Timber Bridges in Central Europe, yesterday, today, tomorrow

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Abstract

Historically, limber bridges have played an important role. The decline of timber bridge building was triggered by the development of competing materials: steel and concrete. Governing factors for the revival of limber bridge building in the eighties has been the development of timber engineering, of glued laminated timber (treated and untreated), as well as of the laminated bridge deck.

Keywords: Bridges, competition, concrete, development, design, history, innovations, steel, tradition, timber, timber engineering, trends.

General Remarks

Building bridges is a matter - among other things - of topography, transportation needs, economic potential, cultural heritage, availability of suitable materials and experienced craftsmen, fashions, prestige, preferences and prejudices. Bridges often have a symbolic character and reflect the spirit of the times in which they were built.

Nowadays bridges are usually engineered structures - designed solely by engineers. Architects have only been involved in bridge designs in very few cases - and this has not always been beneficial.
While craft skilled timber structures have shown more or less a steady appreciation and demand on the building market through the last decades, the engineered timber structures, including timber bridges have demonstrated a significant increase over the last fifteen years. This has been especially true for Switzerland and later on to some extend also for neighboring countries.

The background of this development, the reasons and the perspectives shall be explained: Europe - in spite of its small size - is characterized by many climatic, topographical and cultural differences, as well as a considerable variety of building traditions. The following considerations are mainly valid for the alpine region with its major through roads overcoming many obstacles, rivers, streams, gullies, ravines, gorges etc.

Bridges in Retrospective

Bridges certainly played an important role in the transport systems of old cultures, but amazingly little is known about them. Exceptions are Caesar's bridge over the Rhine or Trojan's bridge over the Danube.

Considering the entire history of men, timber has been undoubtedly the most frequently used material for bridge building Even the Romans, who developed a highly sophisticated building technology with natural stones, used a lot of timber not only for bridges but also for other major structures like the Coliseum in Rome. After the collapse of

the Roman Empire their amazing road system broke apart due to the lack of maintenance and many of the building skills of the Remans were lost. More simple methods were applied later on, techniques which had been used at all times by craftsmen for less important crossings. These techniques can be characterized by short span, low load bearing capacity, cheap material, little workmanship and low durability.

Very little is known about the art of bridge building between the Roman times and the Middle Ages (approx. 1200 a.D.). By then the road systems had gained importance again and included safe and durable bridges. From that period, we have considerable evidence of timber bridges, mainly of covered ones. The roof obviously was recognized as being a most efficient means of protecting the bearing structure from the adverse influence of the weather. These bridges mostly had an abutment of stone to separate the timber structure of the bridge from the moist soil. Those builders knew perfectly well that - besides hostile men - rot is the most dangerous enemy of timber bridges - and can be prevented by keeping the wood reasonably dry.

The evidences of those timber bridges are not restricted to pictures and written documents, for the durability achieved with the technology of that time allowed many of these structures to stay in service until now. One of the famous examples is the Chapel-bridge in Lucerne. which lasted until 1993 when most of it was destroyed by a fire.

By the way, this has been the fate of most of the historical timber bridges: They were not destroyed by the ravages of time, but were burnt down in the many quarrels and wars of European history.

The most famous bridge of the builder Hans Ulrich Grubenmann was built in Switzerland in 1758 over the Rhine at Schaffhausen and had a length of 120 m (400ft). Even though longer bridges were built by other builders. the Grubenmann family represents a certain climax of craft skilled timber bridges up to the 19th century.

Then new techniques were introduced, triggered by a increased availability of iron at a considerably reduced price due to new manufacturing methods. New types of structures were introduced in Central Europe, especially of the truss type, like lattice truss or Howe's truss. However, they never became as popular as in North America, where they had been invented and were built by the thousands.

Decline of Timber bridge building

Promoted by decreasing prices the iron and later steel, the technology developed quickly.. Iron and steel became increasingly popular for bridge building and the use of timber declined rapidly in the second half of the 19th century.

Steel and - fifty years later - reinforced concrete represented modern times and technology. The seemingly unlimited new possibilities have edged timber completely out of the minds of ridge-) engineers. Besides the image of being outdated - and not offering any superlatives (strongest, biggest, longest), - timber as a bridge material was disregarded for several other reasons:

The traffic loads had multiplied, urging the use of high strength materials. Scientific research and development resulted in a high level technology of steel- and concrete production. Large and powerful steel and concrete industries developed, absorbed and implemented new know-edge. Tough competition kept (and still keeps) the price of steel and concrete low, and professional training in steel- and concrete technology and design is thorough and well recognized.

