High Tech Concrete: Where Technology and Engineering Meet

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Editors

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Steel- Concrete- Composite Bridges with Innovative Prefabricated Slab Elements

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Abstract. The Institute of Structural Engineering of TU Wien is working on a new method for the construction of deck slabs for bridges, using partial-depth precast concrete elements with an in-situ concrete layer. Even though this construction method can be used for all types of bridges, the main focus for application is set on steel- concrete- composite bridges.

For the main structure of a steel- concrete- composite bridge, a steel bridge girder will be erected by conventional construction methods in the first step. There are different methods for the construction of concrete bridge decks. They can either be made out of in-situ concrete, partial-depth precast elements or full-depth precast elements. In-situ slabs are either cast on fixed formwork or with the use of a formwork carriage. The new construction method is based on the advantages of both, formwork carriage and partial-depth precast elements.

Building the slab with partial-depth precast elements, lattice girder elements are used. These elements will be delivered from the precast factory to the building site, where they are stored next to the abutment. The necessary reinforcement will be placed on the elements and an installation carriage will carry the elements to the installation site. The installation carriage has vertically adjustable steel bars for picking up the elements next to the abutment and carrying them to the installation site where the elements are situated in their final position. The additional reinforcement will be placed and a concrete layer will be applied.

The essential advantage of this innovative construction method for the production of slabs for bridges is the reduction of construction time. While the fabrication of one slab section using a formwork carriage takes one week, the proposed method can double the speed of construction to two sections a week due to the high prefabrication level.

Keywords: Precast concrete elements · Deck slab · Installation carriage

1 Introduction

Building a steel-concrete-composite bridge for a highway, usually two main girders made out of steel are required to span a 15 m deck slab. Such a typical cross section of a highway bridge can be seen in Fig. 1.

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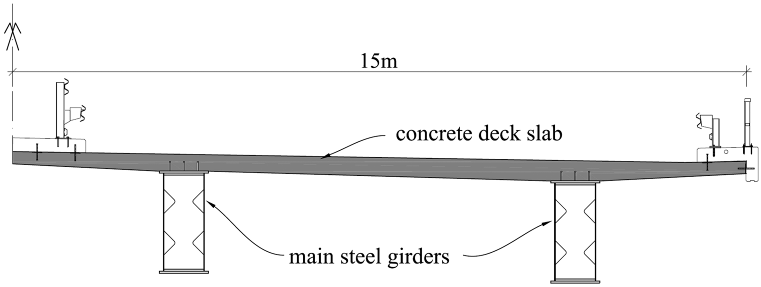

Fig. 1. Typical highway bridge cross section

The steel girders can be fitted by using common construction methods, as erection with cranes, erection by launching or cantilever erection. For building the deck slab, different methods are available. The slab can be made out of in situ concrete, cast either on a fixed formwork or on a formwork carriage, which can be seen in Fig. 2. In 2005 and 2006 such a formwork carriage was used for building a new deck slab for a bridge in Austria, called "Talübergang Wolfsgraben". Therefore, a formwork carriage, which was similar to the formwork carriage shown in Fig. 2, moves along the steel structure and supports the necessary formwork during casting. Ten days were necessary for building one section with a length of 35 m (Hofbauer 2008).

Producing a deck slab by using precast elements, either full-depth precast deck elements or partial-depth precast deck elements can be used. Usually these precast

Fig. 2. Formwork carriage (Doka 2016)

Fig. 3. Assembling precast elements with a crane on cantilever cross girders (Jung et al. 2009)

elements are raised with a crane into their final position on top of the supporting structure. This crane can be situated on the ground, as it is seen in Fig. 3. The crane can also move along the deck for placing the elements.

