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Pedestrian and cyclist bridges made with durable hardwoods

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Abstract

The dense network of waterways and roads is plausibly the reason for the existence of a large amount of small timber bridges in the Netherlands. Many of these bridges are made of hardwoods like oak and ekki. These timber species have a higher natural durability than regular softwoods, hence, open structures and simple building methodology are possible. This paper aims at providing an overview of several examples of large timber bridges built in ekki.

1 Introduction

According to a recent study from 2021, there should be about 31000 timber bridges in the Netherlands [1]. Their large number is plausibly related to high density of waterways and canals in combination with the large network of bicycle roads. In many of these bridges, ekki and oak are a primary raw building material. These small bridges can also be made of concrete, steel and plastic composites. Ekki has also found its way into many other types of timber structures like lock gates, guide rails, fenders, balconies, sheet piling, terraces, etc (Figure 1). It shows the diversity of applications of hardwood timber in structures exposed directly to water, wind, rain and sun.

Figure 1: several examples of the use of ekki in timber structures other than bridges (from left to right, top to bottom): Lock gates (Bernhardsluis, Deventer), guide rail (during tests, Lelystad), fenders (location unknown), and stairways and balconies (Kop van Lombok, Utrecht)

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Concrete, steel and plastic composites have not always been able to compete with the advantages timber sometimes offers: its workability on the construction site, its durability, and recyclability. In specific scope of LCA, wooden bridges easily outperform plastic composites, concrete and steel counterparts [2].

Before the introduction of ekki from the tropics on the European timber market, oak was used for the construction of these bridges [3]. Ekki has exceptional qualities that are rarely found in softwood [4] or hardwoods from temperate climates: The strength class of Ekki is marked as D70 by the EN 1912 [5] and corresponding properties are found in the EN 338 [6]. The resistance to fungi is marked I/II and the resistance to marine borers M-D in EN 350 [7]. The density at 12% moisture content is 1060 kg/m^3 [8]. Freshly cut, it weighs about 1200 kg/m^3, which means that it is heavier than water. In the floods of 2021 of the Ahr river in Germany for instance, a timber bridge in ekki near Sinzig was still found on its abutments after being submerged. It did not float during the floods, partially due to its weight. Unfortunately, after closer analysis, the abutments had suffered severe damage, along with several structural elements of the bridge, and it was demolished anyway [9].

Forest Stewardship Council (FSC) guarantees a sustainable raw material through forestry practices based on social, economic, and ecological principles further explained in ten rules [10]. The forestry practices are carefully monitored by independent parties. Using certified wood is incredibly important to guarantee future supply of timber. Using sustainable harvested timber helps to protect forests, too.

2 Hardwood timber as a building material

2.1 Timber engineering, joints, connections

Ekki has proven nearly impossible to glue into engineered wood products for structural applications like Glued Laminated Timber (GLT) or Cross Laminated Timber (CLT). However, connections can easily be made using either (1) carpentry joints, (2) connections with mechanical fasteners such as screws, bolts, dowels, in combination with slotted in plates, too (Figure 2). In the design of connections, general rules set by the EN 1995 [11] are used, along with requirements set by national annexes. (3) Separate beams can be dowelled together to form a dowel laminated timber beam [11], like done in the largest span of 15 meters of the ‘Fietsen door de Heide’ bridge in Belgium (Figure 3). In practice, beams with a height of a little over 1 meter and lengths up to 25 meters are built using this technique, making it a easy way to build cyclist in and pedestrian bridges with medium spans, even for light traffic loads such as service vehicles even up to 16 tons.

Figure 2: dowelled connection

Figure 3: 15 meter span of the 'Fietsen door de Heide' with dowel laminated beams

2.2 Dimensions of timbers elements

Ekki can also be obtained from the trees in large dimensions. The timber is known to grow straight, containing only little number of irregularities like knots. A special case are the pillars of the ‘Botterbrug’ in Harderwijk which are 22 meters long and have a tapered diameter of 60 cm/80 cm (top/bottom) and are made out of one single trunk (Figure 4). These trunks were specially selected in the forest and transported in on single piece by road and sea, to the woodturner and then to the building site.