In the same period wood and timber engineering remained a research topic of low significance. Production - except that of the wood derived panel products - remained in the hands of numerous local saw-millers and craftsmen, lacking a substantial capital base and innovative drive. Professional training at the crafts-men's level was (and is) satisfactory but traditional - and at the engineers level either modest or non existent.

For at least half a century the art of timber bridge building remained in a state of hibernation, fifty years during which an enormous increase of all building activities took place in the industrialized part of the world - a period strictly dominated by concrete and steel.

Revival of Timber bridge building

A gradual revival of timber bridge building started about 1980. It was based mainly on earlier developments in timber engineering and of glued laminated timber. Numerous innovative projects resulted in some spectacular structures, particularly roof structures for sport stadiums. All these structures have one advantage bridges don't have: The carrying structure is normally well protected from the weather and presents few complications regarding durability.

Even though adequate durability is one of the major tasks in timber bridge construction, there were and

certainly still are more dominating obstacles to a more frequent use of timber. It is well known that, not only in Central Europe, but in most countries the limited knowledge and experience of most design engineers and officials in highway departments leads to a generally negative attitude towards the use of timber for bridges.

A US-American investigation revealed in detail the uncertainties and knowledge gaps of the responsible engineers (1). The study certainly also reflects the situation in Central Europe and many other countries.

The renaissance of the timber bridge demonstrates, that technical as well as mental obstacles can be overcome. Today there arc a considerable number of arguments to encourage the use of timber for bridge construction:

Technical arguments -

- the availability of new types of wood based products with engineered properties

- the fun of rediscovering a "new-old" fascinating material with many interesting properties

- the better knowledge of the properties of wood and the increasing ability to take advantage of specific characteristics of wood in an appropriate manner

new possibilities of modifying wood and combining it with other materials to fulfill special tasks within the timber structures

- new ways and means of manufacturing, quality, control, transporting and erecting wood structures

Other arguments -

- the rediscovery of timber as an environmentally friendly, renewable resource with virtually unlimited supplies

- a fashion-like preference for architectural features expressing the characteristics of timber structures

- the potential of wood and timber structures to promote a certain design quality which cannot be achieved with other materiels

and last but not least

- some loss of image of the materials competing with wood. particularly the increasing awareness that concrete is by far not the everlasting material it was expected to be.

Focal points of Innovations

If we analyse critically the circumstances leading to the current increase in the use of wood as construction material for bridges in Central Europe, wc come to the conclusion that three dominating factors are responsible for it, two of which are of a technical nature:

The *first* factor is the development and use of pressure treated glulam for which a base was laid in extensive tests in the seventies. This has allowed the use of glulam elements in the more hazardous circumstances normally occurring in bridge constructions.

The *second* factor has been the development of the stress laminated bridge deck, a development which started also in the seventies in Ontario. A later development was the glued laminated bridge deck. Compared to former techniques, such bridge decks are characterized by a certain monolithic solidity, allowing an efficient plate action of the deck, i.e. a better load distribution and providing also a solid base for the moisture barrier and the wearing surface (pavement). In view of the everyday problems of bridge maintenance and repair this factor should not be underestimated. Today laminated bridge decks are important for new timber bridges, as well as for retrofitting existing ones.

The *third* and last factors has been a slowly changing attitude of building owners, politicians and especially the responsible officials in highway departments, which lead to a more positive attitude towards the use of timber.

Types of new Bridges

Trying to characterize the timber bridges of the last fifteen years, we can distinguish three quite different categories:

The first type - which I would call *'utility bridge'* - is expected to be cheap, simple to build and to maintain. It is standardized and restricted to the most favourable circumstances for timber (e.g. short to moderate spans). It is durable and has little beauty or design ambitions, but can compete economically with any other bridge material.

The second type is just the opposite and could be called *'designer bridge'*. Its characteristics are bigger spans, a higher level of sophistication, innovative design and the implementation of new and/or unusual ideas. It has esthetic ambitions, but the economy is usually less favorable.