Another method for producing the deck slab is called slab launching. According to the launching process for building bridges, precast elements are sliding on top of the girders. However, for placing precast elements, a supporting structure is necessary. This structure are usually the bridge girders, where the elements can span transversely. For building a cantilever slab, cantilever cross girders are needed. These girders are usually important for the final construction but they can be used for the construction of the deck slab as well. Therefore, the elements span in longitudinal direction, between these cantilever cross girders. Figure 3 shows the building site of the “Bahretal-bridge”, situated in the east of Germany. It is a steel- concrete- composite bridge with one hollow box bridge girder with cantilever cross girders on each side. The slab has a total width of 10,5 m, wherefore cantilever slabs are necessary which are made out of precast elements. Figure 3 shows the crane placing the full-depth precast elements on top of the supporting structure. This shows a limitation of using such a crane, which is on the one hand side the height of the bridge and therefore the height of the crane. On the other hand, on the ground along the bridge must be enough space for the crane and for a storage area of the elements. If one of this limitation occurs, a crane on top of the structure can be used as well.

The new construction method for building the deck slab unifies the advantages of both techniques, partial depth precast elements and the usage of a formwork carriage.

One advantage of using a carriage is to build the deck slab without contact to the ground. All tasks can be executed from the top of the bridge girder. Due to the hangers at the installation carriage, no additional girders are required for building the deck slab. The big advantage of partial depth elements is, among other things, the possibility to produce in a factory without weather influences. Apart from that, a high quality of the concrete elements can be expected.

Hence, the idea of the new construction method is, simplified, using an installation carriage in the style of a formwork carriage and assemble with this installation carriage partial depth precast elements.

2 The Concept of the New Construction Method

Starting with the erection of the steel girders, there is no difference work in comparison to any other bridge construction method. As building the deck slab with a formwork carriage, supports on top of the steel girder are required. These elements, also required for the new construction method, have to be fixed on the girder before erection, seen in Fig. 4 in the upper construction phase. For building the deck slab with the new construction method, an installation carriage is required. As seen in Fig. 4 in the middle, this installation carriage can be installed at the assembly area next to the abutment. In addition, precast elements will be delivered from the precast factory to the building site, where they are stored next to the assembly area. These elements have a thickness of 120 mm and obtain already the statically required lower reinforcement. For transporting these elements by truck, the size of the elements is important. Building one section with a total length of 25 m, several elements have to be fixed together, which will be described in the further chapters. The upper reinforcement can also be installed partially at the assembly area. Afterwards, the installation carriage will pick up the slab section with vertically adjustable steel bars. The precast elements are in a raised position while the installation carriage is moving along the steel structure to the installation site, seen in the lower part of Fig. 4. By lowering the steel bars, the elements will be situated to their final position. Completing the upper reinforcement above the girders, a concrete layer will be applied at this new slab section. While all these work steps are going on at the installation site, another slab section can be prepared at the assembly area. When the concrete is hardened, the steel bars can be removed and the installation carriage can move back to pick up the next section.

For building the deck slab of a steel-concrete composite bridge, a common method is to build the deck slab by using the so called “back-step method”. Therefore, the sections in the fields are built first to reduce the tensile force in the slab and therefore to reduce the crack width. This back-step method is also applicable with this new construction method. Building first the sections in the fields and afterwards the sections above the pier means that crossing a finished slab section is necessary. This crossing is possible by raising the steel bars higher than before.

