TERNER & CHOPARD AND THE NEW TIMBER – EARLY DEVELOPMENT AND APPLICATION OF LAMINATED TIMBER IN SWITZERLAND

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Keywords

Laminated Timber, Material Industry, Material development, Prefabrication in timber

Abstract

In 1906 German master carpenter Otto Hetzer (1846 – 1911) was awarded a patent for the concept of a curved glued-laminated beam. This development responded to an increasing shortage of large-sized timbers due to the extensive building activity at the end of the 19th century and was conceptually based on earlier developments from De l'Ormes (1567), Wiebeking (1817) or Emy (1837).

Only a few years after Hetzer's technological invention the Swiss based Romanian engineer Bernhard Terner (1875 – 1960) acquired the patent and the exclusive right to use Hetzer's invention in Switzerland. Together with Charles Chopard (1879 – 1954) he found the engineering office Terner & Chopard in 1909. During the following 24 years they developed many extraordinary timber structures, a time, which turned out to be a first global climax of industrial large-scale timber construction and benefited from the steel and coal crisis after World War I.

Terner and Chopard's timber works range from industrial long span halls to train station roofs, from road brigdes to architectural buildings featuring ambitious geometrical forms. Their most important works are the cupolas of the main building of the University of Zurich (1911) and the SUVA head quarter in Luzern (1914) as well as large tram depots and platform roofs throughout Switzerland. In parallel with their own technological and constructive development, Terner & Chopard have been involved in some important material research programs together with the Swiss Federal Laboratories for Materials Science and Technology (EMPA) which led to a better understanding of stress limits and the performance of new component shapes. Chopard was also involved in the development of the first Swiss timber building code in 1925.

Beyond their sense for delicate structural frameworks in both reinforced concrete and laminated timber they have proven great confidence and will to use timber in new ways and forms and to push its technical and constructive limits. Terner and Chopard helped to establish an early high profile timber engineering focus in Switzerland.

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INTRODUCTION

Bernhard Terner (1875-1960) was born and raised in Romania, and came to Zurich to study structural engineering at the young polytechnic school found in 1855. Charles Chopard (1879-1954) came to Zurich at the same time; they finished their studies in 1903. Their teachers were prominent engineers and academics, such as Culmann, Ritter, and Tetmajer. Terner worked as a railway engineer on construction projects in Switzerland and Germany as well as for several engineering offices; Chopard served as an assistant engineer to Terner during the construction of the Wendelsteinbahn in Bavaria. Together they found the engineering office Terner & Chopard in 1909. Focussing on modern structural timber and reinforced concrete they were responsible for many important buildings until the office liquidation in 1933.

Terner and Chopard have been participating in the development and application of modern engineering timber from the early days. At that time, German master carpenter Otto Hetzer (1846-1911) just patented the technology for producing "curved structural timber elements" in 1906 (fig. 1b). This development responded to an increasing shortage of large-sized timbers due to the extensive building activity at the end of the 19th century and was conceptually based on earlier developments from De l'Ormes (1567), Wiebeking (1817) or Emy (1837). After carrying out various own studies on glued laminated timber, Terner acquired the patent and the exclusive right to use Hetzer's invention in Switzerland. There was an established timber building culture and extensive construction knowledge among craftsmen and engineers at the early 20th century in the country. Already in the 18th century many European travellers reported the outstanding timber bridges developed by the carpenter family around Hans Ulrich Grubenmann (1709-1783), which reveal a skilful use of structural timber in form of interlaced frames and trusses or even in the use of stacked timber pieces forming robust timber arches (fig. 1a). The diversified timber culture and the massive shortage of coal and steel after World War I turned out to be a solid foundation for a strong development of the laminated timber technology. Terner and Chopard's most important works are the cupolas of the main building of the University of Zurich (1911) and the SUVA head quarter in Luzern (1914) as well as large tram and railway depots throughout Switzerland.