The third type is the *'modernized classical bridge'*. It was the first one of the timber bridge revival. Its appearance bears features of traditional bridge design, especially of covered bridges, but technically it is taking advantage of all modern developments, such as glulam, microlam and other wood based products, pressure treatment, newest types of connectors, prestressing of bridge decks, etc.

Following this simplified classification in reference to highway bridges we may say that the *designer bridge* is at the moment the preferred type in Central Europe. The *modernized traditional bridge* is also popular, but of decreasing importance, not only for price reasons. Up to now the *utility bridge* plays a secondary role in Europe, but this could change rapidly according to local initiatives.

For obvious reasons railway bridges in timber are virtually non existent in Europe.

Pedestrian and other low duty bridges are quite popular in most regions. The far lower loads allow a much greater degree of design freedom, and their development and application follows a different pattern.

Many people have mixed feelings about the construction of new covered bridges. It is a controversial topic. but should be handled from a rational point of view. This supposes a clear distinction between the technical, economical and architectural aspects. Covered bridges are traditional in some regions and fit well in some landscapes and surroundings. They tend to have a heavy appearance, if they carry more than one lane. Even though various samples of this type were built, the majority of covered bridges are rather narrow. To like the architecture of covered bridges or not, is a matter of taste, but all the historical bridges still in service were and are - if not of natural stones - *covered* timber bridges.

Design Trends

There is no doubt that technically the roof is an extremely efficient protection against the adverse impact of the weather. It increases the bridge construction costs noticeably but, on the other hand, clearly cuts expenditures for maintenance - nearly by half according to German investigations (2). This may result in competitive annual costs or life cycle costs.

Undoubtedly the improved durability image of outdoor timber structures - among them also bridges - is based to a considerable extent on chemical treatments for preservation. However, durability is becoming more and more a dominating design factor.

In the last ten years environmental concerns have clearly spoken increasingly against the use of toxic chemicals for wood preservation. This has recently prompted some less experienced designers to omit chemical treatments completely, without taking into account the far reaching consequences: Some design configurations just don't work without the help of chemical treatment, and completely different designs may be necessary. The borderline between feasible and non-feasible is not well defined and depends on a number of factors, but improper approaches may result in substantial damage within a short time. This could quickly and thoroughly destroy the 'durability image' of timber bridges.

The requirement to minimize or to avoid completely chemical preservation clearly reduces the multiplicity of design possibilities and enhances the importance of constructive measures, i.e. structural detailing (see contribution of F. Kropf). Nevertheless one hopes that the innovative drive in timber bridge design observed in the last few years will not lose its momentum.

Looking at other perspectives of Central European timber bridge design - beyond durability considerations - it seems that the engineers have acquired a new freedom of combining the various materials available to them: timber, steel, concrete, wood derived materials, and last but not least high performance fibres, which are increasingly the subject of R&D and full scale implementation also in the building domain.

Composite structures will certainly be one of the distinct trends in the next few years, based on newly developed technologies for joining various materials by gluing or more conventionally with mechanical fasteners. Concrete bridge decks on glulam girders are in many cases a viable alternative and the monolithic deck can provide an efficient weather protection for the underlying timber structure. One of the important details still in need of improvement is the efficient and economic shear transfer between deck and girders.

Closing Remarks

In retrospective there has been a remarkable innovative drive in timber bridge building in Central Europe. Starting from a lower level than North America, there is a clear potential for a quantitative development. However, substantial efforts are necessary to maintain and consolidate the current

rather favourable general attitude towards timber bridge building.

For such an objective it is highly desirable that many engineers with enthusiasm and solid knowledge of timber construction create and try out new attractive designs.

On the other hand it may be less spectacular but still of higher importance regarding the marketing potential that the respective industries get interested in developing, producing and marketing technically and economically convincing utility bridges.

References and Bibliography

Wipf T. J. et al., 1993. Development of a Six-Years Research Needs Assessment for Timber Transportation Structures. USDA Forest Service. Forest Prod. Lab. Techn. Rep. FPLK-GTR-74

In: Ritter, M.A.; Duwadi, S.R.; Lee, P.D.H., ed(s). National conference on wood transportation structures; 1996 October 23-25; Madison, WI. Gen. Tech. Rep. FPL- GTR-94. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory.