On the origin of modern timber engineering

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The depression at the end of World War I forced German civil engineers into timber construction which had almost been ignored in the second half of the 19th century. Within a few years methods of engineering were applied to traditional carpenters’ woodwork. They facilitated new wide spanning truss and arch constructions based on joints that reduce the joint-slip to a minimum. In building storehouses for chemical industry, railway engine sheds and antenna towers timber construction becomes even superior to steel construction. In the 40’s, timber engineering was part of the upcoming standardisation of construction in Germany.

PROTO-TIMBER-ENGINEERING

Up to the 1850’s, wood has been the standard material for light wide span constructions. Thus the most important inventions in construction at the beginning of the 19th century were originally timber constructions with additional parts made of steel: laminated arches, elliptic and suspended beams and various truss girders. Particularly the girders by Howe and the suspended beams by Wiegmann and Polonceau may be looked upon as if designed by engineering means, a kind of proto-timber-engineering.

At that time, Modern engineering developed mainly as the result of three events: 1. the transfer of natural science into building practice initiated by the foundation of technical schools in France; 2. the evolution of metallurgy in England that supplied the industrialising countries with cast iron, later with steel at low costs unknown before; 3. the new types of construction created by North American carpenters evoking the theories of framework set up simultaneously by Whipple, Culmann and Jourawski (Whipple 1847; Jourawski 1850; Culmann 1851).

Straub (1992, 287) considers this event as the break-through of modern engineering: «In establishing graphical statics a progression had been completed in a certain way, an aim had been achieved: static behaviour of the most important structural principles in construction had been mainly cleared, engineers were enabled to design their buildings on scientific principles».

In about 1865, modern engineering is constituted, steel had replaced wood in almost all wide span constructions like bridges and halls. Meanwhile, mill technology and ship building, for hundreds of years «high end» timber construction, have become a domain of steel as well. Carpentry was reduced to its basics: floors and roofing. Around 1900, seldom used truss girders according to Howe and laminated arches according to Emy remained as poor heritage examples of the creative époque around 1850.

START-UP 1900

As a reaction to workers’ unions that appeared in the 19th century, carpenters in Germany began to
The Role of Timber Construction in the Development of Engineering

Table 1
The Role of Timber Construction in the Development of Engineering
reorganise themselves by the turn of the century. It was at that time, when some German carpenters and architects started experiments on new forms of timber construction, using engineering methods of calculation. (NN 1907, vol. 25, 2)

After 1890, Philipp Stephan, an architect from Düsseldorf, succeeded in bracing slender arches by using crossed struts to avoid buckling, followed by other enterprises like Carl Tuchscherer, Breslau experimenting as well with solid web profiles (NN 1902, 195; Kersten 1921, 50).

In 1904, Paul Meltzer from Darmstadt started building girders of bundled lattice-work fixed by steel pins. In the beginning, he used Australian Jaraah hardwood, later European and American pine as well (Zipkes 1914, 406).

Based on a patent of 1906, Otto Hetzer a carpenter from Weimar developed casein-glued laminated timber bows and trusses. Due to very successful marketing and international franchising, Hetzer-girders became very common all over Germany, Switzerland, Scandinavia and the Netherlands (Hetzer 1907).

Around 1910, enterprises like Adolf Sommerfeld in Berlin, built timber-steel-framework based on Howe’s principles using adjustable steel elements for the tensile parts of the construction and wood for the elements in compression (Gesteschi 1919, 89).

**THE RAILWAY IMPULSE**

In the beginning of the railway, the main buildings and bridges were built of wood for economic reasons. Before the success of the new transportation system, construction had to be achieved at low costs and in a short time. Later, more representative stations were built of stone with halls of steel and glass. Wooden bridges were replaced due to fire prevention in North America and Europe before the end of the century. In 1937, the last regular wooden railway bridge in England was taken out of service (Brown 1994; Brockstedt 1994, 101; Dietrich 1998, 106).

