DESIGN OF PEDESTRIAN BRIDGE FROM TEXTILE REINFORCED CONCRETE

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Abstract

A pedestrian bridge from prestressed textile reinforced concrete was designed as a case study in diploma thesis. The pedestrian bridge has span a bit over 17 m. It is reinforced with carbon textile reinforcement and prestressed with two parabolic tension cables with 12 strands in outside beams. Outside beams are connected with a 50 mm thick deck. The textile reinforcement is placed in anchorage area, in the deck and in outside beams.

Keywords: textile reinforced concrete, footbridge, pedestrian bridge, post-tensioned

1. Introduction

Textile reinforced concrete (TRC) is a new type of composite material which consists of fine graded concrete and textile reinforcement with exact position in the cross-section determined in the structural analysis. The textile reinforcement is mostly made from glass fibres (tensile strength is about 1500 MPa) or carbon fibres (tensile strength is over 3000 MPa). Advantages of textile reinforcement are high efficiency of reinforcement, resistance to corrosion, minimal cover, lower weight than steel reinforcement, easy handling with textile reinforcement. Three pedestrian bridges from TRC have been already built in Germany. The aim of this article is to present a case study of the TRC footbridge and to describe a design of bridge superstructure at the location of existing bridge structure in Bezruč Park (fig. 1).

2. Existing structure

Existing footbridge over Mlýnský brook was built in 2011 by company OHL ZS and connects Korunní fortress – today botanical garden with Olomouc centre. Total cost of current structure was 5 422 844 Czech crowns.

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The existing pedestrian bridge is a frame structure from prestressed concrete. Arch shaped bridge deck spans over the Mlýnský brook with a span of 17 m. Width of the bridge is 2 m in the centre of the span and 3 m at both ends of the deck.

Fig. 1: Location of bridge [source: www.mapy.cz]

The designed footbridge assumes supporting on existing abutments. Different height of abutments would cause longitudinal inclination of the deck. There is no curvature of the bridge deck in a plan; the straight bridge was assumed in case studies. For the newly designed footbridge constant width 2 m was established.

Four design concepts of pedestrian bridge superstructure were proposed and for the chosen variant detailed design was performed. Particular concepts are briefly described in following clauses.

3. Concept 1

For concept number one a beam bridge system with three main girders and two parapet girders was designed (fig. 2).

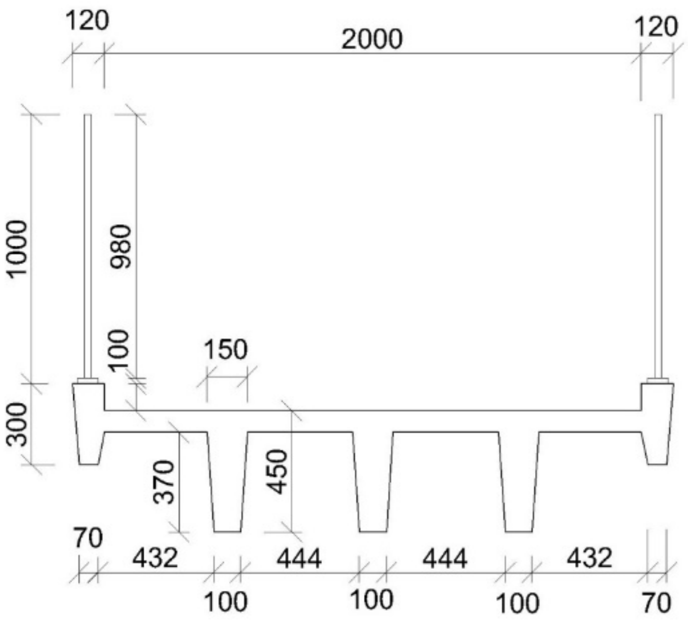

Fig. 2: Cross section, concept 1

Footbridge was designed as a prestressed prefabricated simple beam with span over 17 m. The structure is reinforced with textile reinforcement; no common mild steel reinforcement is used. The height of the main girders was estimated from formula (H= 1/35 L = 450 mm), established in Germany for TRC footbridges. The total width of the footbridge is 2,24 m.

This variant of structure was not chosen for detailed design. Compared to other concepts the first concept looks massive and is does not fit local conditions in Bezruč Park. Benefits of this solution would be easy concreting and production of the beam in a steel mould in the concrete plant.