Figure 4: Illustration of the sizes of pillars used in the 'Botterbrug' in Harderwijk

2.3 Typical bridge typologies

Five construction types are typically identified in the timber bridge construction using ekki: the small bridge using straight beams up to about 8 meters. This is a bridge type that can be constructed in a modular way. Medium spans can be made using dowel laminated beams, up to lengths of about 20 meters, sometimes more. If even longer spans are required, the truss bridge can be used, until now used for lengths up to about 40 meters in bridges like the ‘Pieter Smitbrug’ and the ‘Stönner Meijwaardbrug’. Large spans like these can also be covered using arch type structure or cable stay bridges. Amongst these is the earlier mentioned ‘Botterbrug’ in Harderwijk spanning a total of 76 meters, crossing the highway A28.

The main structure of each of the bridges of Ekki are unprotected from impact of rain and sun and are built into Service Class 3 in the EN 1995 [11]. Ekki bridges generally achieve service lives of 50 years if at least a minimal maintenance is performed. This has also been observed in sluice doors. Once the service life is reached, most of the structural elements can often be re-used in other structures. Due to the absence of chemicals that extend the longevity of the material, it is also naturally degradable and causes no harm to the environment.

3 Case studies

3.1 The ‘Pieter Smitbrug’

The ‘Pieter Smitbrug’ with a length of 800 meters was the largest cyclist bridge in Europe at the time of its construction. It crosses a canal (Winschoterdiep), a highway (A7), a nature reserve, and a part of a lake ‘Oldamstermeer’ (Figure 5). Being a bridge of these dimensions makes it an exceptional example of how timber can be used to create infrastructure for pedestrians and cyclists using a renewable material, modular design, with outstanding end of life capabilities. Apart from connecting two smaller towns and thus creating an easy access of each other’s education, commercial, and recreational facilities too, the construction of the bridge was also used to strengthen the local ecology. Trees were planted along the new bridge to encourage bats to cross the highway. Nesting boxes for birds were placed below the deck and lighting was especially selected that would not disturb wildlife at night. The bridge was designed for a service life of 80 years. This was achieved by protecting the main structural elements with ekki boards.

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Figure 5: Aireal photo of the 'Pieter Smitbrug' along with a detail of the main span (above) and the main span and transport for the production site in Kampen to the building location by boat.

As the main span of the bridge crosses a highway, it was necessary to account for possible collision forces from traffic underneath the bridge [13]. According to the Eurocodes, this needs to be done once the bridge is less than 6 meters above the underlying road. In the Netherlands, this height is increased to 7 meters. These loads are in the order of 200 tons. This led to the reinforcement of the lower chord of the truss structure with steel. The upper chord and the bracing were made of timber. The bridge was officially opened for use in winter of 2021.

3.2 The ‘Stönner Meijwaardbridge’

The ‘Stönner Meijwaardbridge’ in Oirschot and has a total length of 240 meters. The truss bridge crossing the ‘Wilhelminacanal’ under an angle has a span of 41 meters and a width between parapets of 4 meters. It connects the town’s neighbourhoods located south of the canal with the city center.

Although this bridge was not located over a highway or other road, collision loads had to be accounted for that originated from inland shipping traffic. This also meant that the lower chord of the truss structure had to be reinforced with steel. The upper chord and bracing could be carried out in timber. It still resulted in a slender and elegant bridge, which was officially opened for use in summer of 2020.

