WORLD CONFERENCE ON TIMBER ENGINEERING 2025
BRISBANE, AUSTRALIA
Advancing Timber for the Future Built Environment

CASE STUDY OF AN INTEGRAL TIMBER-CONCRETE ROAD BRIDGE WITH SPECIAL CONSIDERATION OF THE INFLUENCES OF CREEP, SHRINKAGE AND TEMPERATURE IN THE PRE-DIMENSIONING PHASE

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ABSTRACT: As part of its sustainability offensive, the Austrian railroad company OEBB is planning to build a timber concrete composite bridges as a serious alternative to steel composite bridges. For the bridges, the case study focused on the key static criteria for the design. This bridge is a road bridge with a span of approx. 42 meters. This bridge is to be realized as an integral bridge. The primary aim of this paper is to investigate whether influences from creep, shrinkage, swelling and temperature are already taken into account in a preliminary structural analysis or if it is sufficient to initially consider the permanent and traffic loads as decisive. To prove this, a static model was created and the internal forces of the different loads were compared.

KEYWORDS: timber-concrete composite bridge, integral bridge, road bridge

1 – INTRODUCTION

In order to achieve the climate targets, everyone must make their contribution. This means that the public sector must also implement the planned infrastructure measures while taking the ecological footprint into account. There are currently hardly any road bridges in Austria that involve timber. For this reason, Austrian railroad company OEBB commissioned two newly planned timber-concrete composite bridges.

The long term behavior of the timber-concrete-composite bridge and its effect on the dimensioning and detailing of the cross-sections always require closer considerations for such bridges. In this study, an alternative, simplified static model was used to calculate the internal forces due to various load causes.

2 – BACKGROUND

The advantage of integral bridges is that bearings and deck transition structures can be dispensed with, thus reducing life cycle costs. However, some important aspects must be taken into account. On the one hand, effects such as creep, shrinkage, swelling and temperature trigger internal forces due to the impeded change in length. These internal forces are small for non integral bridges, but they could become decisive for integral bridges. On the other hand, the change in the tension and compression area in the superstructure must be taken into account, which can be disadvantageous in composite.

Timber-concrete composite is a good way of integrating timber into bridge construction. the concrete protects the timber structurally and so various other timber preservatives can be dispensed with and the bridge is therefore more sustainable and durable.

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https://doi.org/10.52202/080513-0095

3 – PROJECT DESCRIPTION

For the integral TCC bridge under investigation, a new type of geometry was chosen compared to existing projects. In previous projects, the frame corners were constructed in pure reinforced concrete. This means that the TCC part in the middle of the beam's span starts at the point of contrafelxure and therefore the benefits of timber and reinforced concrete can be used perfectly. In Germany, for example, several pedestrian and cycle bridges have already been built using this construction method in Germany [1]. In Austria, there is currently also a road bridge in Carinthia [2].

In comparison, in the variant under investigation the timber girder is extended to the frame corner, which means that attention must be paid to compressive strength perpendicular to grain, moisture problems and other problems, but that is not focus of this paper.

Furthermore, the span of the road bridge is around 42m, the superstructure is timber-concrete-composite and the substructure is build with reinforced concrete. the bridge has space for one lane and is approved for heavy goods traffic. The geometry of the TCC bridge is shown in Fig. 1 and 2.

