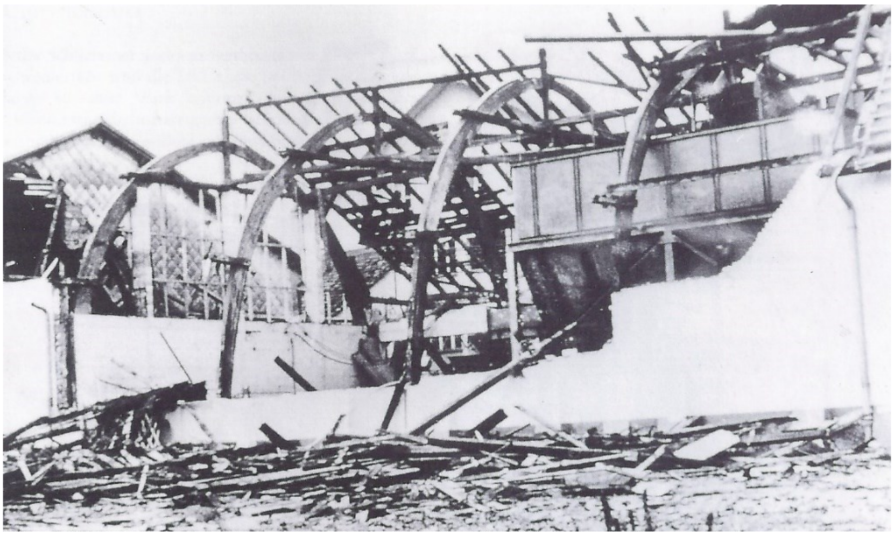


Fig. 20 A glulam structure of the Geistlich factory remained standing in its initial position, while the roofing burned out and collapsed.[115] The combustibility of timber, has long been considered as the weakness inherent in the material, particularly in comparison to steel. However, what is important in the case of the buildings is that it is not only the combustibility of the material that is decisive, but even more its behavior in fire. A wooden column, post, although it burns, still supports a load-bearing structure as long as there is still a load-bearing core. The charcoal then provides a safety layer and prevents further burning. On the other hand, wood, which has become hot, does not give rise to great destructive stresses in the material and in the joints. This is not the same with iron! Iron loses load-bearing capacity during glowing and the expansions due to heat have a destructive effect on construction and components. Besides, glulam, avoiding all the many collar beams, struts, posts, etc., connections and therefore gives the fire a corresponding smaller number of points of attack-fire safety is also significantly improved.[116] In addition, no dangerous stresses and strains are caused in the heated wood, as is known to be the case with iron, strains that may push out the walls and cause them to partially collapse. The load-bearing capacity of the wood decreases only slowly during a fire, at least more slowly than with iron, which loses more than half of its strength at around 500° Celsius. With complete charring, the individual beams disintegrate into smaller pieces, whose low weight further destroys, in particular the breakthrough of the substructures so makes it virtually impossible.[117]

[115] Meier, Philipp, and Heinrich Geistlich. Von der "Lymhütte" zum chemischen Unternehmen. Vereinigung für Heimatkunde, 1994, pp. 64-65.
[116] Seger, Jakob. "Feuerschutz und Feuerbeständigkeit des Holzes". *Schweizerischer Kongress zur Förderung der Holzverwertung, Vorträge und Diskussionen*, Bern, Verbandsdruckerei, 1936, p. 380. – Schlüpfer. "Grundsätzliches über die Verbrennung des Holzes". *Schweizerischer Kongress zur Förderung der Holzverwertung*, *Vorträge und Diskussionen*, Bern, Verbandsdruckerei, 1936, p. 382.
[117] Zentralblatt der Bauverweltung 1919, n° 94, p. 92.

Conclusion

Wood and glue were combined by Otto Hetzer at the beginning of the 20th century, and constituted a relatively simple composite material. This composite was then bent into desired curves to be used as structural elements for large-scale structures. Although the juxtaposition of these materials, i.e. wood and glue, has a civilization-long history and therefore was nothing new, it made an essential contribution to the building industry, through its use in large-scale projects and in a systematic way. The significance of this material-technology, namely glulam, is increasing in our time, as building with wood is booming and glulam is being promoted to become the ubiquitous building material of the near future.