On the other hand, the lack of corrosion resistance against engine fumes and the high costs of maintenance soon became obvious. A milestone was the «Reichseisenbahnhalle» for the 1910 World Exhibition at Brussels built by Hetzer which had lamella frame girders of 43 m span. In 1912 the Swiss Railroad Company ordered a central engine hangar at Bern and advised all subdivisions of the company to use timber instead of steel for halls and hangars. In 1913, Kopenhagen Central Station was built with wooden halls by Philipp Stephan. These halls still exist like those at Malmö from 1922 and Stockholm from 1925 built by Hetzer (Mannheimer 1910, 206; NN 1913, 289; De Bruyn 1913, 377; 1994,79).

During World War I the work on the halls of Stuttgart Central Station had been stopped. After the war, work was continued on the halls, for economic reasons however, not in steel, as planned before, but in timber construction. Karl Schaechterle, responsible for the construction department of the Württembergische Staatsbahnen, at that time and, after 1918, of the united Deutsche Reichsbahn, initiated scientific studies on timber construction linking the practical knowledge of Karl Kübler AG from Göppingen with the theoretical and experimental possibilities of the Materialprüfamstalt, associated with the Stuttgart Technical University nearby. The studies were proceeded under the leadership of Otto Graf who took the heritage of August Lang, from Hannover.
was the first to do scientific experiments on wood as a construction material. As a result, the «Preliminary Specifications on Timber Constructions» of the Reichsbahn were issued in 1926, the precursor of DIN 1052 from 1933 (Graf 1922; Schaechterle 1921, 33; Schaechterle 1927).

Corrosion resistance against acids and bases makes timber a preferred construction material in chemical industries and salt mining. Wood is widely used for hangars, bridges, water and conveyor towers, even for pipelines (Kersten 1926, 231; Waninger 1923, 45).

**GROUND TO AIR**

Spanning around 30 meters in width and more than 100 m in length, airship hangars for one decade became one of the top challenges for civil engineering. At the 1909 Internationale Luftfahrt Ausstellung in Frankfurt, some timber airship hangars were displayed. Brockstedt listed 24 wooden hangars, nine of them by Ambi (Arthur Müller, Berlin). All the well known timber entreprenes present projects, even though most of them were not realised (Dean 1989; Brockstedt 1994a). Schütte-Lanz even built the frame of their lighter than air ships with asp plywood. Similar to Hetzer’s caseine glue Schütte used glutene glue based on cattle blood (Schütte 1926). Sonntag asserts in 1912 (p. 606): «The needs of competition have lead to a more careful treatment of details, to new designs and to new ways of utilisation of timber material and forms, known before only from iron constructions. The progress in knowledge on statics and strength of materials versus handcraft has been successfully pushed by the construction of airship hangars».

Beside the airship hangars Hetzer, Sommerfeld, Ambi, Meltzer, Stephan and Tuchscherer built lots of...
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wooden aircraft hangars, supplying the airfields of World War I (Sonntag 1920, 111). Moreover, as an electric isolator, wood was superior to steel in broadcasting constructions up to the 1930’s, when wooden antenna towers reached 190 meters in height (Traub 1934, 485; Leiter 1933, 487; Föppl 1933, 305).

TIMBER CONSTRUCTION IN AND AFTER WORLD WAR I

In supplying the army of the German Empire during the World War, innovative structural designs beyond the constraints of legal and administrative regulations were attained by the timber construction companies. New designs that relied on engineering principles, lead to interim bridges and to wide span hangars for airship and aircrafts avoiding steel, which was claimed for weapons. Civil engineers gained experience with temporary timber construction that had to be build for heavy duty and as quickly as possible to repair damaged bridges for railways and streets. Timber was the preferable material because of its general availability and the easy and fast handling.

There was also a strong impulse towards standardisation concerning the entire war economy, including the construction sector. Part of the Hindenburg-Plan was to increase the industrial production of weapons, ammunition and other warfare by unifying standards. Based on these ideas, standardisation continued after the war spreading as well into non-industrial sectors of the economy. DIN meaning Deutsche Industrie Norm got a wider, new signification: Das ist Norm (Schaechterle 1943, 36).

