World Conference on
Timber Engineering
Oslo 2023

AN INSIGHT INTO THE DEVELOPMENT OF TIMBER BRIDGES IN NORWAY AND SWEDEN

Martin Cepelka[1], Per-Anders Fjellström[2], Ashish Aeran[3]

ABSTRACT: Timber has historically played an important role as a building material for bridge construction both in Norway and Sweden. Although a decline was seen due to rise of other competing materials such as steel and concrete over the past century, it has regained popularity in recent decades due to pioneer developments in timber engineering including glued laminated timber and stress-laminated timber decks. There has been a specific focus on development of timber bridges in the Nordic countries after a Nordic Timber Bridge Project was started in 1994. Hundreds of bridges have been constructed throughout these countries including both pedestrian and heavy traffic bridges thereafter. Although the information about the number and type of these bridges can be found on several public administration sources, the information is very scattered and difficult to interpret. In the current study, several sources and databases were used to collect data on timber bridges in Norway and Sweden. Based on the collected data, a comparative view of the development of timber bridges in the two countries is presented with main focus on modern timber bridges built after year 2000. Detailed statistics are included in the study regarding year of construction, type of traffic, bridge types and bridge lengths. Discussions are presented in the end with focus on current trends and possible outlooks for use of timber bridges.

KEYWORDS: Timber, Bridges, Norway, Sweden, Statistics

1 INTRODUCTION

Timber bridges represent an environmentally friendly alternative to concrete bridges for medium-span bridges. As numerous LCA analyses have recently showed, by using timber instead of concrete, reduction of CO_2-equivalent can be achieved for bridge constructions [2]. Both in Norway and Sweden, number of modern timber bridges have been built since 1990's and good knowledge regarding the use of timber in modern bridge structures have been obtained [3]. An example of a modern timber bridge in Norway is shown in Figure 1. With today's focus on green transition, timber bridges can be utilized for lower environmental impact of infrastructure projects. Besides lower environmental impact, timber bridges feature low weight and rapid assembly on site due to large amount of prefabrication and manufacturing precision.

Lately, timber load-bearing structures have been facing tremendous growth in multi-story buildings in Norway and Sweden. According to Norwegian Byggfakta, timber was used in the load-bearing structure in about 40 % of all new school projects in Norway in 2021, while the share on the building market was about 10-20 % in past 10 years in average [1]. The reason behind the growth of share of timber buildings compared to other structural materials is believed to be facilitated mainly by use of a new technology by cross-laminated-timber (CLT), and increased focus on environmental impact of new projects.

Given the large increase of use of timber in multi-story buildings, we were interested in investigating whether same trend can be observed for timber bridges. We found the available data being difficult to use directly and decided therefore to perform a statistical study based on own collected data for timber bridges in Norway and Sweden. The results of the investigation are presented in the current paper including details regarding bridge types and bridge lengths. The data are complemented with description of the current trends in timber bridge construction in order to provide an inspiration for bridge designers and bridge owners.

Figure 1: *Vinsnes Bridge over Rv. 22 near Lillestrøm in Norway from 2015. Design: COWI AS. Photo: Martin Cepelka.*

[1] Martin Cepelka, COWI AS, Norway, macp@cowi.com
[2] Per-Anders Fjellström, TBS Timber Bridge Specialists AB, Sweden, paf@timberbridgespecialists.se
[3] Ashish Aeran, University of Stavanger, Norway, ashish.aeran@uis.no

 https://doi.org/10.52202/069179-0517

2 DATA COLLECTION

Neither in Sweden, nor in Norway, there exists an overall database governing all bridges within the countries. There are numerous bridge owners, each having their own databases with rather varying quality. In addition, the private owned bridges are not covered by any database. The collection of a total number of bridges is hence difficult. We have therefore chosen to collect data from the leading timber bridge contractors in Norway and Sweden: Moelven, Svenska Träbroar, Martinsons, and the central bridge databases Brutus (Norway) and BaTMan (Sweden), where most of road and pedestrian bridges over main roads are registered. In addition, some bridges were registered manually based on the authors' knowledge. All bridges were then checked across the different databases such that double-registration was avoided. For most bridges, GPS coordinates were available which gave possibility to plot the bridge locations for validation.

Besides data on timber bridges, we have also used Brutus and BaTMan to provide number of bridges built in concrete and steel for comparison and overall trend on the number of built bridges.

For most of the bridges, we have collected additional information in terms of bridge length, type of traffic on bridge (road, or pedestrian), and bridge type. This gave a possibility to look deeper into the development of timber bridges over time, as presented in Section 4.

We have chosen to focus on "larger" bridges built since year 2000. We were interested in bridges that either carry vehicle loads or pedestrian bridges that cross main roads or larger rivers. That means that smaller bridges, as for example park bridges, were disregarded. In some plots, we have also included data on bridges built before year 2000 to visualise a particular trend. However, it must be kept in mind that the data on older bridges bear higher uncertainty. All registered bridges are currently in operation, i.e. bridges that have been replaced or removed were disregarded (this is mainly relevant for older bridges).