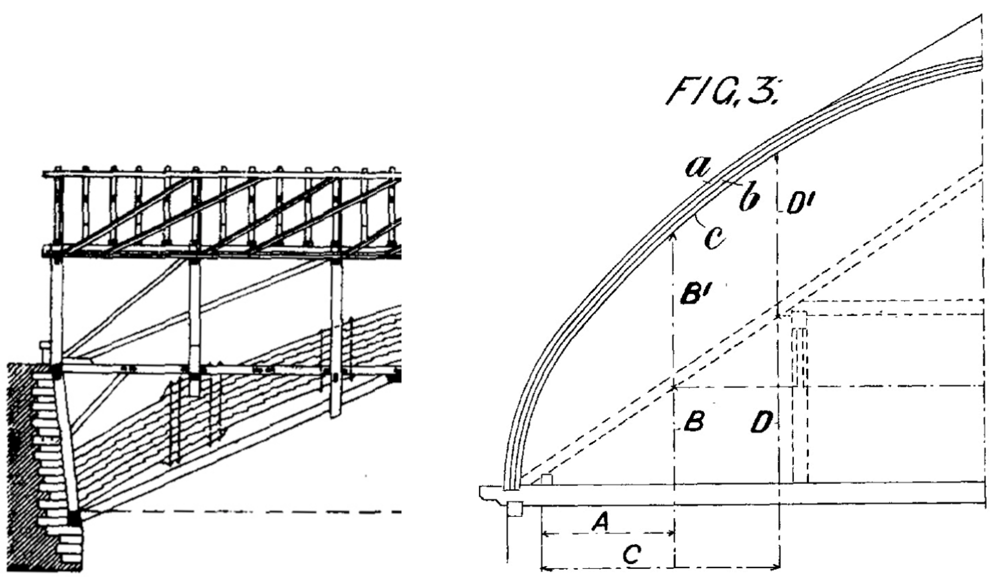

Figure 1: (a) Section of Grubenmann's timber bridge in Wettingen (1766) (Killer 1942) and (b) Hetzer's patent for a "curved structural timber element" (1906) DRP 197773

REGULAR CONSTRUCTION TYPES FOR COMMON BUILDINGS

During the first years of their practice Terner and Chopard developed some outstanding timber structures. One of which was the Swiss Railway depot Aebigut in Bern in 1913 (fig. 2a), which was highlighted by "Swiss Federal Railways as a typical example of greatly successful and modern timber construction" (SBZ 1913). Timber was the preferred building material for a railway building because it provided greater resistance against the smoke gas from the railway locomotives compared to steel plus it allowed for fast fabrication, assembly and dismantling.

The building structure consists of four timber frames side by side, each spanning between 20 to 24 m, forming a hall, irregular in plan, with a total width of some 88m and a length of 95m. The timber frames comprise two curved legs and a cross-piece tying the upper ends of the legs. The large prefabricated timber elements are slotted at the upper third just after the bent to allow for easier transport and assembly. Interestingly, many construction details already reflect modern timber engineering solutions. For example, for the connection detail of the two-part leg a type of strapping was used (fig. 2b) enabling the legs to be working in one plane only, i.e. the lower part continues straight away in the upper part by entirely connecting both parts on each side over the full depth. The detail ensures a quasi-continuous solid beam performance and has been adopted from industrialized standard iron construction technology at that time. Accordingly, the entire timber frame has been designed as a common moment resisting 3-hinged frame allowing for a predictable stress distribution and a familiar overall structural geometry. As mentioned by the Swiss Building Journal when presenting the Railway depot, "it became possible through new timber construction technology to create statically correct and aesthetically pleasing construction types also for timber" (SBZ 1913).

