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SECOND GENERATION OF EUROCODE 5-2 ON TIMBER BRIDGES, AN OVERVIEW

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ABSTRACT: The Eurocodes are design standards published by CEN that are being updated. The first generation was published between 2002 and 2007. Work on the second generation is at different stages, with a common implementation expected in 2027/2028. Design rules on Timber Bridges is published as EN 1995-2.

The second generation implements new knowledge gained the last 20 years. Within timber structures this is quite a fair amount. The mandate given by the European Union, being a large financier of the work, was to improve the structure and clarity of the code, reduction of nationally determined parameters and reduction of alternative equivalent application rules and procedures, removal of rules that are little in use and explanation of the mechanical background of formulas.

Consolidation on design practice has been a great part of the work. Though calculating timber bridges has been conducted in a common way, protecting the timber is as much tradition as it is architectural taste. A timber bridge according to the Eurocode is expected to endure for its design service life independent on being located far south or far north in Europe. The term protected timber bridge is introduced, where weathering is not expected to govern the service life.

All parts of EN 1995-2 have been examined and updated if needed, as here presented.

KEYWORDS: Timber Bridges, Design rules, Eurocode

1 INTRODUCTION

In 2004, the EU and several EFTA states introduced uniform design codes, the so-called EUROCODEs (EC). The goal of the European Committee for Standardization (Comité Européen de Normalisation, CEN) here was to replace the member states' differing or even missing design guidelines by a common set of technical rules that provide the same level of safety and thereby to further minimise barriers within Europe. In 2012, the European Commission issued a mandate for the development of a second generation of the Eurocodes to ensure their long-term applicability and reflect the constant technical developments and knowledge gains (see Figure 1).

Figure 1: *European design codes – Eurocodes*
Source: European Commission, 2021

In the work of 2nd generation Eurocodes updates in Eurocode 0 and 1 forced updates for the other parts. For the series of standards "EN 1995 – Design of timber structures," (EC 5) experts regularly prepare drafts for specific topics in timber construction. To this purpose, six project teams (PT) have been convened from 2015 to 2022. Today, their work is continued by ten working groups (WG), which before the start of project teams conducted a review of existing content of the EC5, in cooperation and coordination with the national standardisation bodies. After extensive revision of the entire Eurocode 5 series, new versions will be available for all members states for enquiry September 2023, following expected formal vote in 2025 and publication around 2027.

2 SUSTAINABLE TIMBER BRIDGE CONSTRUCTION

One of the main topics of editing EN 1995-2 was the implementation of the specifications of EN 1990 and EN 1991-2, in particular requirements for reaching a design service life of 100 years. Since construction professionals speak the language of implementation planning, a new Annex is suggested with simplified figures exemplifies how timber bridges can be protected given proper service. Service is topic in another new suggested annex covering inspection and maintenance of timber bridges. Both

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annexes are informative and may be subject to changes nationally.

Like the building construction code, the code for timber bridges was extended to include requirements and regulations for the durability of structures, taking into account the issues of corrosion protection, deck plates, and timber-concrete composites. The creep factors for concrete in timber-concrete composite bridges are different from those in known building constructions, as the cross-sections are significantly larger. Accordingly, a new normative Annex A of prEN 1995-2 provides relevant conditional equations. prEN 1995-1-1 shall stipulate requirements for numeric analyses (keyword Finite Element Method, or FEM for short).

Eurocode 8, Part 2 ("Design of structures for earthquake resistance"), will in 2nd generation take timber bridges into account. In an Informative Annex, additional hints for the design of bearings are given. It is also relevant to point to the Informative Annex E, which contains suggestions to be considered in view of deformations and dimensional changes of timber constructions under changing environmental conditions such as temperature or timber moisture, and notes on transversely prestressed timber deck plates (among other things for the "cupping" of the deck sides).

Most regulations on deck plates (timber decks) were added to one normative and one informative Annex of prEN 1995-1-1, as these regulations can also be applied to, e.g., nail-laminated timber constructions.

With the technical work basically being done, the document is being translated into German and French before being sent on public Enquiry for 16 weeks starting September 2023. The remaining steps of the standardisation process are shown in [1] and [2].