The authors are of opinion that the vast majority of larger timber bridges in Norway and Sweden are covered in the study. However, it must be emphasized that the study does not cover all timber bridges due to the limitation of the data collection as it is very difficult, if not impossible, to obtain data on all bridges within the countries.

3 RESULTS ON NUMBER OF BRIDGES

This section presents an overview of the number of timber bridges built in Norway and Sweden. Additional statistics on bridge types is presented in Section 4. As the study does not cover all timber bridges, it must be kept in mind that trends, rather than absolute numbers, should be interpreted.

3.1 Timber bridges in Norway

The number of timber bridges in Norway since 2000 are presented in Figure 2. The number of bridges seems to be rather stable, and it fluctuates around a year-average of about 10 timber bridges per year. The bridge number is particularly high in 2019 due to contribution of 11 flyover arch road bridges on large motorway projects Rv. 3/Rv. 25 Løten–Elverum (8 bridges), and E6 Brumunddal-Moelv (3 bridges). Figure 3 presents the distribution of road and pedestrian bridges in Norway and it is fairly even in general. The total percentage of road bridges are 47 % compared to 53 % pedestrian bridges during the considered period. The total built lengths of these bridges are also presented in Figure 4. Although the total built length of road bridges is much higher in some years, the overall length is nearly the same during the considered period (4.47 km for road bridges and 4.03 km for pedestrian bridges). The historical development of road and pedestrian timber bridges over past decades is also presented and shown in Figure 5. Here, a clear trend in increase of number of road bridges can be observed after 1990s.

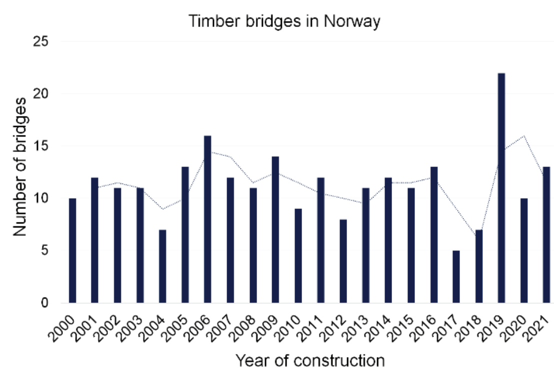

Figure 2: *Number of timber bridges built in Norway (both pedestrian and road bridges), based on selected database. The dotted line represents moving average with period of 2 years.*

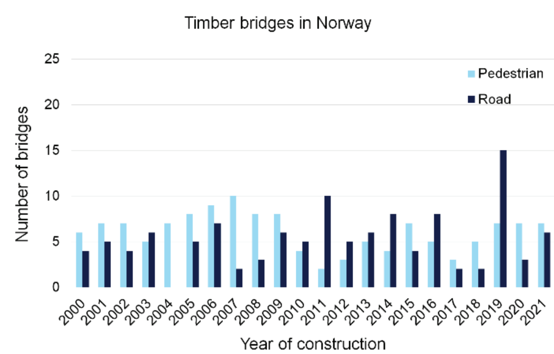

Figure 3: *Number of road and pedestrian timber bridges built in Norway, based on selected database*

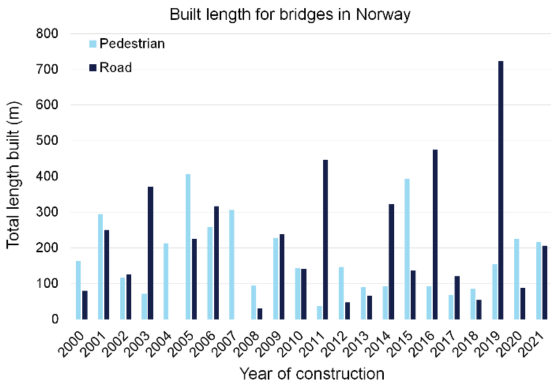

Figure 4: *Built length of road and pedestrian timber bridges built in Norway (2000-2021), based on selected database*

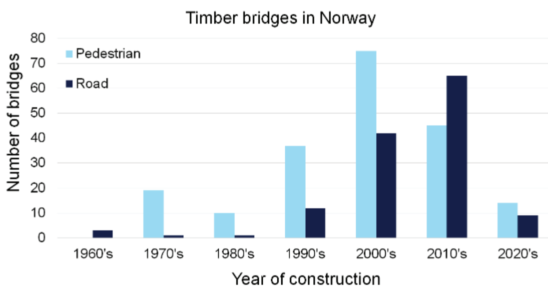

Figure 5: *Built length of road and pedestrian timber bridges built in Norway (1960-2021), based on selected database. Note that data on older bridges are less reliable.*

Figure 6 shows a comparison between share of timber, concrete, and steel bridges built in Norway. The share of timber bridges is relatively stable, and it fluctuates around 5 % every year for studied period.