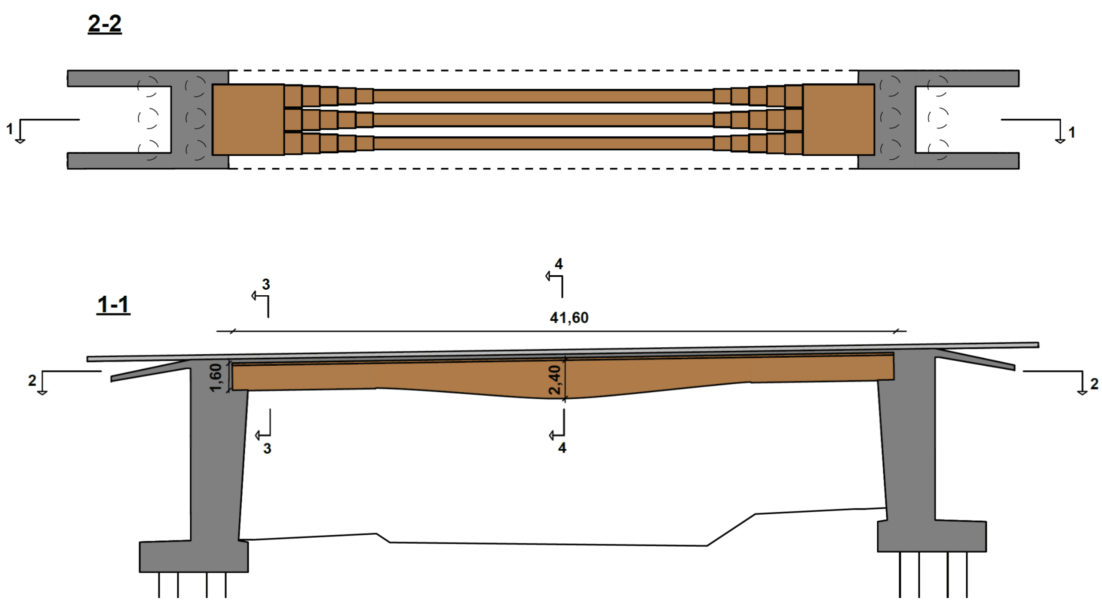

Figure 1. upper image: top view of the TCC bridge; lower image: longitudinal cut of the bridge

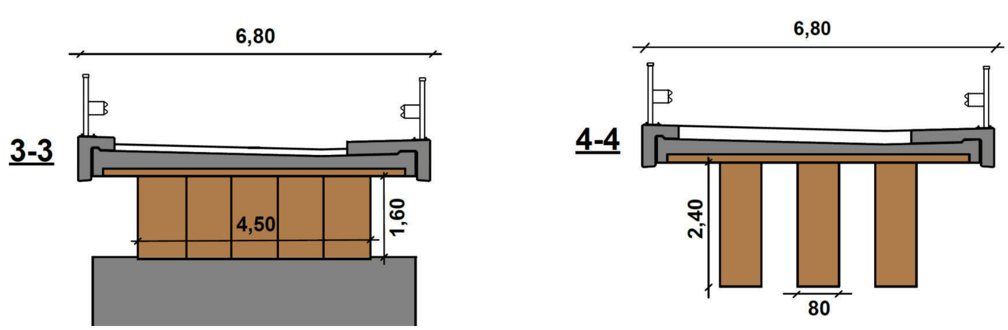

Figure 2. left image: cross-section in the corner of the superstructure, right image: cross-section in the middle of the superstructure

https://doi.org/10.52202/080513-0095

4 – DESIGN PROCESS

In order to have clear rules, how to design timber-concrete-composite structure the existing knowledge was collected and summarized into the Technical Specification CEN/TS 19103 [3] and will be the basis for a new part of the next generation of the Eurocodes. The focus of the Technical Specification is the application of timber-concrete-structures in buildings. To enable the application in bridge structures, ÖNORM prEN 1995-2 [4] contains some additional rules.

4.1 Materials

- Superstructure: GL32h, C35/45
- Substructure: C30/37

4.2 Static model

In order to obtain an overview of the effects of the different loads, a 2D lattice frame model according to Rautenstrauch [5] was created in RFEM 6 (Dlubal Software). To consider the compliant joint, the shear connectors are illustrated here using bending bars, which have a joint at the height of the shear joint [5]. By varying the stiffness of these bars, a loose, flexible and rigid connection could be represented. A schematic sketch of the lattice frame model is shown in Fig. 3. The cross-section of the overall system was divided into thirds. This simplified model was compared with the results of a 3D model using SOFiSTiK (SOFiSTiK AG). A rigid composite was assumed to be easier for comparison. Fig. 4 and 5 give an overview of the static 2D model.