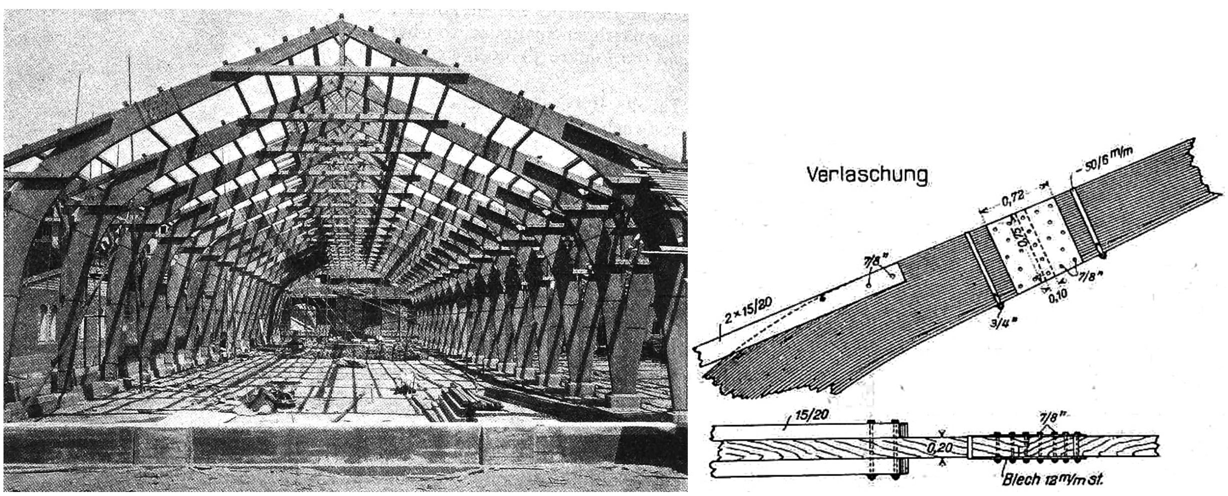

Figure 2: (a) Swiss Railway depot in Bern (1913) during construction and (b) joint detail (SBZ 1913)

Only three years later another important timber hall was finished: the tram depot "Dreispitz" in Basle. The building measures 92 by 44 m and its load bearing structure consists of two rows of timber arches resting on interior concrete columns and a brick wall on the outside. The three-hinged arches have been developed, as explained by Terner and Chopard also in the Building Journal, "to eliminate any static obscurity which can still be observed with many arches today" (SBZ 1918). Therefore, "extra care has been taken to design the hinges". Indeed, there was certain scepticism about the reliability of glued laminated timber to take shear forces resulting in lateral tension stresses in the members, which could lead to cracks and delamination effects. In the early phase of laminated timber construction the timber lamellas have been joint using casein glue, which was somewhat water-resistant. Before casein glue was used timber elements have been joint with glutin glue but both had to be warm, the glue and the timber piece, making the joining process rather impracticable for larger applications (Kühne 1979). Many early laminated timber components have been tied regularly with metal straps on the outside (fig 2b).

Terner and Chopard also designed some halls for temporary use such as the festival hall for the Schützenfest in Aarau in 1933 (fig. 3), one of the last projects of the joint office. The structure of the venue consisted of a series of rather slender glued laminated timber arches spanning some 30 m giving the hall an overall length of 104 m. The timber structure was later used in Berne.