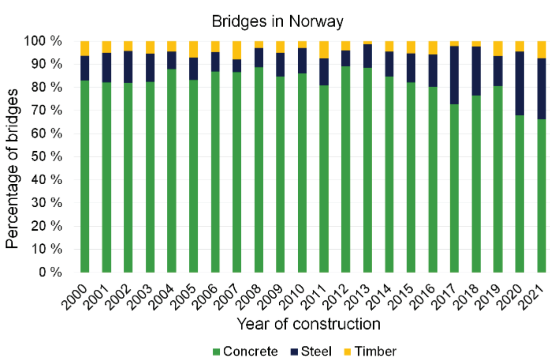

Figure 6: *Comparison of share between concrete, steel, and timber bridges built in Norway in period 2000-2021 as registered in Norwegian bridge database Brutus.*

3.2 Timber bridges in Sweden

The number of timber bridges in Sweden are presented in Figure 7. The number of bridges built in the early 2000's is around 50 bridges per year, and the trend seems to be decreasing in last 10 years.

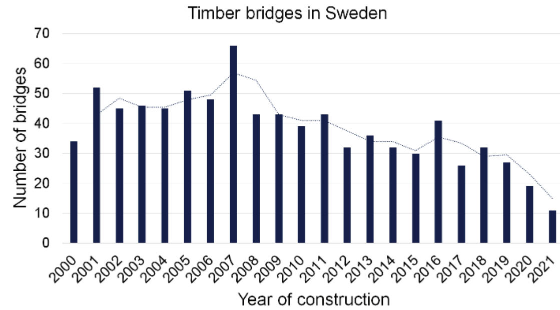

Figure 7: *Number of timber bridges built in Sweden (both pedestrian and road bridges), based on the selected database. The dotted line represents moving average with period of 2 years.*

The distribution between road and pedestrian bridges is shown in Figure 8. Almost 70 % of the bridges are pedestrian during the considered period, although this gap seems to be decreasing in the recent years. The total built lengths of road and pedestrian bridges are shown in Figure 9 with pedestrian bridges around 15 km as compared to 4 km road bridges.

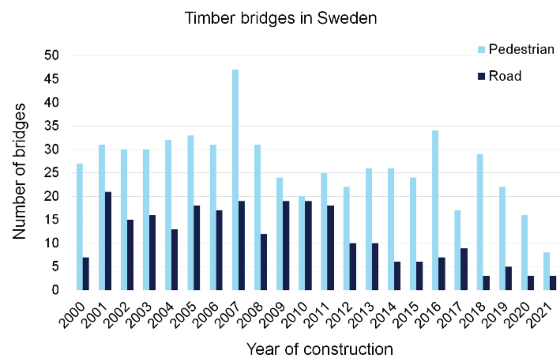

Figure 8: *Number of road and pedestrian timber bridges built in Sweden (2000-2021), based on selected database*

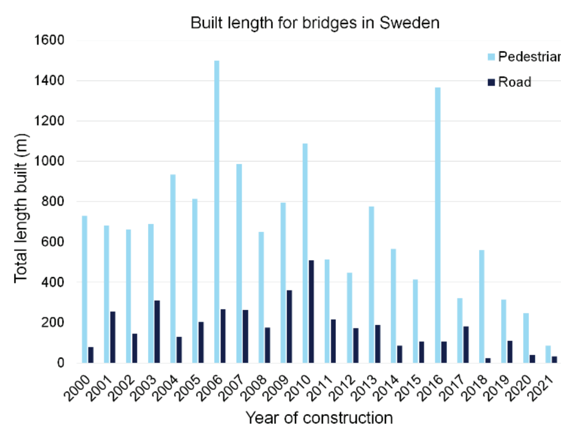

Figure 9: *Built length of road and pedestrian timber bridges built in Sweden (2000-2021), based on selected database*

https://doi.org/10.52202/069179-0517

Figure 10 shows a comparison between share of timber, concrete, and steel bridges built in Sweden based on the bridges registered in the national database BaTMan. The share of timber bridges is relatively stable, and it fluctuates between 3-7 % for studied period besides year 2021, for which no timber bridge has been registered in the database.