To simulate the lateral distribution of loads on the timber cross-sections, a simplified spring model, shown in Fig. 6, was created in RFEM 6. The timber beams were represented by springs with a spring stiffness of around 32000 kN/m in the center of the span. The equivalent spring stiffness was calculated by applying 100 kN in the center of the span (one third of the cross section, rigid composite). The resulting deflection (3.1 mm) was used to recalculate the equivalent spring stiffness.

This resulted in the decisive beam (the beam in the middle) absorbing around 45% of the live loads for the decisive load case due to a lower lateral distribution.

4.3 Loads

The bridge was exposed to constant loads, traffic loads, earth pressure, creep, shrinkage, swelling and temperature.

Creep, shrinkage, swelling

In order to be able to discuss whether internal forces from creep, shrinkage, swelling and temperature must already be taken into account in the preliminary design of integral bridges, these influences were implemented in the structural model. This was done by means of imposed length change.

The influences of the long-term behavior at the time t=0 and t=∞ were only investigated on the 2D model. For this purpose, creep, shrinkage and swelling were modeled by means of imposed length changes, listed in Tab. 1. The ÖNORM prEN 1995-1-1:2023 [6], ÖNORM EN 1992-1-1:2015 [7], DIN EN 1992-2/NA:2013-04 [8] were used for their calculation.

Table 1: imposed length changes

time	timber	reinforced concrete
t = 0	0,3 ‰	-0,3 ‰
t = ∞	0,3 ‰	-0,9 ‰

Temperature

There are currently no standardized values for the temperature influence on wood-concrete composite components. Therefore, the values for concrete structures were assumed to be on the safe side. The load assumptions are based on ÖNORM EN 1991-1-5:2012 [9] and ÖNORM B 1991-1-5:2012 [10].

$$T_{min}=-29°C$$

$$T_{max}=39-0,006*h=39-0,006*550=35,7°C$$

$$T_{e,max}=T_{max}+2°C=37,7°C$$

$$T_{e,min}=T_{min}+8°C=-21°$$

$$\Delta T_{N,con}=T_0-T_{e,min}=10-(-21)=31°C$$

$$\Delta T_{N,exp}=T_{e,max}-T_0=37,7-10=27,7°C$$

$$\Delta T_{M,heat}=10°C$$

$$\Delta T_{M,cool}=5°C$$

The constraint stresses are significantly overestimated in the normative superposition of the temperature stresses, which is why the standard is not recommended for integral bridges. The superposition is therefore carried out in accordance with RVS 15.02.12 [11].