The unfortunate end of World War I brought Germany into a deep depression that forced engineers into timber construction, for they were too short on energy to produce steel, concrete or even bricks. The timber experience during the war served to establish a multitude of new timber construction companies in the years following 1918. Documented in lots of patents for special dowels, in the early 1920’s, timber construction regained a competitive position towards steel construction (Kersten 1921; Jackson 1921; Seitz 1925).

WHAT IS THE CHARACTERISTIC OF MODERN TIMBER ENGINEERING?

The specifics of timber construction lie in the use of engineering methods of calculation and the implementation of mechanical fasteners made of steel to reduce the traditionally tall joint slip in wooden construction (Lewe 1922). Special glue is used to build more or less homogeneous profiles of a bigger size than given by natural sources. Both means allow to build composite profiles that can compete against steel trusses in terms of span and loads.

Dowels and fasteners can be classified by their material, their cardinal strain, i.e.: tension, compression, shear or bending, their geometry and their stiffening or articulating effects on the static model. The implementation of modern steel connectors in timber construction was due to the benefit of the invention of the portable power drill.

Figure 4
Drill centered fraise (Nordell 1919)
Table 2
Rotationally Symmetric Connectors

With drill centered fraises, accurate recesses became possible that allowed the proper fitting of the connector. The arrangement, axially symmetric to the leading bolt, forms an ideal pin. The handheld drills allowed to work true to size, even on the construction site, in assembling the parts (Nordell 1919; Seraphin 2002).

ESTABLISHING A TECHNOLOGY

The reorganisation of the German society after Versailles gave industries the opportunity to proceed in standardisation by installing the group for unified technical reglementation at the board of normalisation of the German Industry (ETB —Einheitliche Technische Baubestimmungen— Ausschuss im Normenausschuss der deutschen Industrie —NDI) The newly founded «Deutsche Holzbau-Verein» succeeded in representing the concerns of modern timber engineering. In the beginning, practical knowledge met theory in a manner of misunderstanding (Sommerfeld 1920).

The growing awareness of the problems timber construction has had to face, due to a series of spectacular collapses, would probably have defeated a useful standard, simple enough to be practised, if not Schaechterle had managed to find rules for railway buildings based on the Stuttgart Central Station. The 1926 «Preliminary Specifications on Timber Constructions» of the Reichsbahn were followed in 1930 by DIN 1074 «Bridges in Wood» and finally in 1933 by DIN 1052 «Construction in Wood» (Seitz 1925; Schaechterle 1926).
Between 1918, the year of the boom of inventions, and 1933, the year that DIN 1052 was issued, modern timber engineering made up for some 50 years of ignorance. In a rush, wood construction regained competitive qualities against steel and concrete.

The following decade was dedicated to the consolidation of the findings by scientific tests on timber. Timber engineering research has been strongly supported by the authorities of the «3rd Reich» to reach autarchy. Like in the former imperial era, construction of temporary bridges—now built by nailed boards—was a key task to armament in the 1930’s. And normalisation provided the structures for this process.

After several updates based on research, particularly on dowel and nail joints by the Technical Universities of Stuttgart and Karlsruhe, the German standard DIN 1053 achieved in 1943 a status that kept its fundamental validity up to the actual conversion into European standardisation (Graf 1944; Schaechterle 1943, 36; Wedler 1944).

THE PROTAGONISTS OF MODERN TIMBER ENGINEERING

Carpenters, architects and civil engineers participated in the evolution of modern timber engineering, that was performed by companies, not by single craftsmen. Some of the leading companies were or became public incorporated.

Many construction enterprises got involved in timber construction after the war from 1914–1918. Getting out of the worst depression, some of them, for example Hünnebeck, dropped their timber activities as soon as possible, some of them like Karl Kübler AG or Siemens Bau Union continued work in a special timber department.

Most of the companies were acting nationwide and some of them like Hetzer and Christoph & Unmack may be looked upon as early global players, trading aircraft hangars and prefabricated houses and barracks all over the world. Companies installed a system of franchising, with local carpenters being partners of the license owners. In order to convince the public of their systems, designers published lots of examples and often even the calculation schemes in engineering journals (Christoph 1926; Lewe 1920).