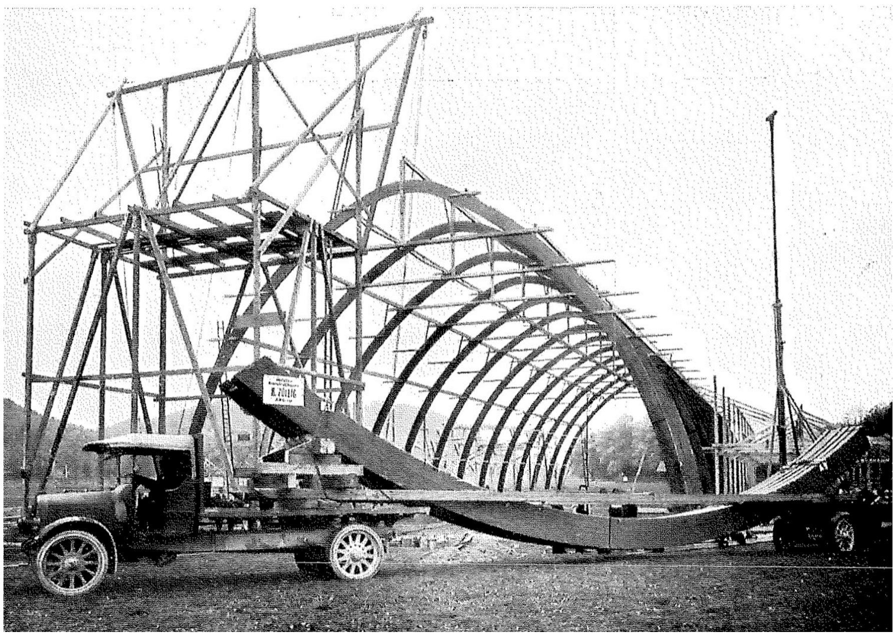

Figure 3: Structural arches for the festival hall in Aarau, 1933, during construction. (Roš 1925)

SPECIAL APPLICATIONS

Among the many constructions of laminated timber there were also those, which brought the basic concept of fragmentation and bonding in the industrial fabrication process to a particular form. By cutting the original timber pieces into thin layers, the lamellas, each of the now flexible members could be bent according to the desired shape and then glued resulting in multiple or highly curved timber elements. This application has been used for the structure of the bell-shaped dome of the University of Zurich in 1911 (fig 4a). The dome is square shaped in plan, 15 m wide, and the rafters are inwards and outwards bent giving the dome a total height of 8.5 m. The curved rafters are 10 cm wide and only 28 cm deep, placed at intervals of some 90 cm. The roof structure allows for an unobstructed space since the rafters are only stiffened at the top by several horizontal bracings. Until a very late design stage there was a conventional timber roof structure planned but then eventually replaced by the curved rafters. There must have been economic reasons for this change since the room in the cupola has never been used and still is not.