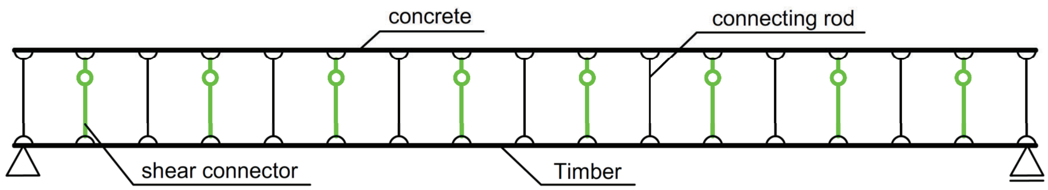

Figure 3. schematic lattice frame model according to Rautenstrauch

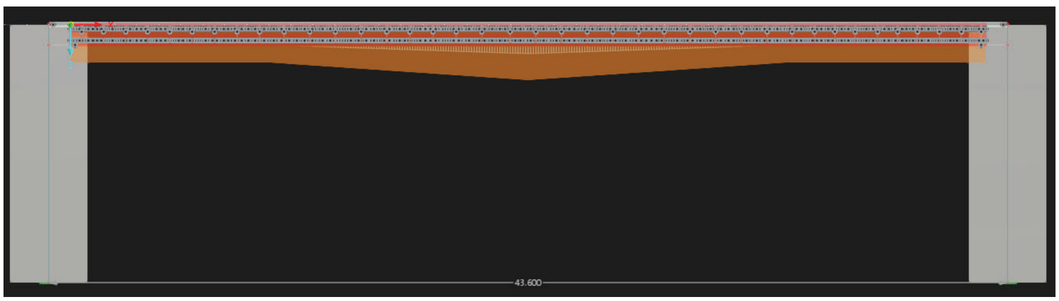

Figure 4. overview of the static model

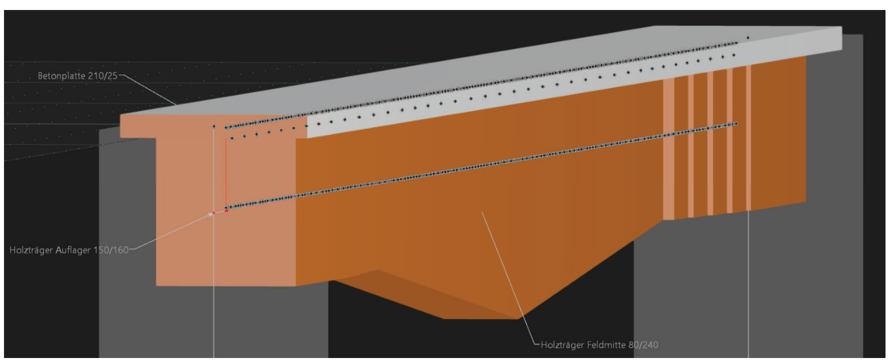

Figure 5. overview of the superstructure, static model

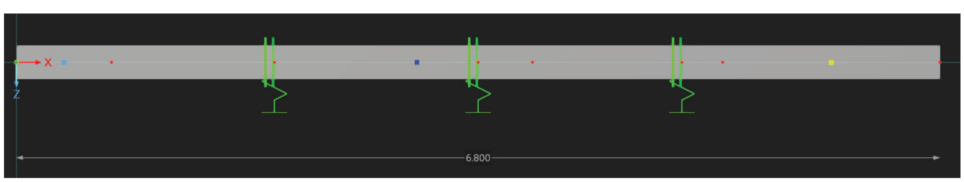

Figure 6. transverse model

https://doi.org/10.52202/080513-0095

5 - RESULTS

5.1 Creep, shrinkage, swelling

The 2D model provides almost identical results as the simplified 3D model for the internal forces due to permanent loads and traffic loads. Therefore the internal forces due to creep e.g. were only calculated in the 2D model.

Table 1 compares the results of the of the calculated design bending moment in the center of the beam and in the corner of the frame. On the one hand due to permanent loads and traffic loads (M1) and on the other hand due to creep, shrinkage and swelling (M2).

Table 2: bending moments due to permanent loads and traffic loads M1 and due to creep, shrinkage and swelling M2.

$t = \infty$	M1	M2	divergence
center of the beam	+13,43 MNm	-13,43 MNm	-100%
corner of the frame	-20,73 MNm	-13,25 MNm	64%

As can be seen in Tab 2, creep, shrinkage and swelling result in similarly large bending moments as permanent loads and traffic loads. Therefore these have a major influence on the dimensioning of the components and cannot be neglected.

5.2 Temperature

The internal forces in the center of the beam and in the frame corner are negligibly small. On the other hand, the enormous bending moments at the base of the substructure (M3), which is listed in Tab. 3, are striking.

Table 3: bending moment at the base of the substructure due to temperature in summer and winter

season	M3
summer	26,49 MNm
winter	-31,03 MNm

6 - CONCLUSION

When calculating the internal forces and support reactions due to shrinkage, creep, swelling and temperature, for integral TCC bridges the results reach an order of magnitude that cannot be neglected and must be considered in any case.

Another finding was that the simplified two-dimensional static model for calculating the internal forces provides practically identical internal forces for permanent and live loads as the more complex 3D model.

7 – REFERENCES

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