3 PROTECTION AND SERVICE LIFE

3.1 DURABILITY OF WOODEN MEMBERS

General requirements regarding expected service life, i.e. design service life T_{lf}, form the basis for all bridge design in Eurocodes are given in EN 1990 A.2. Together with requirements on Quality Management are the requirements on Maintenance and Durability that form the basis of bridge building. The latter are defined as:

Maintenance

set of activities performed during the service life of the structure so that it fulfils the requirements for reliability

Durability

Ability of a structure or structural member to satisfy, with planned maintenance, its design performance requirements over the design service life

Based on this, different categories are defined for expected service life. For bridges 100 years is the basic option or choice, and is expected independent of material types. Lower service life may be relevant for simple bridges used for instance in recreational purposes where consequence of failure is very little, but still 50 years are expected. Further lower service life is given for replaceable and temporary structures.

For timber bridges, achieving 50 years, which is the same as building structures and thus the design requirements in the general part of Eurocode 5 are to be used. Requirements for 100 years service life are outlined in the bridge part, comprising:

- Requirements on design;
- Recommendations on structural protection;
- Requirements membranes;
- Requirements on steel protection embedded in timber structures.

Environmental actions, i.e. expected moisture variations and thermal actions, are included in simplified calculation models depending on member size. General information on moisture variations are given in the main part.

For the design of durable timber bridges the term protected and unprotected member are included. Protected member is defined as:

Protected Member

structural member not exposed to direct weathering such as rain, snow, or other sources of moisture ingress

Examples of protected members are given see Figure 2, see also [3]

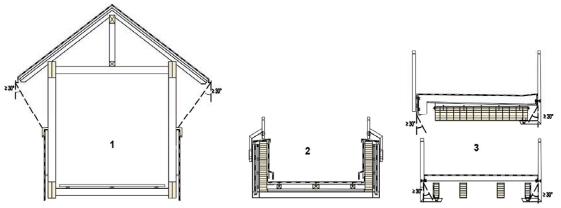

Figure 2: *Examples of protected timber bridges*

Key

▬ ▭ ▬ membrane or weather-resistant layer

Unprotected member is defined as:

Unprotected Member

structural member that is not protected or partially unprotected from weathering but is within the limits of Service Class (SC) 3

The methodology is that a protected timber bridge is expected to last for 100 years. When parts of a structures are not within the definition of a protected member these must either be easily replaceable, or the expected design service life will be less than 100 years.

Durability and thus sustainability ensure the economic viability of timber structures. Therefore, the following so-called "magic triangle" must be observed:

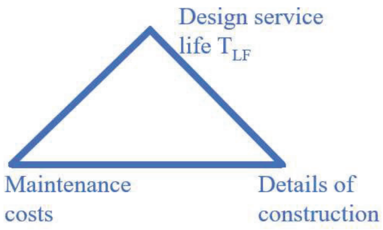

Figure 3: *Important considerations on design*

Requirements on basic structural protection are given in EN 1995-1-1 and EN 1995-2, in some countries with additional national requirements. This leads to a higher robustness of the expected service life, expecting to lower maintenance costs.

2nd generation of EN 1995-2 includes detailing by figures in Annex how timber bridges can generally be protected. Five possibilities for basic structural timber protections are given (see e.g. Figure 4), together with more detailed examples on expansion joints (three methods; see e.g. Figure 5) and bridge caps (2 examples).

Furthermore, a suggested monitoring scheme is included as monitoring timber bridges may be a useful addition to inspection, in some European countries mandatory. Currently an arch bridge is taken as example showing which parts of the bridge are expected to be critical and thus wise instrumenting, also with regard to the Use Class according to EN 355.

Because of translation of European standards all figures are language neutral, creating rather lengthy keys to each figure.

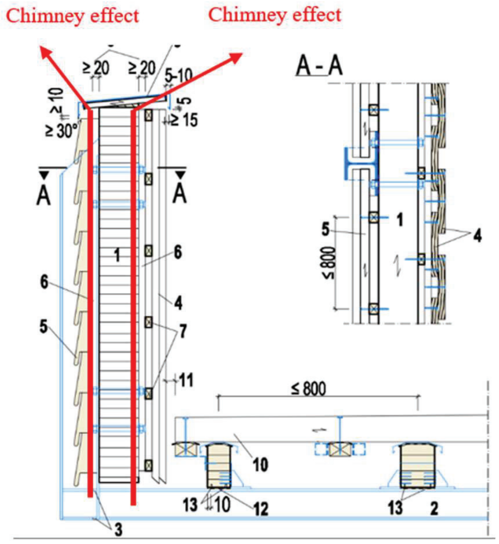

Figure 4: *Example of detailing figure with explanation text on ventilation in red*

Key

A-A	Section A – A
1	Main girder
2	Steel frame
3	Borehole in top and bottom flange
4	Cladding (generally outside)
5	Vertical weather boarding (outside)
6	Vertical battens
7	Horizontal battens
8	Ventilation openings, horizontal ≥ 100 cm²/m, vertical ≥ 50 cm²/m
9	Aluminium plate or equivalent
10	Grooved planks (e.g.)
11	Gap with: 15 mm if floor-cover shuttering, 30 mm if cover stripe, groove and tongue
12	Rubber or elastomer mat
13	Weather groove (notch)

The ventilation openings for such a detail should be the following:

- Horizontal ≥ 100 cm^2 / m
- Vertical ≥ 50 cm^2 / m
- Minimum width 20 mm

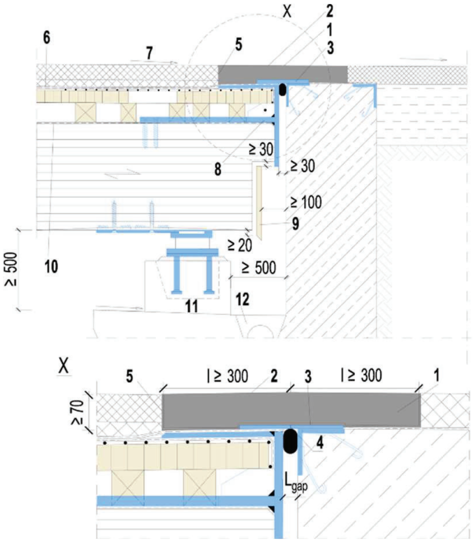

Figure 5: *Example of detailing on a closed transition between bridge and abutment*

Key

X	Detail "X"
1	Trough filling
2	Surface seal
3	Cover strip
4	Fixing peg
5	Trough flank
6	Sealing system
7	Longitudinal gradients
8	Closing profile (steel)
9	Face board
10	Permeable protection layer with glued overlapping
11	Pier
12	Drainage

3.2 DURABILITY OF STEEL MEMBERS

For steel members the updated standard gives requirements of protection of steel members in wooden structures by declaring a timber exposure category class T_E. Different protection levels depending on atmospheric exposure C_E, service class SC and expected design service life results in different recommendations of minimum protection either by steel grade or zinc coverage. Requirements of protection of steel in general is covered by Eurocode 3.

Situation	***Timber exposure category [a] T_E***	***Atmospheric exposure category [b] C_E***	***Typical atmospheric exposure [c] (informative)***	***Examples of minimum***	
				zinc thickness [d]	***stainless steel grade (type) [e]***
Protected outdoor with access of pollution (SC2 and SC3)	*T_E3/T_E4*	*C_E2*	*$L_{sea} > 10$ km $L_{street} > 100$ m and/or low polluted area (< 5 µg/m³ of SO_2)*	*T_R3: 40 µm [f] (n/a [g] if T_E4) [20 µm [f] (55 µm if T_E4)] [h]*	*CRC II (e.g. 1.4301)*
	T_E3/T_E4	*C_E3*	*10 km > L_{sea} > 3 km 100 m > L_{street} > 10 m and/or medium polluted area (5 µg/m³ ≤ SO_2 ≤ 30 µm/m³)*	*C_R3: 110 µm [80 µm] [h]*	*CRC III (e.g. 1.4401)*
	T_E3/T_E4	*C_E4*	*3 km > L_{sea} > 0,25 km L_{street} < 10 m and/or high polluted area (30 µg/m³ < SO_2 ≤ 90 µm/m³)*	*C_R4 [b]: n/a [g] [110 µm] [h]*	*CRC III (e.g. 1.4401)*
	T_E3/T_E4	*C_E5*	*L_{sea} < 0,25 km and/or very high polluted area (90 µg/m³ < SO_2)*	*C_R5 [b]: n/a [g]*	*CRC III (e.g. 1.4529)*
Permanent in contact with ground- or fresh-water (SC4) [i]	*T_E5*	*n/a [g]*	*For T_E5/SC4 especially in case of seawater each case should evaluated individually.*	*C_R5 [b]: n/a [g]*	*CRC III to CRC V*

[a] Timber exposure categories T_E3, T_E4 and T_E5 are according to prEN 1995-1-1:202x, Table 6.1

[b] Atmospheric exposure categories C_E2, C_E3, C_E4 and C_E5 are according to prEN 1995-1-1:202x, Table 6.2 and Table 6.3

[c] The specified values for SO_2 are references values only and may vary.