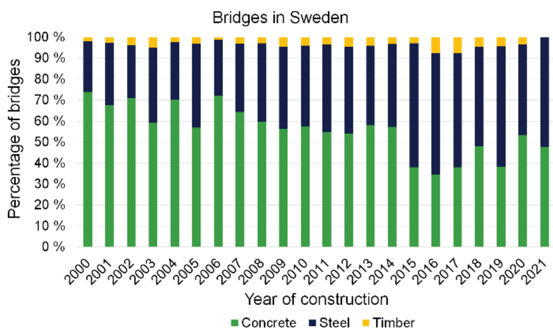

Figure 10: *Comparison of distribution between concrete, steel, and timber bridges built in Sweden in period 2000-2021. The data are only valid for state owned bridges registered in the Swedish Road Administrations bridge database BaTMan.*

3.3 Comparison of bridges in Norway and Sweden

A comparative study is done for timber bridges in Norway and Sweden as shown in Figure 11. The number of bridges is substantially higher in Sweden as compared to Norway. This is primarily due to a larger number of pedestrian bridges in Sweden as shown in Figure 12, annual built length, and Figure 13 the total built length. However, as also mentioned earlier, the gap between the number of road and pedestrian bridges is getting closer in the recent years, both in Norway and Sweden.

The number of road bridges is also much higher in Sweden, and this number is more than twice of that in Norway. However, interestingly, the total built length of road bridges is higher in Norway than Sweden, see Figure 14. Same trend can be observed for pedestrian bridges for which the factor of 6 in difference between Norway and Sweden in terms of number of bridges is reduced to 3 when comparing accumulated bridge length. This indicates that a typical timber bridge in Norway is longer compared to a typical timber bridge in Sweden.

Figure 11: *Total number of timber bridges built in Norway and Sweden (both pedestrian and road bridges), based on selected database*

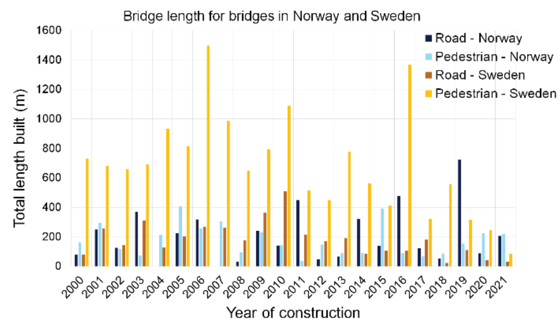

Figure 12: *Number of road and pedestrian timber bridges in Norway and Sweden, based on selected database*

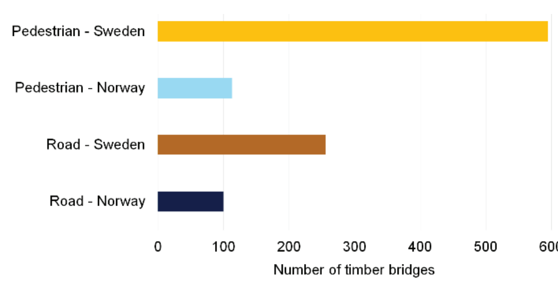

Figure 13: *Number of road and pedestrian timber bridges in Norway and Sweden (2000-2021), based on selected database*

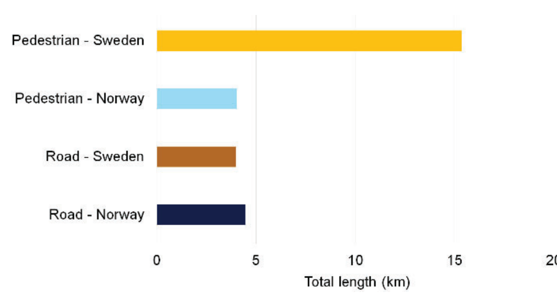

Figure 14: *Built length of road and pedestrian timber bridges built in Norway and Sweden (2000-2021), based on selected database.*

4 CURRENT TRENDS AND BRIDGE TYPES

4.1 From historical to modern timber bridges

Use of timber in bridges in the main load-bearing elemens has a long tradition both in Norway and Sweden. Up to the 20th century, timber was the main building material for both pedestrian and road bridges. Two examples of old timber bridges are Gamle bybro (1861) in Trondheim, Norway, and Lejonströmsbron (1737) in Skellefteå, Sweden shown in Figure 15. With the development of steel and concrete, timber bridges became less popular and up to 1990's, use of timber was limited to mainly smaller pedestrian bridges.

Figure 15: The Lejonström bridge built in 1737 with a combined kingpost strut-frame design is still open for road traffic. Location Skellefteå, Sweden. Photo: Per-Anders Fjellström.

Three Nordic Timber Bridge research projects were carried out from 1994 to 2001. The purpose of these projects was to increase knowledge and competitiveness for timber bridges in Norway, Sweden and Finland. Denmark and Estonia were also involved in some parts of the projects. In Norway, the focus was on developing the typical trusses and arches with dowel joints in combination with creosote treated glulam used today. In Sweden, focus was on the use of stress-laminated decks made of glulam of spruce, in combination with wood protection by design and structural health monitoring. In Finland, they focused on wood-concrete composite bridges and shear connections in treated glulam. The Nordic Timber Bridge projects represent a gamechanger in use of timber in bridges in Norway and Sweden. As can be seen in Figure 16 and Figure 17, both the number of bridges and bridge length accelerated noticeably in 1990s and 2000s, especially for road bridges.