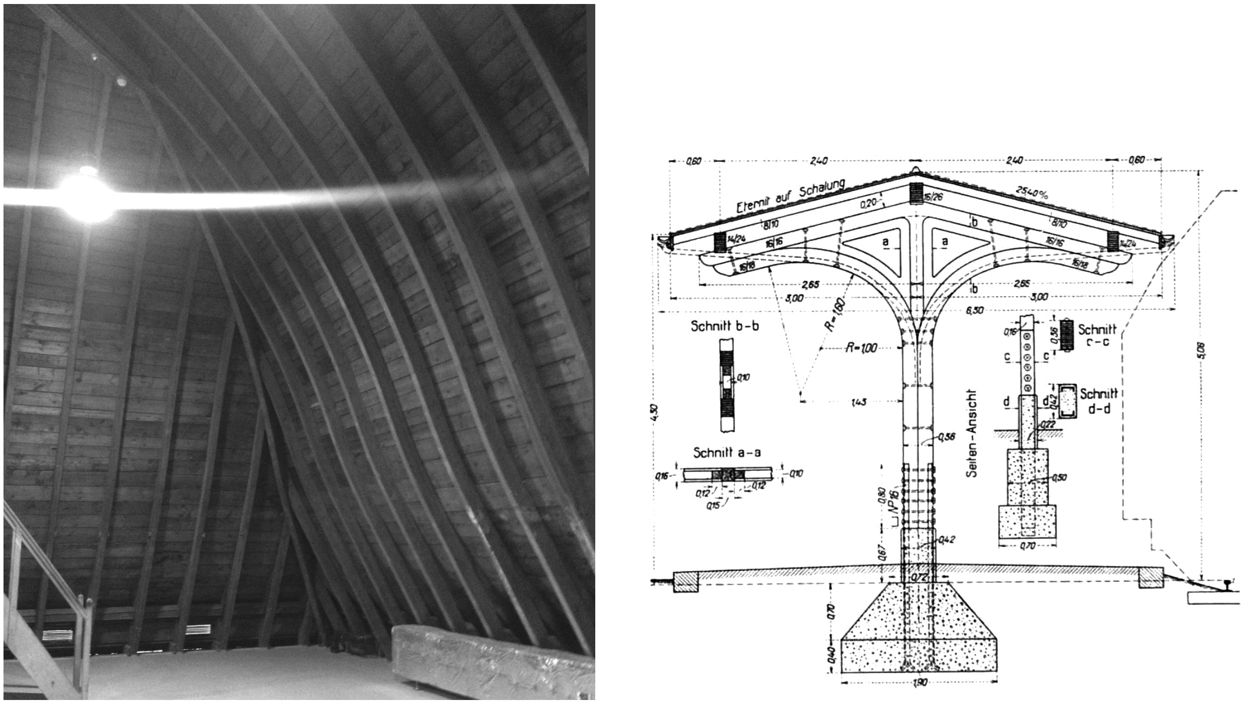

Figure 4: (a) Roof Structure of the Cupola of the University of Zurich (1911) and (b) platform roof in Interlaken (1921) (Chopard 1925)

Another interesting application of curved timber elements is roof structures for train platforms. Charles Chopard designed a single-column platform canopy for the railway station Interlaken West built in 1921 (fig 4b). The restrained column, fixed to the concrete basement via embed steel beams, consists of continuous lamellas spreading at the top to form a roof. The curved upper part features an extremely small radius of curvature between 1.4 and 1.6 m which is only possible with particularly thin lamellas with a varying thickness between 10 and 15 mm. For better consistency of the structure and for structural reasons also the horizontal beams at the top are of glued laminated timber, and so are the roof beams in between the columns.

EXPERIMENTS AND CODE DEVELOPMENT

In order to receive approval for the glue laminated timber frames proposed for the Swiss Railway depot in Bern, Terner and Chopard were asked by the national railway authority to carry out large scale breaking tests. Beside the "practicality of the construction type" the authority also wanted the static calculation made by Terner and Chopard to be verified since this type of timber was first used for railway facilities here. New standards of the department could then be based on the stresses measured and the performance monitored with the test specimens (Chopard 1913). There were two specimens used, which were built in one third of the original frame size, together with a load scaled accordingly (fig. 5). The gradually loaded frame performed surprisingly well and showed no damage under the sextuple load. It was found that the static model of a three hinged arch is appropriate for the proposed frames and that they performed to everyone's satisfaction. From the measured and calculated stresses a stress limit of 80 kg/cm^2 was determined for bending stresses (today in Switzerland ca. 160 kg/cm^2) "given that the application of the static conditions (…) can be ensured during construction". It can be observed, that along with the great uncertainty regarding the new type of material there was a close orientation towards static models serving as a solid base for understanding and controlling stresses and performances rather than adopting and adjusting traditional timber construction techniques.

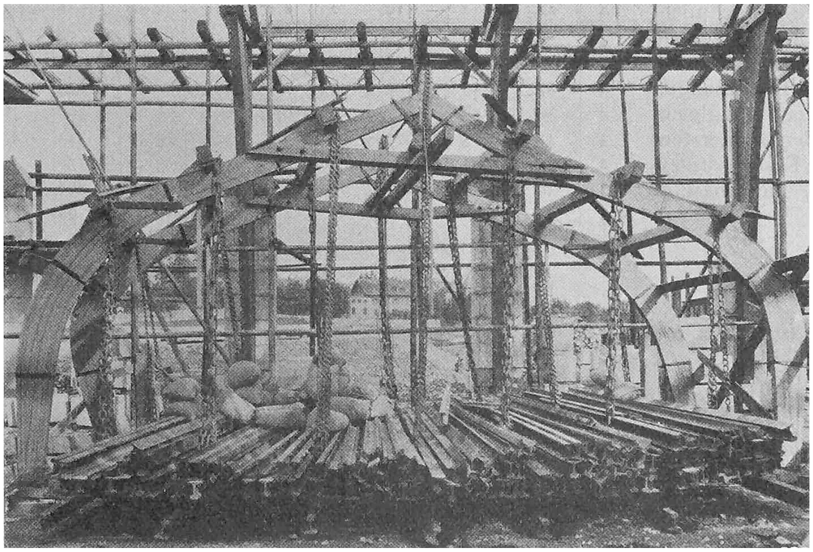

Figure 5: Large scale breaking test with glued laminated timber frames in 1912 (Chopard 1913)