4. Concept 2

Concept 2 has also span ca 17 m and consists of four precast segments 4,25 m long. Each segment is reinforced with textile reinforcement only. All segments are tied together with a post tensioning system. The structure was designed as a simple beam on the elastomeric bearings. Draining of the deck is solved by longitudinal inclination given by different heights of abutments.

Advantages of this structural solution are a very thin slab; with thickness only 80 mm (preliminary estimation), low weight and low material consumption.

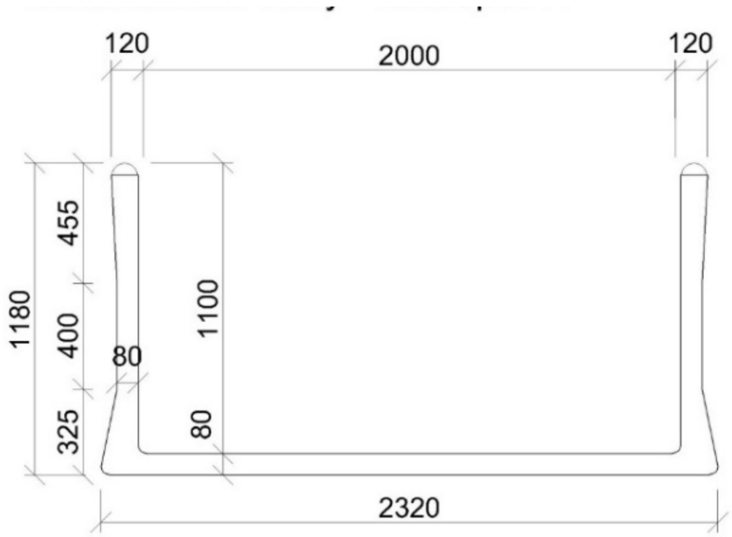

Fig. 3: Cross section, concept 2

5. Concept 3

Concept 3 is very similar to concept 2. The cross section of the structure consists of three parts. These parts are connected with shear connectors. Remaining technical solution and details are same as in the concept 2.

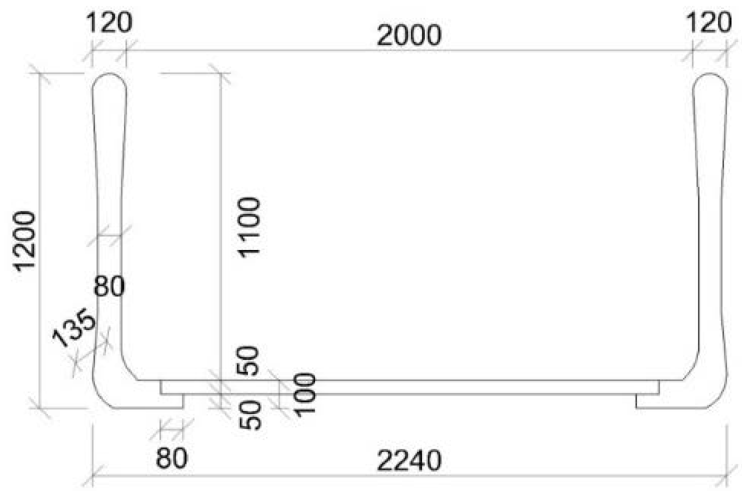

Fig. 4: Cross section, concept 3

6. Concept 4

This concept was chosen as the best solution and it was developed in detailed design including drawings.

6.1 Structure of footbridge

The fourth concept is a prefabricated beam structure formed by two girders and a slab between them. Span of the footbridge is 17 210 mm and length of the girder is 17 810 mm.