Timber was transformed into glulam for several reasons. The most apparent one was to make long and continuous shapeable structural elements, needed for constructing large-scale halls and factories with clear spans. This is however the function of glulam: glulam being perceived as a tool to serve a purpose. The historical perspective provided by this thesis towards this technology demonstrated however that many other reasons, essentially nontechnological, were the driving forces of this technology. It was within this framework, that the momentous contribution of Switzerland to the development, diffusion, and success of this technology, was investigated in this dissertation.

The transformation of timber into glulam showed very soon great potential to solve specific, not only design, but also cost, raw material supply, labour, and power-relation problems. The history of the emergence and development of glulam, as understood in this project, was closely related to the efforts of a part of society, that endeavoured to keep the use of a strongly devaluated material, namely structural timber, significant and institutionalized. In Germany and in Switzerland principally due to the decentralized political system, and the particular dual educational system, these efforts flourished in a series of solutions to the structural timber crisis: several engineered timber construction systems, including glulam were developed and introduced to the building market in the early years of the 20th century. The notion of engineered timber, therefore, was understood beyond the concerns related to timber, joint, glue, static calculation, and so on. Timber was transformed into glulam by people's hopes, ambitions and insights, but also disbelieves and prejudices, collaborations, as well as conflicts and tensions, whose social, economic, and political status was strongly related to timber. The first chapter demonstrated that beyond the availability of raw materials, namely wood, in Germany and Switzerland – as the analysis in comparison with the cases of England and France demonstrated – many other fundamental reasons such as power distribution and political economy, the perspective of government towards education, towards the concepts of mass and elite, towards the relations with neighbouring countries, accompanied with historical events like the wars and revolutions made essential contributions to the emergence and early development of the glulam technology. This explains how deep the hopes, ambitions, and efforts for technological changes and their implementation can be dissociated from the technology itself.

Moreover, it could be demonstrated, that considerable differences in the organization of the domestic economy, the scientific and technological infrastructures of the government, the market and the role of the government in this regard, influenced the path forged by early glulam, which showed significant differences in Switzerland and in Germany.

Assessing the pivotal role played by the early glulam consortium in Switzerland, the particularities of the Swiss approach to the early development of glulam were discussed in three spheres, the business spaces (consortium as a patent-licensing cartel, discussed in chapter two), the institutional spaces (consortium as an elites' cartel, discussed in chapter three), and in technological spaces (consortium bringing together the mainstream structural knowledge, craft skills, and material know-how next to political and economic networks, discussed in chapter four).

The comparison between the entrepreneurship strategies of glulam in Germany and Switzerland demonstrated that this technology benefited from two different types of economic theories. Hetzer's company, by increasing the variety of products (parquet, railway slippers, carpentry elements, composite beam, reinforced beam, glulam, etc.) while using the same set of resources (concentrating on the German beech wood), aimed at increasing the use of this wood. This model, strongly supported by government policies of the time, pushed the relatively short-term performance of the company, until 1926 when the whole business went bankrupt. Moreover, his patent licensing model in Germany resulted in a scattered network of design and construction, research and development, and marketing. In the Swiss context, the network of early glulam developed over a single-output scenario, the structural glulam, and set up protectionist policies, in order to promote this single product. Moreover, this consortium limited the network of design and construction, research and development, and marketing to its few members, namely well-established carpenter-contractors and top general contractors who were themselves the president or board members of related employers' associations, trade unions, high-ranked army officers, and elected politicians. The cohesive power of this particularly dense and closed elites' network of the early glulam consortium gave an early and rapid push to the development of glulam.