4.2 Current trends in Norway

In addition to Nordic Timber Bridge project, important contribution to use of timber in load-bearing structures were Olympic games in Lillehammer in 1994. As there was a wish for more extensive use of timber in larger structures, a connection technique with slotted-in steel plates and dowels was developed allowing strong joints for large truss structures. In addition, production of glued laminated timber became more controlled and effective, which allowed for production of stronger and larger timber elements. For bridges, increased quality of pavement and need for improved durability of timber decks was required and later efficiently facilitated by using stress-laminated decks. This type of deck provides sufficient stiffness for asphalt pavements and can be protected by moisture membrane, similarly to concrete bridges [4]. In 1996, Evenstad bridge was erected, facilitating all afore mentioned techniques. This is widely considered as a new start, or renaissance, for timber bridge construction in Norway. The vast development in 1990s allowed for use of timber in road bridges that could compete with concrete bridges. These new types of bridges have normally stress-laminated plate decks that are either directly supported by substructure (plate bridges), or by transversal beams connected to arches (arch bridges) or trusses (truss bridges).

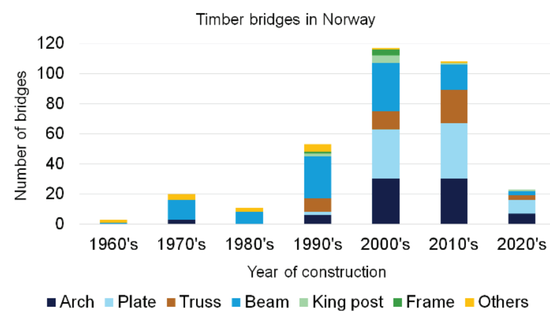

Figure 16: Distribution of built timber bridges in Norway per bridge type and decade, based on selected database. Note that data are missing for some few bridges, and data on older bridges are less reliable.

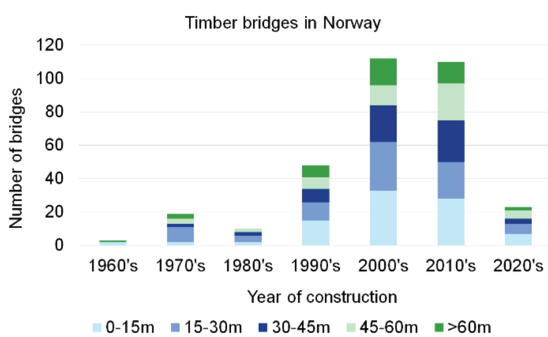

Figure 17: Distribution of built timber bridges in Norway per built bridge length and decade, based on selected database. Note that data are missing for some few bridges, and data on older bridges are less reliable.

https://doi.org/10.52202/069179-0517

As the statistics in Figure 16 shows, majority of timber bridges built in 1970s and up to approximately 1990s were beam bridges. These were typically pedestrian bridges with shorter spans and simple timber plank decks. As can be seen in Figure 18, the use of beam bridges has decreased over the past decades, and it is nowadays typically limited to shorter pedestrian bridges crossing streams or small rivers. These bridges are competitive due its simplicity and low weight allowing for fast and easy erection for cases where shorter service life than standard 100 years is acceptable. There were built few girder bridges where the beams were connected together with stress-laminated plate creating a T-beam. However, the low number of such bridges indicates that this structural system is probably not competitive to concrete bridges with prefabricated beams.

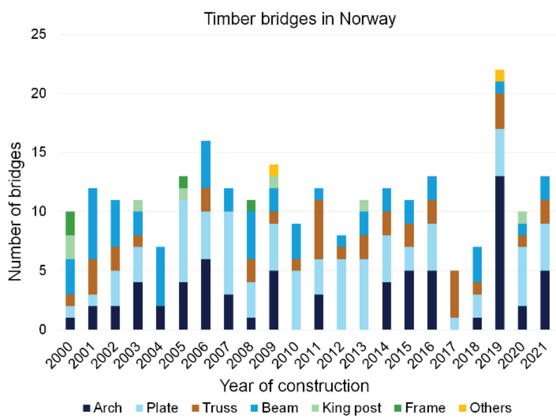

Figure 18: *Distribution of timber bridges per bridge type (2000-2021) in Norway, based on selected database.*

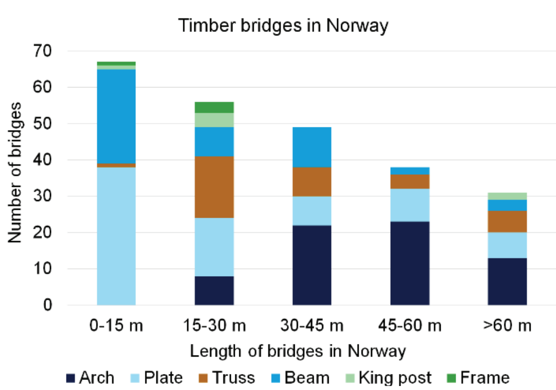

Figure 19: *Distribution of timber bridges per bridge type and built length (2000-2021) in Norway, based on selected database.*