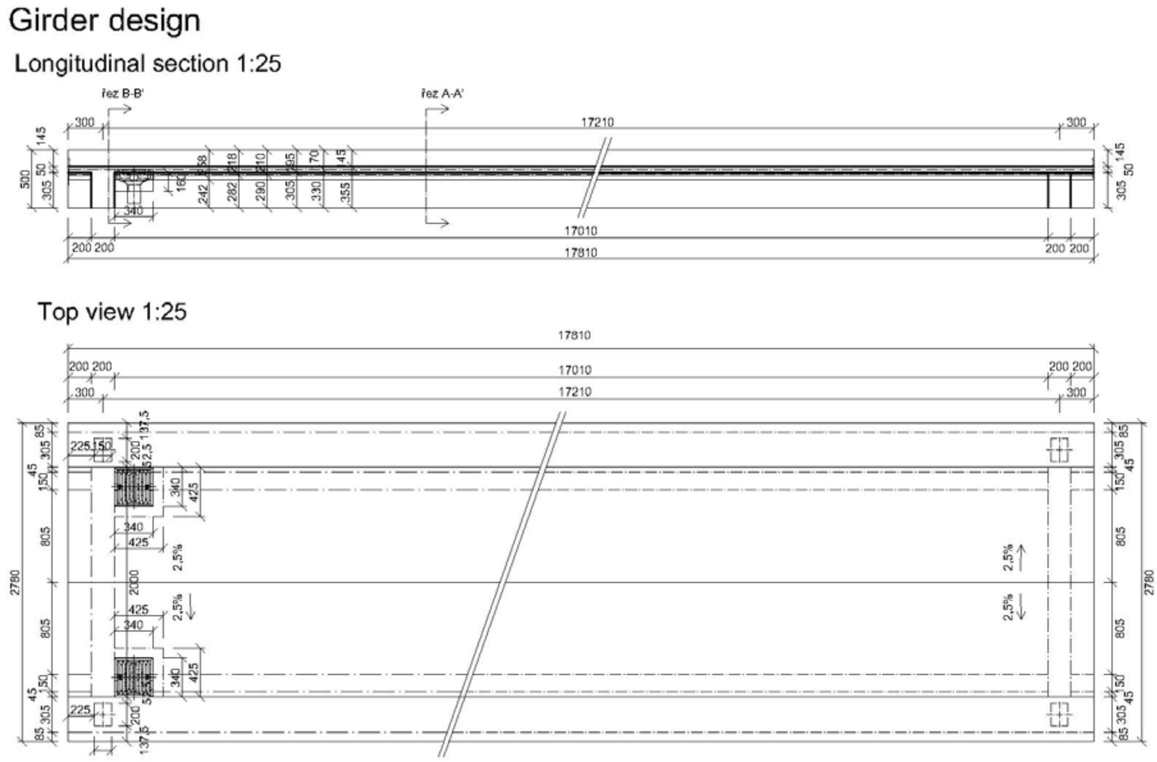

Fig. 5: ketch of the longitudinal section and top view of the girder

Outside girders are 500 mm high. The lower part of the beam is 305 mm wide; and width of the upper part of cross section is 390 mm. The upper part creates a bridge cornice. Beams support 50 mm thick bridge deck with haunches at supporting outer beams. Total width of girder is 2780 mm and width of sidewalk is 2000 mm.