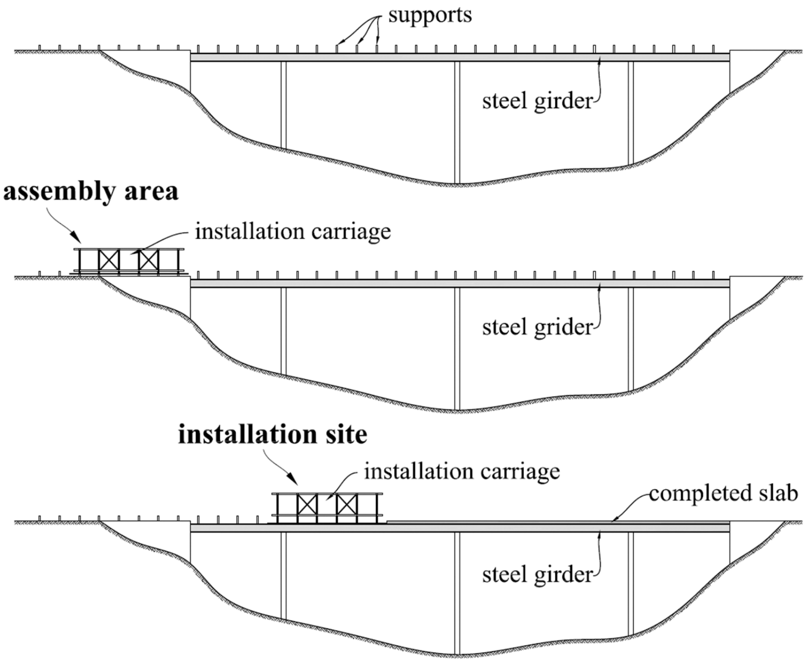

Fig. 4. Construction phases

3 Work Steps for One Slab Section

As described above, a section with a total length of 25 m will be prepared at the assembly area and will be carried with an installation carriage to the installation site. Figure 5 shows the installation carriage on top of the supports, carrying partial depth precast elements. In this case, the precast elements are already placed on the steel girders. The lifting and lowering process of the elements is possible with vertically adjustable steel bars, which can be moved with hollow piston jacks which are situated at every steel bar.

Figure 5 also shows the joints between the several precast elements. For building a 25 m long slab section, six elements in total are necessary for the cantilever deck slab (three on each side) and seven elements are required to build the middle part of the slab. The size of every element depends on the maximum by truck transportable size. For carrying the elements with the installation carriage from the assembly area to the installation site, it is important, that the joints between the elements are able to transmit bending moments.

Therefore, the joint between two elements has to be designed carefully. Figure 6(a) shows a section through the elements. The elements have a thickness of 120 mm, but at the joint, it is reduced to 70 mm.

To achieve a fixed connection between two elements, additional reinforcement is required (seen in Fig. 6b). This reinforcement should be located as close as possible to

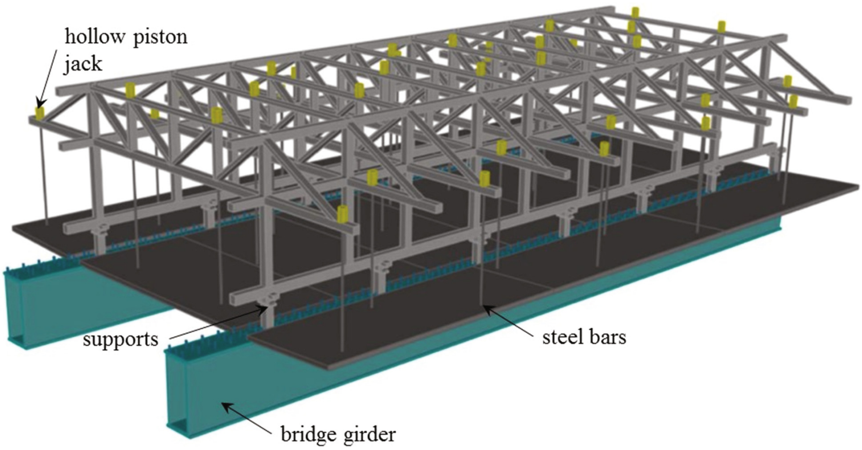

Fig. 5. Installation carriage carrying precast elements

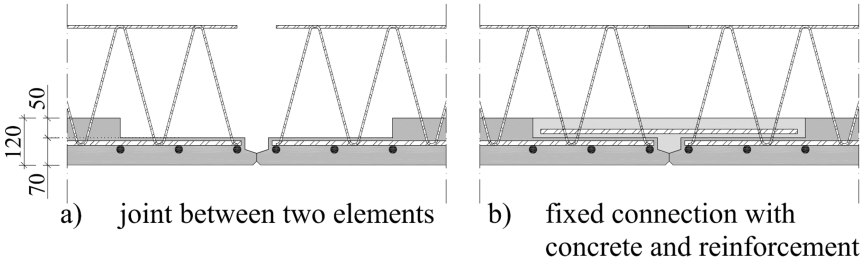

Fig. 6. Joint of two partial depth precast elements

the lower reinforcement of the elements. The lattice girders as well as a rough surface of the precast elements are important for transmitting the tensile force from the additional reinforcement to the reinforcement of the elements. For a fixed connection the space between the elements, where the reinforcement is placed, will be filled with concrete at the assembly area. To transmit bending moments during the installation process, the lattice girders will be welded. After connecting the elements, one slab section can be carried by the installation carriage.