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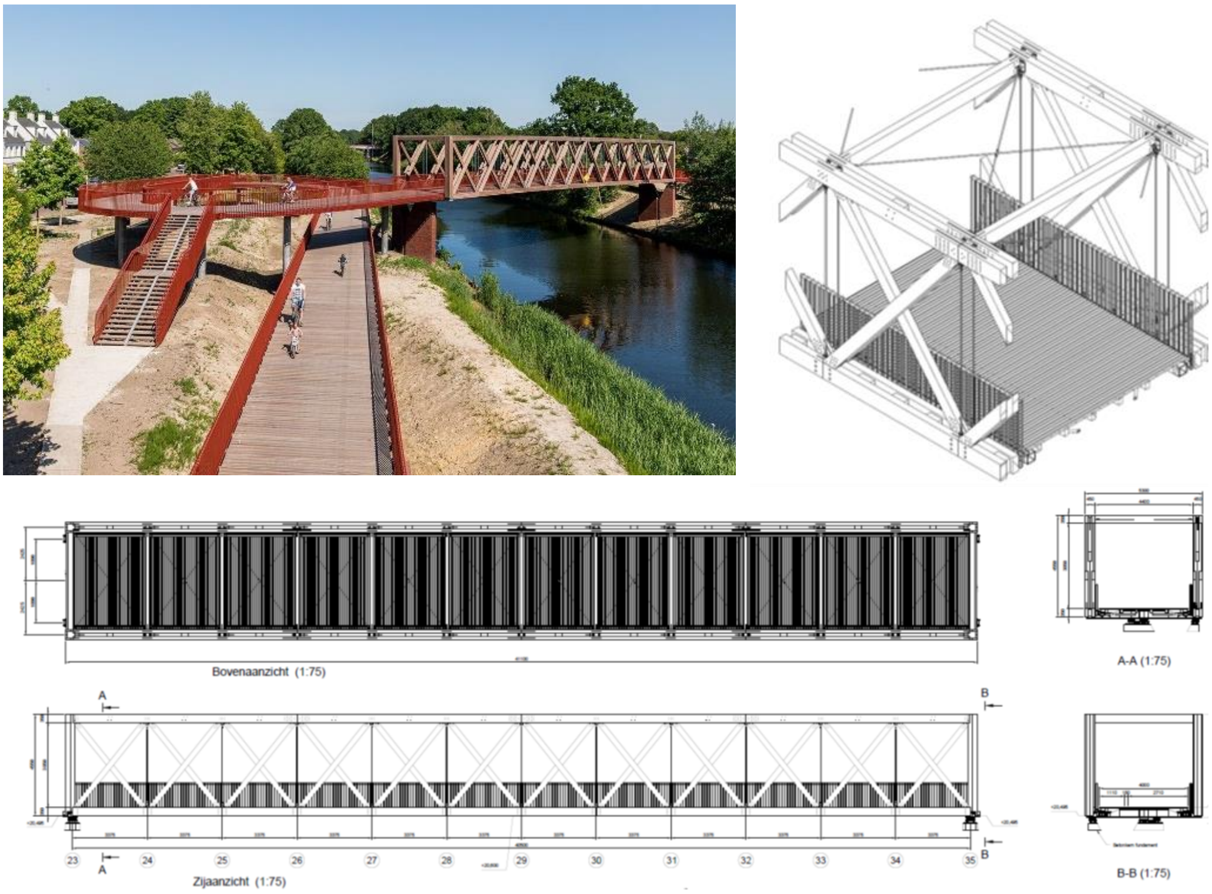

Figure 6: the 'Stonner Meijwaardbridge' (@JDFV, 2020) along with a cross section of the main span (above) and the top and side view of the main span (below)

3.3 Fietsen door de Heide

‘Fietsen door de Heide’ is part of a touristic cycling route through the national park ‘de Hoge Kempen’ near Maasmechelen in Belgium. The length of the bridge in this cycling route is almost 300 meters long and has a width between parapets of 3.5 meters. The bridge provides cyclists a look-out point over the moors in a region that is candidate for UNESCO world heritage site. The fine and regular structure of posts and supports refers to the region’s long history of coal mines. The architects recently won a prize for its design on the International Design Awards in Los Angeles.

The parapets were made with softwood that was partially obtained from the local forest. The softwood was treated to increase its natural durability. The deck was made of prefabricated concrete elements, which span the distance between the timber supports of 3 meters. In the main span of 15 meters length crossing a road, dowel laminated beams were used to carry not only vertical loads, but collision loads from traffic too. Figure 7 shows a picture of the final bridge and an illustration of the bridges main load bearing system.