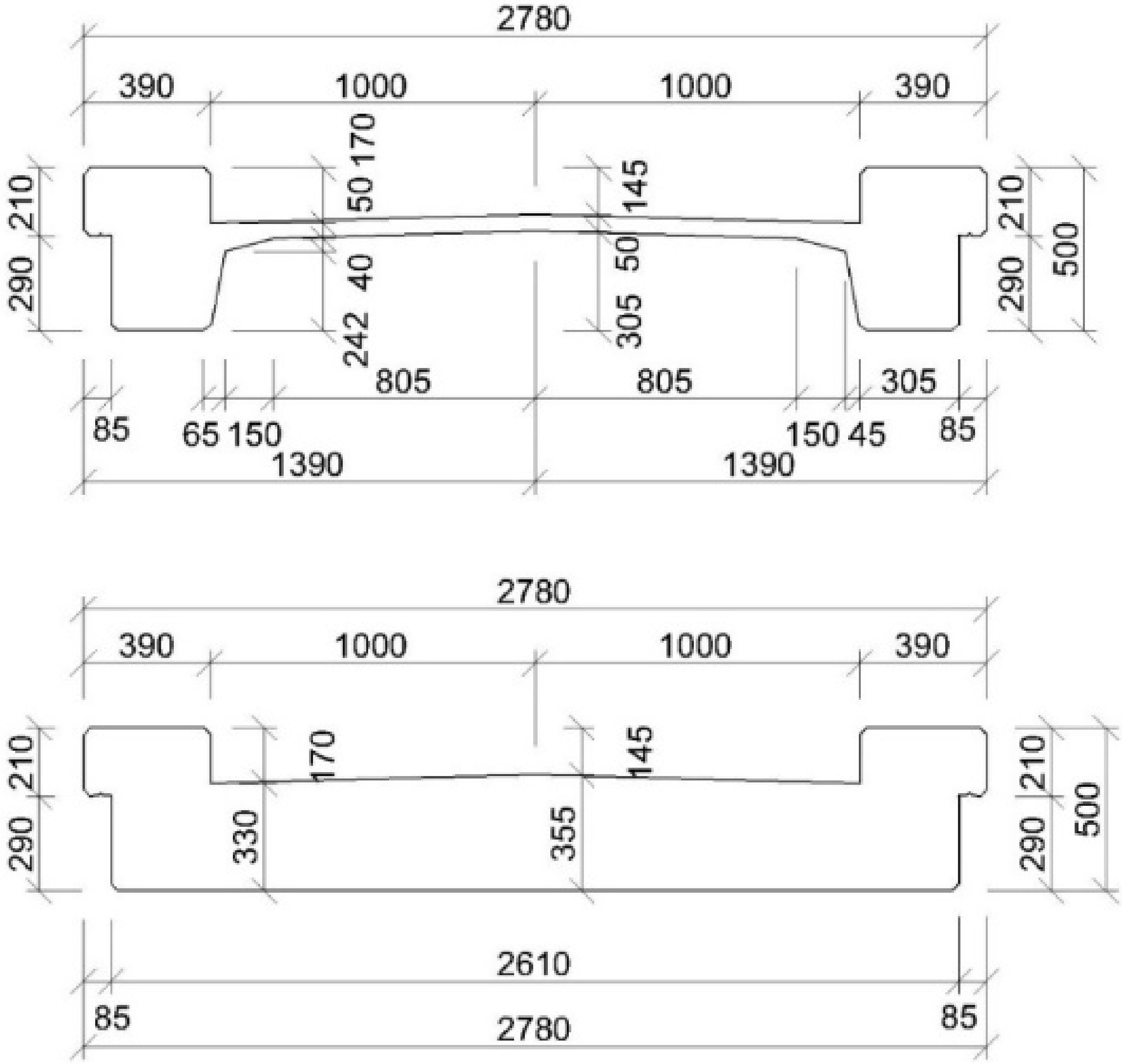

Fig. 6: Cross section at midspan and at support area

6.2 Reinforcement of girder

Two types of reinforcement were designed in the footbridge – prestressing steel cables and textile reinforcement.

Girders are reinforced with post tensioning system and textile reinforcement. There are twelve post tensioning strands (Freyssinet system) in each beam. Cable lines have parabolic shape. Post tensioning cables consist of strands with nominal area 150 mm^2 and tensile strength 1 860 MPa. The prestressing force is anchored with four anchors 12C15 200 x 240 mm. The anchor head is protected against corrosion by a cover and injection.

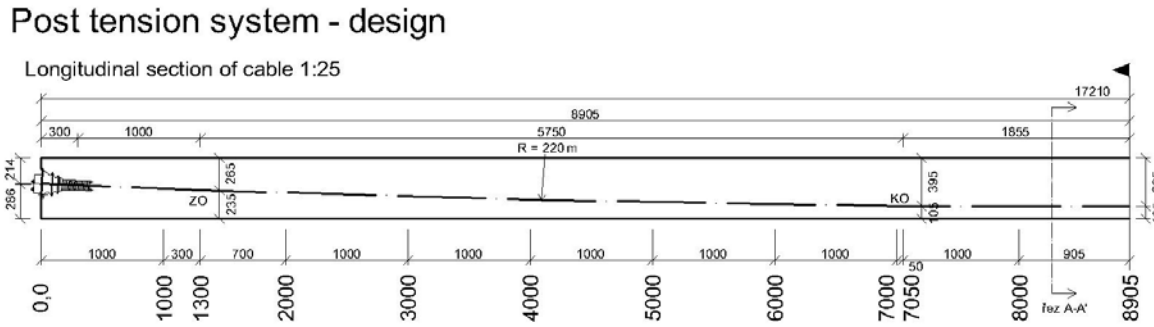

Fig. 7: Post tensioning cable line

The textile reinforcement is provided by textile meshes from carbon epoxy composite. Tensile strength of the material is 1600 MPa. The wires in the textile mesh grid have spacing 25 mm (fig. 8); the wire profile area is 3,55 mm^2. Position of the textile reinforcement determined in the structural analysis is provided by special plastic spacers Disttex (fig. 9). The spacers assure also minimal cover required primarily by reasons of sufficient bond.