4 Numerical Calculations

Initially it is necessary to calculate the upcoming bending moments in the precast elements during the transport by the installation carriage. Therefore, only the dead load of the precast elements has an effect. A 3D finite elements model was prepared for the calculations. Three nodal supports were used to create a statically determinate model. Every hollow piston jack is modelled as a force with its direction of action into the negative z-axis. Using equal forces instead of supports at the steel bars is representing the reality. The hollow piston jacks are all regulated with one hydraulic circulation. During the lifting process of the precast elements, every hydraulic jack gets the same force.

The results of the numerical calculation of the elements between the girders are seen in Fig. 7. It shows the bending moments in direction of x- and y- axis. The maximum bending moment is equal to 6,44 kNm/m, the minimum bending moment is equal to −16,72 kNm/m.

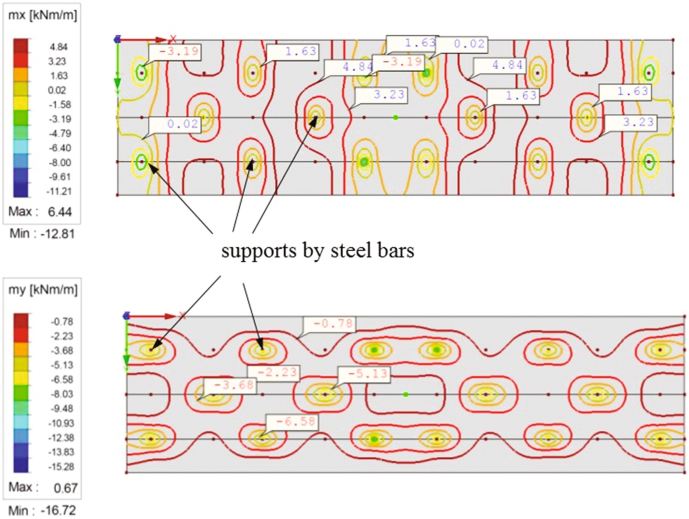

Fig. 7. Bending moments during transport of the middle elements

The elements itself as well as the joints have to absorb these bending moments. Therefore, the maximum absorbable bending moments have to be calculated according to the material models of Eurocode 2 (EN 1992-1-1 2015). For calculating the bending moments, the position of the reinforcement in the element as well as in the joint has to be considered. The maximum absorbable bending moments are bigger than the bending moments in the structure, wherefore the transport of the elements is possible with the chosen positions of the steel bars. The same calculation was carried out for the cantilever slabs. As well as for the other elements, the result for the cantilever slabs was, that they are able to resist the impacts during the transport.

5 Comparison

Comparing the new method of building the deck slab of a bridge with the existing methods, there are some big advantages. First of all, a reduction of construction time is possible by using the new method. While using a formwork carriage one week is needed to build one slab section, it will be possible to double the speed of construction with the new method and build up to two slab sections in one week. This is possible due to the division of work. The lower reinforcement is already installed in the factory while producing the precast concrete elements. Furthermore, the work steps at the building site are divided into the work steps at the assembly area and the work steps at the installation site. Therefore it is possible to work with two teams at one time. Many work steps can already be executed at the assembly area and just a few actions are required at the installation site, before casting the concrete.

Besides that, various different cross sections can be built with this new method. There is no need of extra cantilever girders for building the cantilever deck. Due to the existing steel bars at the installation carriage that supports the elements, the distance between the bridge girders can be higher, compared to a construction method where the concrete elements are only supported by the main girders.

The Austrian Patent as well as the International Patent (PCT/AT2016/050158) is already granted for this new method of building the deck slab. This shows the newness of the method described in this paper.

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