FOREIGN AFFAIRS

The genesis of modern timber engineering in the beginning 20th century, appears initially as a German affair. In contrast to the development of engineering in the 19th century, being the result of French, British and American impulses, the foreign influence on timber engineering was negligible. On the other hand German timber construction showed soon remarkable effects in Scandinavia, the Netherlands and in Switzerland. For the Baltic region the technical universities of Riga and Danzig took an active part in the process.

In France and Great Britain, the adoption of steel and, later, concrete construction in the 19th century was more complete than in Germany. Conversely the resistance against modern timber construction seemed to be rather strong. So a renaissance of timber construction cannot be detected there until the 1950’s.

Refugees from Nazi-Germany, first of all Konrad Wachsmann and Walter Gropius, started to proclaim modern timber construction in the United States of America in the 1930’s. Max Hanisch, who had emigrated from Weimar some ten years before, established the American glulam industries in Wisconsin at that time, using the Hetzer system of caseine glue. Gesteschi reported several reconstructions of suspension bridges in Oregon, in which stiffening Howe trusses were toughened by ring dowels. Already in 1927, the St. Louis Fair built a hall of 60 metres span in Zollinger’s lamellar space structure that persisted as a baseball arena until 1999.

Figure 5
St. Louis Arena under Construction System Zollinger 1927 (Bayerische Hallenbau GmbH 1929, 28)
After the Pearl Harbour attack, the US created an aerial surveillance by airships operating out of 17 identical wooden hangars along the east and the west coast. Measuring 331 metres in length and 90 metres in width they were the biggest buildings made of wood up to now. Some of them still exist (Grüning 1989; Rhude 1995; Smith 1999; Dean 1989).

TIMBER CONSTRUCTION AND MODERN ARCHITECTURE

In 1920 Walter Gropius, the director of the Bauhaus at Weimar praised timber construction as a chance to regain a sense for building «... the broken world will revive newly formed by our brains and hands ... Wood is the building material of the present, the one of the distant future, the one of our wishfulness — pure glass — we won’t have reached maturity until the sense of building will have animated the entire people such as it was during the period of the gothic cathedrals (Gropius 1920)».

In reality the plight is more prosaic. It was a big frustration for Paul Bonatz when the pre-war design of the halls of the Stuttgart Central Station spanning around 40 metres was altered into a 20 metres spanning construction based on continuous beams to reduce the converted space and thereby the costs. «from the architectural view the substitution of the iron halls by wooden halls is not only unobjectionable but the wooden halls are definitely preferable for their special attractiveness, ... It is essential indeed, to choose the 40 metres hall and not the 20 metres hall». The architect’s opinion had been simply ignored lately. Astonishingly the halls had been reconstructed after the damages of World War II in the same appearance, but then in steel. The abdication of high halls and the installation of flat halls with fume outlets is a type of railway station that became common until the actual renaissance of the big halls. (Schaechterle 1921; NN 1921).

The bigger part of the building projects is handled as purely functional: storehouses in industries and railways, antenna towers for broadcasting, hangars for aircrafts and airships. The contractor himself manages the entire project representing engineer, architect and executing company at the same time.

Due to the economic situation decoration takes a back seat in design, compared to the pre-war period. The achieved distinctness of the structural design affords the opportunity of an unostentatious classiness in appearance. In particular the slender bow designs by Stephan and Tuchscherer, the cambered frame trusses by Hetzer and the filigrane lattice work by Meltzer sometimes were of excellent esthetic quality. One of the most impressive examples is the Westfalenhalle, built in 1925 at Dortmund with 76 m in span (NN 1925).

Figure 6
Construction System of the Westfalenhalle in Dortmund 1925 (NN 1925)

Except Conrad Wachsmann, who took an intermediate role between architects and engineers modern architecture and the Bauhaus avantgarde do not seize the regained possibilities of the old material. Wood has still the aura of regression at that time.

CONCLUSION

The disastrous situation in 1918, forced German engineers to resort to new ways of construction in wood that had been a forgotten material for about 70 years. Within a few years, methods of modern engineering were applied to traditional carpenters’ woodwork, restoring its competitiveness by reducing the joint-slip by special dowels, fasteners or glue. The development that took place in Germany between the World Wars defines the birth of modern timber engineering.
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