Figure 18 shows a steadily increasing trend in use of plate bridges and arch bridges both for pedestrian and vehicle bridges. Plate bridges are used either as simply supported plates for shorter bridges over rivers or streams (often on secondary roads), or as continuous plates over several spans. The advantage of plate bridges is their low weight and low depth allowing for effective flyover bridges over existing roads and railways, see example in Figure 20. They facilitate normally very fast assembly, reducing considerably closure time of infrastructure beneath them. Typically, plate bridges are used for spans up to 15 m for road bridges, and up to 20 m for pedestrian bridges.

Figure 20: *Plate bridge with stress-laminated deck in Hell, Norway as flyover road bridge over railway from 2009. Photo: Martin Cepelka.*

Larger spans can be achieved by hanging the stress-laminated decks on arches or trusses. Arch bridges have lately been used as flyover bridges on numerous motorway projects. The arches can normally span 40-50 m which is sufficient to avoid any intermediate support in the road profile, as shown in example in Figure 21. This increases safety on motorways and provides high aesthetical value. For simple road geometry on the bridge (straight and narrow bridges), the arch bridges seem to give an effective and competitive solution.

Figure 21: *Arch bridge as flyover road bridge over E6 near Sorperoa, Norway from 2016. Photo: Google.*

Lately, several arch bridges with large spans over rivers have been obtained by combining timber arches and concrete decks together with network configuration of hangers. There is in total 6 such bridges built in period 2016-2022. Steibrua, shown in Figure 22, is the largest of those, and it is with its 88 m the longest spanning bridge with timber load-bearing structure in the world [5].

Figure 22: Network arch bridge with concrete deck and timber arches. Steibrua in Alvdal, Norway from 2016. Photo: Martin Cepelka.

Alternatively, truss structures have been used to obtain large spans. The longest spanning truss bridge is Flisa bru with 77 m span. Unfortunately, one of the largest timber truss bridges, Tretten bru, collapsed suddenly in August 2022. As the cause of the collapse could not easily be determined, Norwegian Public Road Administration decided to close several other truss bridges to allow for their thorough inspection. For the time being, the cause of Tretten bru collapse is still under investigation and the future use of truss bridges in Norway remains somewhat unclear.

An overall distribution of bridge types and built lengths for years 2000-2021 is shown in Figure 23 and Figure 24. Figure 23 shows that most timber bridges built in period 2000-2021 in Norway are plate bridges (32 %) and together with arch bridges, they represent around 60 % of all timber bridges. Figure 24 shows rather uniform distribution of bridge lengths sorted in groups per 15m for lengths 0-15 m, 15-20 m, and 30-45 m with approximately 25 % contribution each. Bridges with lengths 45-60 m, and more than 60 m represent 16 %, and 12 %, respectively. There are in total 14 bridges with lengths larger than 100 m. Flisa bru is the longest road bridge with 196 m length, and Midgardsormen bru is the longest pedestrian bridge with 230 m length.

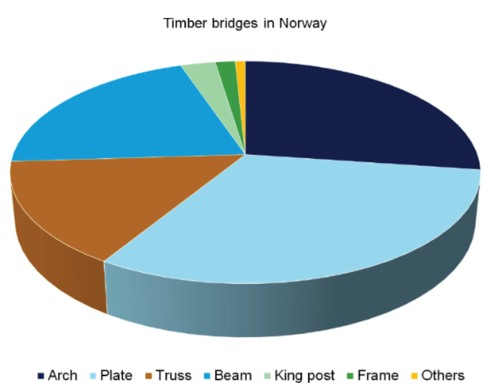

Figure 23: Distribution of timber bridges per bridge type built in years 2000-2021 in Norway, based on selected database

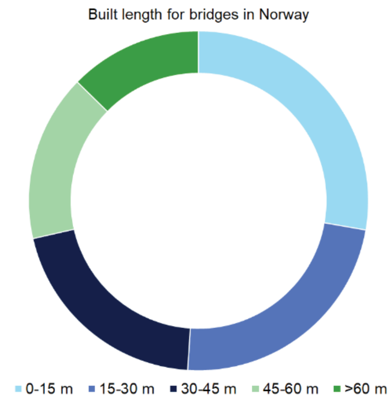

Figure 24: Distribution of timber bridges per built length built in years 2000-2021 in Norway, based on selected database