L_{sea} indicates distance from the sea. The actual exposure depends on the prevailing wind direction and the topography of the coast to saltwater seas e.g. Atlantic Ocean, North Sea, Baltic Sea, Mediterranean See, Black Sea, Irish Sea

L_{street} indicates distance from roads with heavy traffic with de-icing salt

[d] pure zinc coating and hot-dipped galvanized coating

T_R3 is the timber resistance class according to prEN 1995-1-1:202x, 6.3

C_R are the resistance classes for metal fastener or connector made of carbon steel to corrosion according to prEN 1995-1-1:202x, 6.3

Figure 6: *Current proposal on protection of steel members embedded in timber in prEN 1995-2. Numbers in red are for 50 years, other values 100 years.*

4 TIMBER DECK PLATES

Timber deck plates comprise decks made of solid-wood beams arranged side by side in the direction of span, clamped together. As a result, the (punctual) wheel loads can be distributed over several beams (see prEN 1995-1-1 Figure U.3). Nowadays, these deck plates (timber decks) are largely used in Scandinavian and Baltic states often using glued laminated timber (GL) as beams and stressed together with steel rods. Requirements regarding these structures have been updated representing state of the art including newer research on the topics. This also includes requirements on modelling of the bridge decks using Finite Elements Software (see prEN 1995-1-1 Annex V) as well as updated recommendations on friction coefficients and requirements to minimum stress forces.

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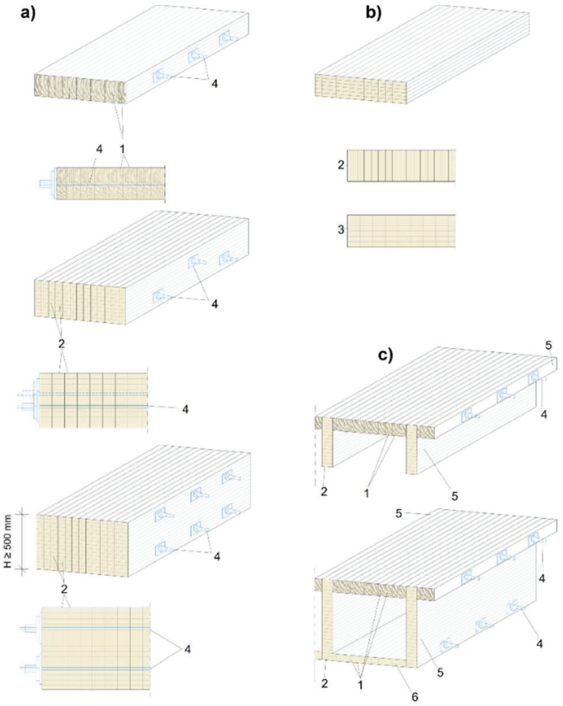

Figure 7: Examples of timber bridge decks covered in prEN 1995-2

5 TIMBER-CONCETE COMPOSITE (TCC) AND INTEGRAL ABUTMENTS

TCC decks are included in the updated bridge standard, giving requirements on design and recommendations on durability and design. Creep must be evaluated carefully and as such this is also topic in the updated draft. For a more detailed presentation on the topic see [5] presentation from Mr. Prof. Dr.-Ing. Jörg Schänzlin
Integral timber bridges, bridges with a flexural connection to a concrete abutment, have gained some experience and are also included in the timber bridge code.

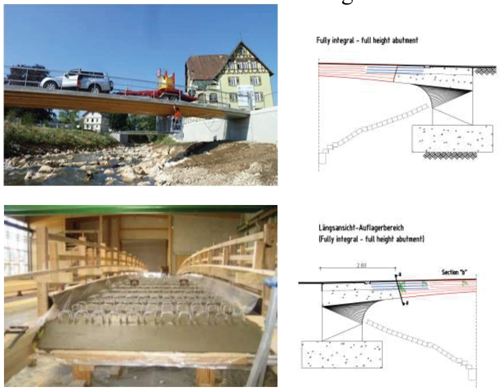

Figure 8: *Examples of integral timber bridge designs.*

6 SERVICE LIMIT STATE

6.1 DEFLECTIONS AND DEFORMATIONS

Requirements on deflections due to traffic-load and wind-force have been updated. These actions should be verified and limited in order to prevent unwanted dynamic impact due to traffic, infringe of required clearances and cracking of surfacing layer, ensuring also sufficient run-off from standing water (see [2]).