The focus on the national-scale economy in this dissertation was supplemented with the study of the micro-economy of a carpentry workshop as the very unit responsible for the production and on-site assembly of glulam structures. The fundamental transformation of the relationship between the master craftsman and the journeymen-carpenters to employer and employee was in favour of the early development of glulam. Glulam, by way of its materiality and through its production and assembly exigences, helped employers to resettle their relationship with the workers who were intimately and sometimes violently affected by the production system put forward by glulam. The one-to-one relationship between the worker and the product, which existed in other engineered timber construction systems, was transformed into a worker-to-other-workers relationship. This transformation extremely reduced the skills, capacities, and effectiveness of the workers: a working model that was highly in favour of the capitalist production system, and a reason explaining why glulam was a technological "choice" over its other alternatives.

In addition, the role played by the early glulam consortium in centralizing the design, construction and assembly processes of early glulam structures, was significant. The consortium brought together mainstream structural knowledge, craft skills, and material know-how next to political and economic networks. This was done through the involvement of the structural engineers, namely Terner and Chopard, the well-established carpenter-contractors and general contractors, in different phases of glulam construction, from the early concept drafts and the fabrication of the glulam elements to the on-site assembly of the structure. This organization was significant since the design and construction process of early glulam projects, as the case studies demonstrated, were developed at the intersection of the design practices, models, and standards typical for timber and steel structures, respectively regular structural materials of carpenters and engineers at that time. After only a few years of collaboration between the engineers and the contractors, this hybrid use of materials (structural timber and glulam) and different construction logic (for structural timber and steel) were replaced by material-independent methods for structural design. The project of the glulam roof structure of the tram depot in Basel, constructed in 1916, is considered as a turning point towards this universal mechanical approach to control the structural performance, borrowed from contemporary steel structures' design.

By emphasizing technological indeterminism, this dissertation focused on a complex of reasons that covered not only the "choices", briefly discussed above, but also the "chances" that altered the trajectory of the development of technology. These chances were sometimes related to particular historical moments, like the scarcity of other rival materials during the wars that encouraged the use of a certain substitute material or technology. Other times, it was the inherent properties of the material or the technology itself, that was in favour of its diffusion. In the case of glulam, one of its chances was its hybrid nature, developed by the synthetization of the glue, a subject that was discussed in chapter five. The synthetization of the early natural glue had indeed a decisive role in sustaining an operating network of interested parties in glulam. When timberness became a barrier, the synthetic component became a driver: the centre of interest being shifted from timber to glue, glulam could get linked to the Chemical Age and benefit from all the infrastructures, perspectives and patterns for development, knowledge, (but also shared misinformation and prejudices), shared set of premises and assumptions, mass of lobbies and propaganda campaigns, shared norms and governmental policies, and shared potential clients, that altogether shaped this age. The same agendas, half a century later, questioned the legacy of this age. Therefore, possessing a hybrid nature, embodying both natural and synthetic features within a material, was a key feature, or a "chance" for glulam, to survive the paradigm shifts of the last century, which once glorified the synthetization, and later challenged it.

By challenging the legacy of the chemical age and the introduction of the new aesthetic and ethic canon for technological development put forward in the last decades of the 20^{th} century, new areas of research were opened to glulam. The contemporary research on glulam is focused on the actual problems facing this technology, such as the transition towards glues with more natural components, finding new areas of use of alternative hardwood, particularly beech wood, whose supply in Central Europe is increasingly growing due to the climate change, and also promotion of methods that privilege the use of different wood types with different properties, or composite use of glulam with steel or concrete, for developing customized cross-sections, in different with the current practice, where solid cross-sections with the use of softwood characterize the state-of-the-art in glulam construction.

These efforts, investigating "novel" solutions for the existing problems, in line with the positivist narratives of technical progress, pose glulam as an ever-performant material, to achieve ever-stronger structural spans. The historical perspective provided by this dissertation challenges these narratives, since the actual questions and approaches to the development of glulam seem to be surprisingly similar to the questions that the early generation of glulam builders faced more than a hundred years ago. This statement, however, does not undermine the significant contribution of glulam to the building industry of the last and present centuries. If the use of early glulam was mainly concentrated on long-span, single story structures, used for halls and factories in the industrial areas or for temporary structures, the development of the technology has opened new areas of use, such as residential and commercial towers, that directly transform the urban environment and influence the everyday life. Glulam, hence had an undeniable role in guiding the course of history in building construction.

The historical perspective opened to glulam by this dissertation, can encourage and support future research regarding this technology, particularly on the transformation of glulam following the paradigm shift in the relation between human and nature beyond the dichotomy and artificial division of these two entities that typified modernity, as briefly discussed in the last chapter of the thesis.

This dissertation is not a prediction of the future, nor is proposing alternatives for today's glulam. It challenges, however, the way technological developments are understood, described, and justified to society. By discussing the technological choices (here glulam), in parallel with their other unsuccessful alternatives, it can be argued that the success of a technology should not be understood in terms of historical causation, or as an inevitable and autonomous process, but rather as the outcome of the power dynamic of the actors that shape a society.

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ETH-Library, Archives, Biographische Dossiers
ETH-Library, Archives, Handschriften und Autographen: Steinhaus, Max.1987. HS 1198 &1199.
ETH-Library, Archives, Martikel
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SBB Historic, GD-BAU-SBBBAU1-107-13
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Abbreviations

EA	Employer Association
EMPA	Eidgenössische Materialprüfungsanstalt
EPFL	Ecole Polytechnique Fédérale de Lausanne
ETH	Eidgenössische Technische Hochschule
IVMT	Internationaler Verband für die Materialprüfungen der Technik
NZZ	Neue Zürcher Zeitung
SBB	Schweizerische Bundesbahnen
SGB	Schweizerischer Gewerkschaftsbund
SIA	Schweizerischer Ingenieur- und Architektenverein
SVMT	Schweiz. Verband für die Materialprüfungen der Technik
TA	Trade Association

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Illustration credits

Chapter 1

Fig. 1 Hetzer, Otto. *Gebogener Holz-Baukonstruktionsteil.* Patent no. 40409, CH, 13.06.1907.
Fig. 2 ETH Library, Hs 1021:10, Notebook of student Carl Gruber, 1897.
Fig. 3 ETH Library, Hs 1021:10, Notebook of student Carl Gruber, 1897.
Fig. 4 Der Industriebau, 1910.
Fig. 5 Terner & Choaprd. *Knotenpunktverbindung für Holzkonstruktionen*. Patent no. 106496, CH, 17.09.1923.
Fig. 6 Schweizerische Bauzeitung, 1910.
Fig. 7 Schweizerische Bauzeitung, 1910.
Fig. 8 Schweizerische Bauzeitung, 1901.
Fig. 9 https://de.wikipedia.org/wiki/Fritz_Kre%C3%9F_(Zimmerer)
Fig. 10 *Die Berner Woche in Wort und Bild: ein Blatt für heimatliche Art und Kunst, 1917.*

Chapter 2

Fig. 1 Hetzer, Otto. *Zusammengesetzer Holzbalken,* Patent no. 24405, CH, 28.06.1901.
Fig. 2 Hetzer, Otto. *Holzbalken.* Patent no. 33871, CH, 02.06.1905.
Fig. 3 Hetzer, Otto. *Gebogener Holz-Baukonstruktionsteil.* Patent no. 40409, CH, 13.06.1907.
Fig. 4 Based on the Swiss map, developed by Mario Rinke.
Fig. 5 https://expoarchiv.ch/
Fig. 6 B. Zöllig Söhne, Arbon Holzkonstruktionen S.I.A, Booklet, printed in the 1930s.
Fig. 7 Schweiz. A. -G. für Hetzer'sche Holzbaiweisen, catalogue, 1917.
Fig. 8 Schweizerische Bauzeitung, 1911.
Fig. 9 Bulletin technique de la Suisse romande, 1925.
Fig. 10 Bulletin technique de la Suisse romande, 1925.
Fig. 11 Schweizerische Bauzeitung, 1911.
Fig. 12 Schweizerisches Sozialarchiv, AK4-44, 4893.
Fig. 13 Schweizerisches Sozialarchiv, AK4-44, 4981.
Fig. 14 Schweizerisches Sozialarchiv, AK4-45, 4984.
Fig. 15 100 Jahre Fietz und Leuthold : [1889-1989]
Fig. 16 EMPA report, 1944.
Fig. 17 Schweizerisches Sozialarchiv, AK4-28, 7039.
Fig. 18 Max Steinhaus archives, Hs 1198:50.

Chapter 3

Fig. 1 https://fr.wikipedia.org/wiki/Valentin_Purrey, public domain.
Fig. 2 https://notrehistoire.ch/entries/ExXYqeLLYrk. © Claude Froidevaux
Fig. 3 EMPA report, 1936.
Fig. 4 La Blecherette, 80 ans d'aviation
Fig. 5 La Blecherette, 80 ans d'aviation
Fig. 6 Schweizerische Bauzeitung, 1911.
Fig. 7 SBB Archives, GD-BAU-SBBBAU1-107-13.
Fig. 8 Schweizerische Bauzeitung, 1911.
Fig. 9 Die Bautechnik, 1923, no. 3.
Fig. 10 Die Bautechnik, 1923, no. 3.
Fig. 11 EMPA, report no. 152, 1945.
Fig. 12 EMPA, report no. 152, 1945.
Fig. 13 EMPA, report no. 152, 1945.
Fig. 14 Max Steinhaus archives, Hs 1198:33.
Fig. 15 SBB Archives, GD-BAU-SBBBAU1-108-05.
Fig. 16 Photo by the author.
Fig. 17 Schweizerische Bauzeitung, 1911.
Fig. 18 Staatsarchiv Graubünden. XX 179 E/3.

Chapter 4

Fig. 1 Staatsarchiv Bern. SLAB 5113.
Fig. 2 Staatsarchiv Thurgau. 8'409-1-2.1 Werner Zöllig AG, Holzbau.
Fig. 3 Schweizerische Bauzeitung, 1911.
Fig. 4 Schweizerische Bauzeitung, 1911.
Fig. 5 Drafted by the author.
Fig. 6 Schweizerische Bauzeitung, 1911.
Fig. 7 Photo by the author.
Fig. 8 Photo by the author.
Fig. 9 Schweizerische Bauzeitung, 1911.
Fig. 10 SBB Archives, GD-BAU-SBBBAU1-107-13
Fig. 11 Halle 58 Architekten GmbH
Fig. 12 SBB Archives, GD-BAU-SBBBAU1-107-13
Fig. 13 SBB Archives, GD-BAU-SBBBAU1-107-13
Fig. 14 SBB Archives, GD-BAU-SBBBAU1-107-13
Fig. 15 SBB Archives, GD-BAU-SBBBAU1-107-13
Fig. 16 SBB Archives, GD-BAU-SBBBAU1-107-13
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Fig. 19 Photo by the author.
Fig. 20 Photo: Arnold Seiler-Rudin, ca 1920, Photographic collection Arnold Seiler PA 6292 01.034
Fig. 21 Staatsarchiv Basel-Landschaft. KP 5009 1770 1
Fig. 22 Staatsarchiv Basel-Landschaft. KP 5009 1770 17
Fig. 23 Staatsarchiv Basel-Landschaft. KP 5009 1770 28
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Fig. 26 Mario Rinke.
Fig. 27 Schweizerische Bauzeitung, 1911.
Fig. 28 Mario Rinke.
Fig. 29 Mario Rinke.
Fig. 30 Mario Rinke.
Fig. 31 Schweiz. A. -G. für Hetzer'sche Holzbaiweisen, catalogue, 1917.
Fig. 32 Staatsarchiv Basel-Stadt, 490.
Fig. 33 Staatsarchiv Basel-Stadt, 374-7.
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Fig. 37 Staatsarchiv Basel-Stadt, 374-9.
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Fig. 43 Staatsarchiv Thurgau. 8'409-1-2.1 Werner Zöllig AG, Holzbau.
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Fig. 54 Staatsarchiv Thurgau. 8'409-1-2.1
Fig. 55 B. Zöllig Söhne, Arbon Holzkonstruktionen S.I.A, Booklet, printed in the 1930s.
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Fig. 57 Staatsarchiv Thurgau. 8'409-1-2.1 Werner Zöllig AG, Holzbau.
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Curriculum Vitae

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