Since the new generation of timber bridges raised in 1990's, there is still increasing focus on durability. In Norway, required bridge service life is 100 years (independent of material). For timber bridges, this is believed to be achieved by use of both structural protection (load-bearing members are mechanically covered/protected by cladding or sheeting) and chemical treatment. In Norway, it is common to use double level of chemical treatment, typically salt treatment for single laminations and creosote treatment for the whole glued-laminated element. The creosote treatment provides very good protection against fungi and insects, in addition to reduction of moisture sorption. As a result, it is not necessary to cover timber elements entirely. This reduces maintenance need and gives more freedom to designers in choice of the structural scheme. In last 20 years, numerous spectacular truss bridges have been built. This is particular for Norway, as the use of creosote is not allowed in most other countries. It is expected that creosote will eventually be restricted in Norway as well, and the design of timber bridges will most likely turn towards trends in other countries where structural protection is the primer measure to obtain durability, as for example in Sweden as discussed further in Section 4.3. It can also be expected that new structural systems will appear in Norway. For example, in Germany and Switzerland, numerous modern bridges have lately been built with timber-concrete composite layout [6], [7]. Besides protection from weather, concrete deck in composite action with timber girders give effective structural system and allows for larger spans. Consequently, we might see a growth in use of beam bridges in Norway again.

4.3 Current trends in Sweden

As in Norway, the trend is to use more renewable materials as wood in larger constructions and buildings. However, the use of wood in bridges has been decreasing for the last decade. There are some obvious reasons for this:

https://doi.org/10.52202/069179-0517

One is that the market for building large timber structures is increasing rapidly and it is an easier and better market than in building timber bridges. The two dominating timber bridge producers are also two of the three largest glulam manufacturers in Sweden. A second reason or a factor is the Swedish road administrations moderate interest in developing and using timber bridges, opposite to the situation in Norway. Another minor reason is that the use of spruce in bridges have shown to be a little more complicated than first expected. Especially railings, cladding and the edges of stress-laminated decks were found to suffer from durability problems. This is a problem for the large forest companies, that owns a lot of small timber bridges, and they are now starting to replace damaged bridges with new steel bridges.

If we look back att the timber bridges built early last century, we will find that Sweden had a large number of strut frame bridges in one or several span often in combination with a kingpost on top of the strut frame, as the Lejonströms bridge. For larger spans, 50 – 125 m, it was common to build suspension bridges with timber towers. A couple of these bridges are still in use in Dalarna region. Another type of bridge that was used for crossing rivers, were floating bridges, two off that design remains over Dalälven, but not in their original design. Covered bridges were not so common in Sweden and only one remains, Vaholms Brohus built in the late 19th century.

For reasons there are very few remaining timber bridges built between 1940 - 1980. One obvious reason for this is that most of them have been replaced, and another is that most road bridges were built in concrete or steel. However, there is a large number of steel girder bridges built with timber deck in that period of time, many of them still in use.
The new era of timber bridges was started by the Nordic TB-project. It opened a new market for factory built modern timber bridges for both pedestrians and road traffic. In the early 1990's most bridges were built with chemically treated wood, NTR A. Now it's used only in pedestrian bridges with truss or beam design designed for 40 years' service life, and some smaller and temporary road bridges, mainly for the forest industry.
Most timber bridges are built of spruce, and they are designed for 80 years' service life.

Road bridges
The first road bridge with a stress laminated deck of spruce was built in 1994, followed by the first stress laminated bridge deck with a T-section of treated wood, one year after. The stress-laminated deck slab of spruce has become a very popular design with over 400 bridges built since 2000. For road bridges it's the most common design to use as a single- or multi span deck. The design is simple, robust and bridges are easy to produce and transport to the bridge site. One big difference between Norway and Sweden is the use of the stress-laminated design in combination with arches, kingpost or trusses. If we compare the number of arch bridges for road traffic, only one is built in Sweden, while in Norway, there is a quite large number of arch bridges.

Figure 25: *A typical stress-laminated timber bridge over railroad. Built 2017 in Hörle, Sweden, by Moelven Töreboda. Photo: Per-Anders Fjellström.*

Pedestrian bridges
The pedestrian bridges built from 2000 to today shows a great variation in both length and design. Some typical Swedish pedestrian timber bridges are the long span cable-stay-, medium span truss- and short span beam bridges and a number of stress laminated decks.

The most common designs are beam bridges and different combinations with a stress-laminated deck with more than 200 bridges built of each type.

Figure 26: *Pedestrian bridge to Strömsholmen in Eskilstuna, Sweden. The design is a 48 m 3-span beam bridge with a transverse plank deck. Built 2001 by Svenska Träbroar. Photo: Per-Anders Fjellström.*

The small Howe Truss bridge is another popular bridge design in spans up to 30 m with close to 100 bridges built the last 20 years.

Figure 27: Pedestrian Howe Truss bridge to Kållandsö close to Lidköping, Sweden. The design is a 25m truss bridge with a transverse plank deck. Built 2017 by Martinsons. Photo: Per-Anders Fjellström.

The modern version of the old suspension bridge in timber is the cable-stay design. It is a popular design and there is at least one ongoing project to build one next year in Ängelholm, Sweden. The Älvsbacka bridge in Skellefteå is the longest with a main span of 130 m. A total of 8 bridges have been built since 2000.