6.2 OSCILLATIONS AND DAMPING

A rather large update has been conducted on the subjects oscillations and damping. Simplification regarding requirements given in other parts of Eurocodes are introduced in the timber bridge part. An example is shown in figure 9, where different requirements are gathered in one requirement, see black line in figure 9.

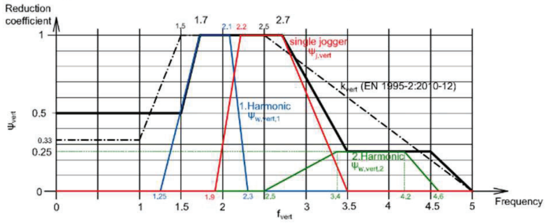

Figure 9: *Examples of integral timber bridge designs.*

For further reading see [4] presentation by Mrs. Prof. Dr.-Ing. Patricia Hamm

7 FATIGUE

It was decided to move fatigue requirements into the general part as these may be necessary also for buildings with cyclic loads, such as crane structures, wind turbine tower, highway traffic sign posts, or bell towers. This means that in EN 1995-2, only those parts were kept that are relevant for timber bridges, in particular:

- some general parts concerning the fatigue assessment of timber structures;
- parts of the document that deal with fatigue load models;
- a simplified fatigue verification model especially for bridges.

Basis in fatigue verification is the stress ratio R_T as the arithmetical minimum stress to the maximum stress of a particular stress cycle in timber design. Since the factor representing the reduction of fatigue strength with number of load cycles k_{fat} values depend on RT, a simplification is also required to offer a real advantage over the 'full' k_{fat} verification. Therefore, it is proposed to consider only whether the fatigue loading is alternating or not and to use the k_{fat} values for $R_T = 0$ or $R_T = -1$, respectively.
The k_{fat} values were evaluated for two lanes and 2*106 cycles (trucks), giving anticipated 100 years design service life using an ß-factor equal to 3 (substantial consequences). This yields a design load cycle number of $1.2*10^9$.

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8 PERSPECTIVE

The completion of the work on the European timber construction standards is scheduled for 2026/2027, which still seems far-off. Current status for the timber bridge code is that it is made ready for public Enquiry by september 2023 together will all other parts on timber structures (i.e. part 1-1 General rules and rules for buildings, part 1-2 Fire design and part -3 Execution). After Enquriry no new technical content will be added, only changes to what is suggested will be made, thus most of the essential changes are already known. The scope of the standard will inevitably grow, as new timber construction products need to be considered and known design approaches need to be extended and optimised. The update is guided by the central interest of increasing the user-friendliness – not only by profiting from digital availability and efficient search options but also by restructuring, homogenising, and simplifying the regulations. Nevertheless, as with the adjustment of the first generation of Eurocode 5, an additional process of learning, training, and education will be necessary, with this process starting already prior to the final publication. In conclusion, it may be stated: the second generation of Eurocode 5 is not a revolution but an evolution that consistently builds on the experiences and principles of the previous version.

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REFERENCES

[1] Schenk, M.; Werther, W.; Gerold, M.: The Next Generation – Die Weiterentwicklung der Holzbaubemessung nach Eurocode 5. Quadriga, H. 6, p. 16–19, 2022

[2] Müller, A.; Schiere, M.; et al.: Details for timber bridges with asphalt wearing surfaces. 4th International Conference on Timber Bridges ICTB2021^{PLUS}, Biel (Switzerland), 2022

[3] Gerold, M.: The further Development of the Design of Timber Structures according to Eurocode 5 – Part 2: Timber Bridges. Overview EN 1995-2 and Annex D Examples for Detailing. 4th International Conference on Timber Bridges ICTB2021^{PLUS}, Biel (Switzerland), 2022

[4] Hamm, P: Vibration, Deflections. 4th International Conference on Timber Bridges ICTB2021^{PLUS}, Biel (Switzerland), 2022.

[5] Schänzlin, J.; Dias, A.: TCC and Integral Bridges. 4th International Conference on Timber Bridges ICTB2021^{PLUS}, Biel (Switzerland), 2022.