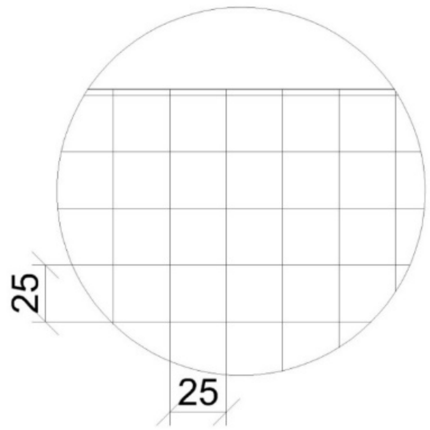

Fig. 8: Sketch of the textile mesh

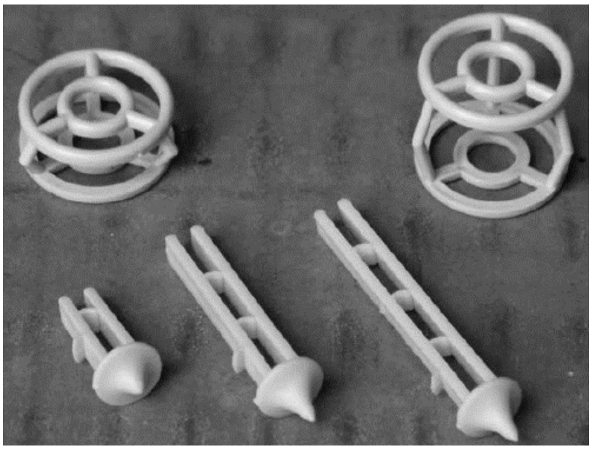

Fig. 9: Spacers (disttex.com)

The dimension of the textile mesh is limited, therefore lapping of the meshes by 5 meters is provided. Minimum length of overlap is 260 mm.

The textile reinforcement was designed in anchor zone, cross-beams and as a longitudinal reinforcement.

The anchor zone does not have common steel reinforcement; it is reinforced only with three layers of textile reinforcement that resist all splitting forces in the anchor area. The anchor area was designed using strut and tie method.

Textile reinforcement in the cross-beams is connected with longitudinal reinforcement by splice pieces. Longitudinal reinforcement is represented by textile meshes in the deck, surface reinforcement in outside beams and the top reinforcement. The textile reinforcement in outside beams substitutes shear reinforcement (stirrups). Sketch of the textile reinforcement layout is in the figure 10.