Figure 28: Älvsbackabron is a cable-stay pedestrian bridge with a 129m span built 2012 over Skellefteälven, Sweden, by Martinsons. Photo: Per-Anders Fjellström.

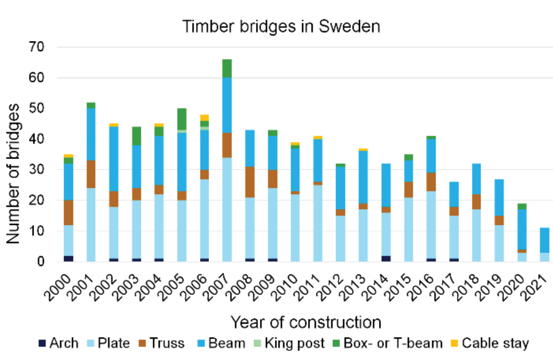

Figure 29: Distribution of timber bridges per bridge type (2000-2021) in Sweden, based on selected database.

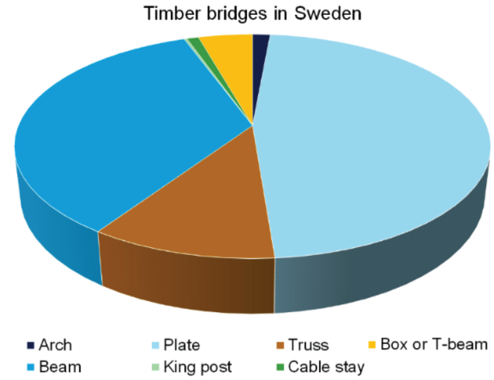

Figure 30: Distribution of timber bridges per bridge type built in years 2000-2021 in Sweden, based on selected database

A lot of work has been done to improve wood protection and durability over the years. Good wood protection by design in combination with factory installed sensors for moisture content measurements is the Swedish way to meet the demands for a long service life. It's an environmentally friendly and hopefully a cost-effective approach to durability. The use of spruce, a not durable species, in a bridge superstructure requires a different approach to inspections and there is still some work to do regarding reliable inspection methods. In the next years, we think that we will see new designs on the Swedish market such as timber-concrete composite, light weight long span designs as the InfraLIGHer winner BIFROST and, hopefully, new state of the art covered bridges.
The biggest question in Sweden is how the market and production of timber bridges will adapt to the fact that the two largest producers have closed down their timber bridge production from 2022.

Figure 31: Factory installed M.C-sensors in a stress-laminated deck provide the owner with reliable data from inspections. Road bridge built 2022 by TBS, Junsele Sweden. Photo: Per-Anders Fjellström.

https://doi.org/10.52202/069179-0517

5 CONCLUDING REMARKS

The current study reveals a great potential for use of timber in bridges as a possible measure for reducing environmental impact of infrastructure projects.

The results presented in Section 3 show an opposite trend in number of bridges compared to the recent growth of use of timber in buildings. In Norway, the number of timber bridges built every year is fairly constant, while in Sweden, a clear decreasing trend can be observed.

As demonstrated in Section 4, several modern timber bridge concepts have been developed since 1990s that can represent a competitive, and more environmentally friendly alternative to concrete bridges.

The choice is in the hands of bridge designers and bridge owners.

6 ACKNOWLEDGEMENTS

The authors would like to acknowledge Moelven and Martinsons for sharing their data. This was an important input into the study, and it is much appreciated.
We would also like to acknowledge Sara Holm for her contribution with data gathering in the beginning of the project.

REFERENCES

[1] Byggfakta, «Norsk byggebransje,» 09 11 2021. [Internett]. Available: https://norskbyggebransje.no/nyheter/trekonstruksjoner-i-sterk-vekst.

[2] A. Pousette,, K. A. Malo, S. Thelandersson, S. Fortino, L. Salokangas og J. Wacker, «Durable Timber Bridges: Final Report and Guidelines,» RISE, 2017.

[3] Statens Vegvesen, «Trebruer, Statens vegvesen Rapporter, Rapport Nr. 422,» Vegdirektoratet, 2017.

[4] O. Kleppe og T. Dyken, «The Nordic Timber Bridge Project and the Norwegian Approach to Modern Timber Bridge Design,» i *IABSE conference*, Lahti, Finland, 2001.

[5] J. Veie, T. Stensby, Y. Aartun og T. Dyken, «The development of timber as a construction material for bridges in Norway,» i *IABSE*, Vancouver, 2017.

[6] F. Miebach, «Robust Timber bridges without cladding,» i *4th International Conference on Timber Bridges*, Biel/Bienne, 2021.

[7] R. Widman og A. Müller, «History and development stages in timber bridge construction in Switzerland,» i *4th International Conference on Timber Bridges*, Biel/Bienne, 2021 .

https://doi.org/10.52202/069179-0517