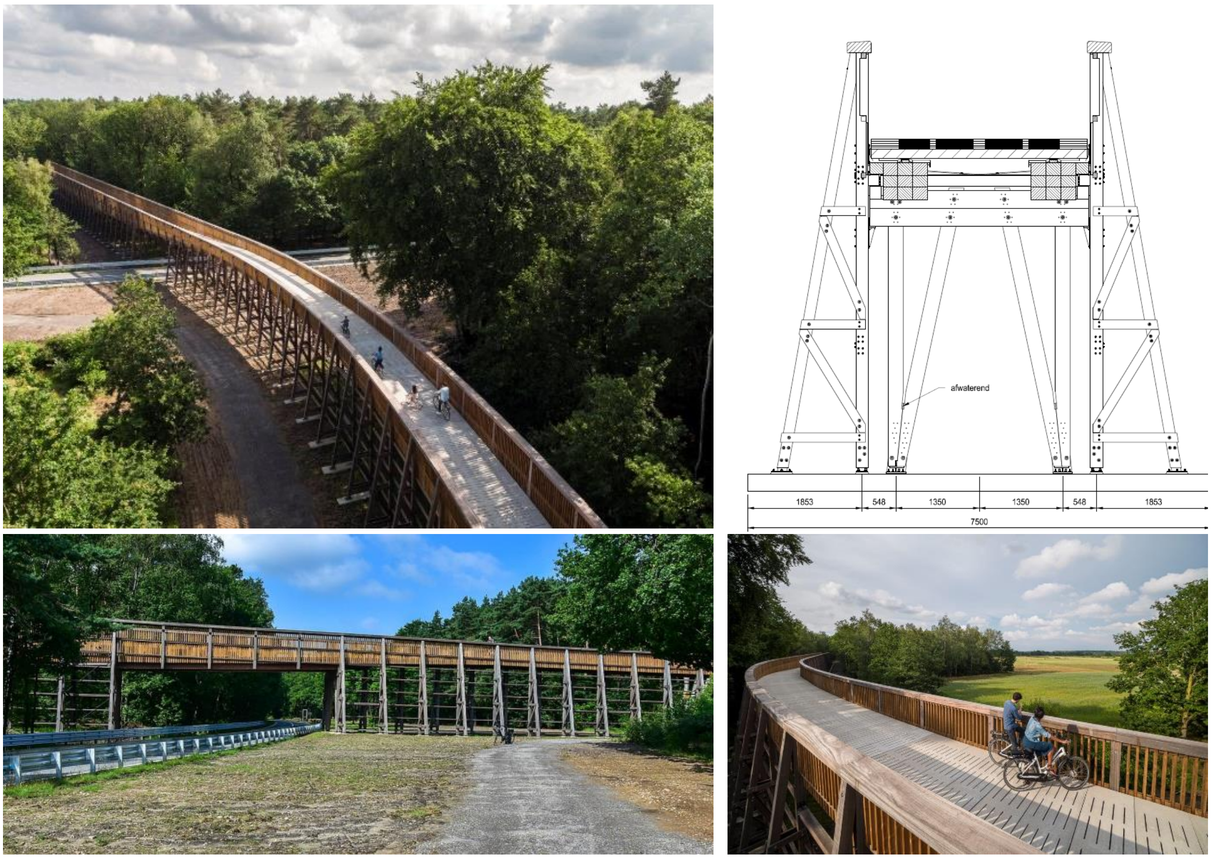

Figure 7: Aerial picture of the highest section of the 'Fietsen door de Heide' (@VisitLimburg) along with a detail of the supporting frames oft he main span (above) and a side view of the main span and the view from the highest point of the bridge (@VisitLimburg)

4 Conclusion

Building with a timber like ekki has offered -and will continue to offer- outstanding possibilities to easily build bridges in timber. Despite difficulties using adhesives so commonly used in engineered wood products, many different types of structures have been made. Design rules and building methods as described in the EN 1995 can be used to make truss structures, arch structures and cable stayed bridges. There are sustainable sources of the timber trough certified chains of supply. The presented case studies have shown that it is a flexible material that fits into a circular approach for modern timber bridge construction to sequester carbon in future infrastructure too.

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