HYBRID JOINTS WITH CASTED CONCRETE FOR TIMBER TRUSSED GIRDERS

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ABSTRACT: This paper presents a novel jointing system for timber trussed girders where the rods to be joint are connected by casted concrete after assembling on the construction site. Therefore, an excavation is placed in the chord where all connecting rods end inside. Chords and compression rods are made of timber. For the tension rods, steel bars with anchor plates are applied. Thus, the concrete block is loaded in multiaxial compression. Due to casting of the concrete all parts of the joint are accurately fitting and almost no slippage occurs, which leads to very low deformations of the structure.

KEYWORDS: jointing technique, truss, timber, steel, concrete, experiments, simulations

1 INTRODUCTION

Modern jointing techniques for timber trusses incorporate a large amount of steel parts leading to a relatively high effort for manufacturing. Thus, solutions for timber trussed girders are often more expensive than glued laminated timber beams although a much higher amount of wood is needed for the latter. Moreover, the fire resistance of the structure is in general reduced incorporating steel. Thus, the objective of the presented investigations was primarily to design timber joints which involve low effort and costs for manufacturing while remaining load-bearing capacity and deformations comparable to established techniques. Therefore, existing techniques known from the structural design for timber, steel and concrete where applied. In particular, techniques known from:

- Traditional carpentry (end offsets)
- Timber-concrete hybrid structures (form-fitting shear joints)
- Steel-concrete hybrid structures (tension anchors for steel bars in concrete)

are applied. Timber, steel and concrete are arranged according to the advantages in their material behaviour. The construction is focussed on the use of timber. The amount of steel and concrete shall be as low as possible.

2 JOINTING CONCEPT

It is well-known that timber has an anisotropic material behaviour leading to the effect that stiffness and strength parallel to the grain are considerably higher than transverse to the grain.

Figure 1: Joint of a lower chord of a timber trussed girder; a) Sectioned joint, b) Schematic sketch with acting normal forces N and flexural moments M; from [1]
Thus, for construction purposes it is in general advantageous to load the wood parallel to the grain, because this will lead to higher load-bearing capacity and lower deformations. Furthermore, timber has a different behaviour in tensile and compressive loading. In compression timber behaves ductile while it fails brittle in tension. Compressive timber joints are much easier to establish than tensile connections. Thus, in the new concept timber is substituted by steel for this purpose.

Structural elements of timber and the joints in between have to be processed in generally quite exact to achieve low deformations and slip. A subsequent adjustment is practically impossible. To achieve an accurate fitting, excavations are arranged at the joints, which are filled after assembling of all parts of the construction with concrete. Applying these principles typical joints for primarily compression loaded truss joints were developed, cf. Figure 1. Therefore, a clearance is arranged in the chord. In this clearance, the connecting rods end. Tension rods are carried out as steel bars with an anchoring steel plate at the end. Compression rods are made of wood.

The remaining hollow space is filled after connecting of all parts with concrete resulting in accurate fitting. Due to the arrangement of the parts, the concrete block is loaded multiaxially in compression while the wood is loaded uniaxially parallel to the grain. In the experimental investigations a commercially available polymeric concrete was applied, which did not introduce water to construction and had a higher compressive strength than the wood.

3 EXPERIMENTAL INVESTIGATIONS

A number of experimental investigations was carried out to determine the load-bearing behaviour and the durability of the joints [1]. Primarily three point bending tests of trussed girder sections were performed. Besides small-sized samples also a girder with dimensions of structural size was tested, cf. Figure 2. The girders showed a load-bearing capacity comparable with established jointing techniques but considerably lower deformations and deflections.

It was possible to provoke a quasi-ductile failure by horizontal sliding of the diagonal rods at the joints due to oversizing the cross-sectional area of the chords.

4 SIMULATIONS

For the design of structures with such concrete joints a design concept was carried out [2] based on numerical simulations with the finite element method (FEM) where the stress distribution in the joint zone was investigated. It was shown that the internal force for the static verifications can be determined by simple strut-and-tie-models with commercially available software programs. Furthermore, it is not necessary to verify the stresses in concrete block if a concrete with higher compressive strength than the wood is used. Thus, only the static verifications for the timber and steel parts have to be carried out.

5 CONCLUSIONS

A novel jointing technique for timber trusses was developed. The respective joints cause low effort for manufacturing as all parts can be prepared in the factory. On the construction site, the parts have to be only assembled and filled with concrete. The application of concrete results in accurately fitting parts and, thus, very low deformations of the structure with almost no slippage in the joints. The load-bearing capacity is comparable with established techniques. The new jointing system is able to increase the cost-effectiveness of timber trusses and, thus, the competitiveness compared to glued-laminated beams. The static verifications can be performed based on existing design codes. The necessary internal forces can be determined by simple strut-and-tie-models.

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REFERENCES


Figure 2: Specimen (length 10m; height 2m) in the testing machine