In the course of the breaking tests for the railway shed in Bern it was found that further material research should focus on the shear strength of laminated beams. Fritz Hübner, chief engineer at Swiss Federal Railways, therefore suggested to carry out a series of shear tests to determine the shear strength of such beams. Chopard and Hübner reported the results and recommended narrow lamellas because of the warping of the individual layers. Eventually, they concluded to "mathematically defining a precise shear resistance is, by nature, not possible". The tendency to specify, control and adjust the mechanical properties for the increasingly industrialized laminated timber similar to familiar industrial building materials like steel can be traced throughout the first years of glued laminated timber. The branch of regular timber construction was long excluded from standardization and regulation other than it was done with new building technologies like reinforced concrete and steel construction, which is why the requirements from the authorities towards laminated timber in the case of the shed in Bern was rather a particular approach. The first draft for a building code for timber constructions dates from 1925 and specified several stress limits but did not include general requirements for construction – and did not include glued laminated timber at all (Roš 1925). Charles Chopard was also involved in the code development as one of the representatives of the building practice in the committee.

Hübner carried out another important study on glued laminated timber again in 1919 when he studied different shapes and connections of "Hetzer beams" at the Swiss Federal Laboratories for Materials Science and Technology (EMPA). He found critical failure mechanisms (fig. 6) and reported that the variation of limit loads of laminated timber is found to be "smaller than those of concrete", stressing the industrial predictable character of the new type of timber (Hübner 1924).

Terner and Chopard developed a great variety of forms and combinations using glued laminated timber but never focused on principal connection details based on the new type of material and its properties. Instead, they proposed a rather industrial new timber connection detail using a ring dowel described by Chopard in 1930 (Chopard in 1930) and patented in 1924 (No 106496).

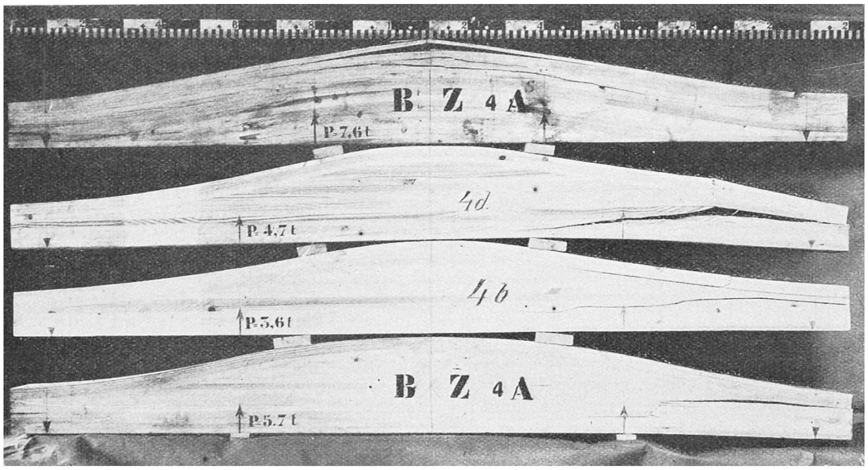

Figure 6: Breaking tests, Swiss Federal Laboratories for Materials Science and Technology (EMPA) (Hübner 1924)

CONCLUSIONS

Terner and Chopard developed numerous timber projects between 1909-1933 based on Hetzer's patent from 1906, which Terner acquired together with the exclusive right to use Hetzer's invention in Switzerland. Many structures have been closely developed with architectural considerations, such as the cupolas or the festival halls. Beyond their sense for delicate structural frameworks in both reinforced concrete and laminated timber they have proven great confidence and will to use timber in new ways and forms and to develop it further with many opportunities during their 24 years of joint practice. Terner and Chopard helped to establish an early high profile timber engineering focus in Switzerland.

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