Development of a modular truss made of HPC precast elements and toothed high-performance connection details

1. Occasion and starting position

Large precast concrete parts can either not be transported at all or only with great effort. For this reason, reinforced concrete joints, which have to transmit large forces, are still concreted on site and requires additional equipment, materials, staging areas and time. Quality control is further complicated by weather conditions (e.g. heat, cold, humidity).

2. Subject of the research project

A wide-span, modular reference truss (fig. 1) of high-performance concrete is being designed, whose individual elements can be easily manufactured and efficiently joined using an innovative joining technology.

The design of the modular reference truss includes studies on geometry optimization, segmental connections, assembly concept and construction conditions, fire protection and durability. The resulting requirements provide the basis for developing the connection.

The connection concept envisages two steel toothed strips that are placed in the reinforced concrete components to be joined together (Fig. 2). Each steel toothed strip has a large steel toothing on the concrete side, through which the forces from the concrete component are introduced into the steel toothed strip. On the opposite side of the steel component small steel teeth is provided. The forces are transferred via contact from one steel toothed strip to the other and thus into the adjacent reinforced concrete component (Fig. 3). The steel teeth in contact with each other are referred to as steel / steel teeth. First, suitable gearing forms are developed and defined. At the joint, the force acts on an angle θ. This angle should be as flexible as possible.

In addition to the load bearing capacity, the tolerance compensation of the connection is also a criterion for the tooth geometry. Machine elements with regard to steel gears are analyzed and examined for adaptation to the construction industry. Here, the “Hirtverzahnung” and threads (Whitworth thread, trapezoidal thread) are used as the basis for further investigations. In numerical calculations, the tooth geometry is optimized in different studies. The resulting tooth geometry is experimentally investigated in four trial phases. In the first test phase, the steel / steel teeth are examined on small-sized steel prisms with toothed oblique contact surface (Fig. 4). By means of the inclination of the contact surface, the force application angle θ at which the force strikes the steel teeth is depict. The angles θ to the vertical of 20 °, 25 °, 30 °, 45 °, 50 °, 70 ° and as reference 90 ° are tested.

The first test phase shows the load-deformation behavior of the teeth locally - without external influences from the connection. Based on this, the influence of the subsequent concrete is included in a second phase.

For this purpose, pairs of toothed racks are embedded in concrete prisms at an angle θ (force application angle) of 30 ° and 70 ° to the vertical (Fig. 5). These angles represent the lower and upper limit of the practical application.

In experiments, it is considered whether the main failure mechanism is also in the steel / steel tooth and how they behave in comparison to the experimental phase I. In two further test phases, the connection is tested on a scale of 1:1 for corbel nodes and truss nodes (Fig. 6). The load / deformation behavior of the connection and thus in a complex installation situation is tested.

The load bearing behavior of the toothed rack is described with an engineer model.

Parameter studies with FE calculations on toothed rack models are carried out. The resulting voltage vectors and reference voltages serve as the basis for the engineering model.

The load flow between two steel toothed strips is interpreted using a framework model. Statements about the stress curve along the toothing are made. From this an analytical calculation approach is developed, with which the comparison stresses on the steel tooth can be calculated.

Furthermore, a dimensioning approach is described for the truss node and the further application, the corbel node.

Finally, the modular reference truss girder is considered from a constructional point of view. This is based on the idea of producing the truss girder in its individual elements in the precast plant as an "endless strand".

This can be sawed to the needed length after the hardening time and further finished (eg ground) if necessary. Thus, the shrinkage process has partially subsided.
The components can be produced continuously, which ensures a continuous utilization of the production. When the order is received, the elements are cut to length accordingly.

1. Conclusion

The goal was to develop a connection that can transmit high forces safely, sturdily and efficiently with the smallest possible dimensions and the lowest possible preload force. The connection is ductile, allows easy production at the factory and rapid assembly and disassembly on the construction site.

The connection concept fulfills these goals. The results on the load of the tests on corbel nodes and truss nodes agree well with those from the small-sized test specimens.

The load capacities are dependent on the force inclination θ and can be specified for the tested force inclinations as force per centimeter of tooth length.
The transferable force can be linearly interpolated for the considered experiments with regard to the number of teeth and the depth of the toothing. The connection can be designed that the failure occurs in the tooth and thus ductile.

Key data

Short Title: Modular truss made of HPC precast elements

Researcher / Project Management:
Prof. Dr.-Ing. Holger Falter
Prof. Dr.-Ing. Volker Schmid
Jonas Schmidt M.Sc.
Tobias Nettekoven M.Sc.

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Pictures
Fig. 1: Elements of the modular truss
Fig. 2: Force transmission in the connection
Fig. 3: Force transmission on the steel toothed bar
Fig. 4: Test specimen Steel prism
Fig. 5: Test specimen concrete prism with steel toothed strips
Fig. 6: Test setup truss node