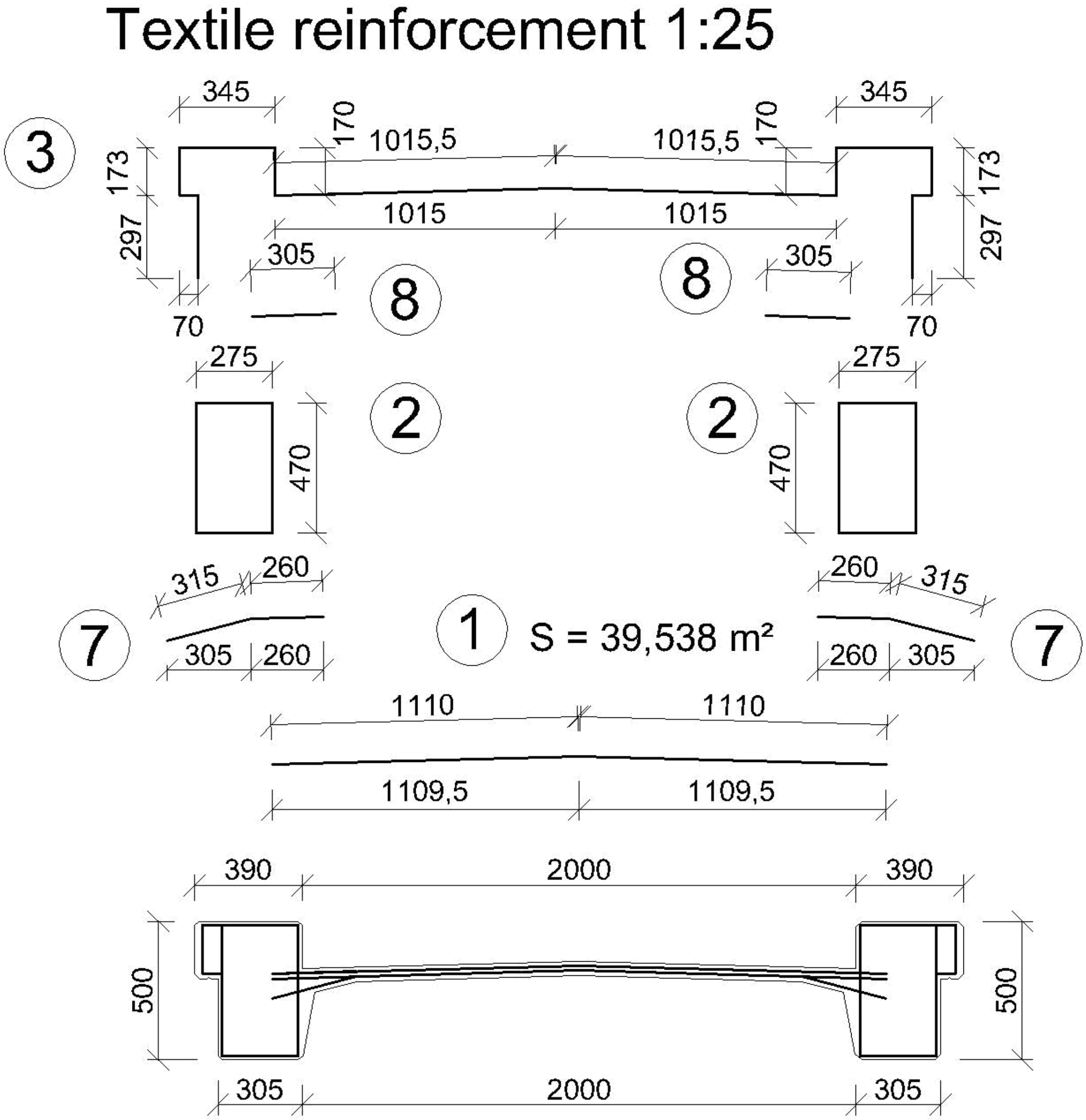

Fig. 10: Reinforcement scheme of longitudinal-going textile meshes

6.3 Concrete mix design, concrete class, curing of fresh concrete

Concrete class is C70/85 with maximum gravel size 4 mm. The total amount of concrete is 8,5m^3. The girder will be concreted in a steel formwork. Possible damage in the area between deck and girders due to shrinkage must be prevented by use of cement with slow increase of strength. Careful curing is required to prevent shrinkage. The prestressing will be applied at the age 6 days when the compressive strength of concrete reaches 60 MPa.

6.4 Bearings, railing, insulation of deck, dilatation

The whole structure will rest on four elastomeric bearings with size 150 x 200 mm (1x fixed, 1x multidirectional, 1x unidirectional (longitudinal translation prevented) and 1x unidirectional (transverse translation disabled).

Concrete deck is protected by sprayed bridge insulation Sikafloor 5 mm.

Bridge dilatation is designed as a steel sheet with anti-slip coating. Structure of rail is made from steel pipes and it is attached to the outside beam by chemical anchor. Height of the railing is a standard value 1100 mm.

6.5 Transport, placing of the girder and assembling

Six days old girders will be prestressed and prepared for transport to Bezruč park. The footbridge will be transported by a lorry with big flatbed EURO 64-04 with dimensions sufficient for the concrete girder. A special route has to be chosen to reach the building site. In the site the girder will be transported by a big crane. Before assembling of the new pedestrian bridge, old abutments will be partly demolished and adjusted to set the girder on them. The support bearings will be concreted and saddle blocks fixed. Final stage of assembly will be installation of bridge dilatation compensators, fixing of the railing and finishing works.

7. Conclusions

The paper introduces four alternatives of a TRC (textile reinforced concrete) footbridge design and describes the design of the selected solution. All variants use a combination of textile reinforced concrete and prestressed concrete. Textile reinforced concrete (TRC) is a new type of structural and composite material that has a big potential in substitution of common steel reinforced concrete in certain types of structural elements. TRC structures are favourable as interesting challenge for architects; because minimizing of cover layers and high resistance of the structures enable designing of slender smart structures. TRC structures satisfy principles of sustainable building by minimizing material consumption, decrease of carbon dioxide emissions, reduction of maintenance and repair cost. The economical and ecological benefits will possibly lead to extension of TRC structures. E.g. Germany plans to replace at least 20 % of steel reinforcement by textile reinforcement until 2030. It will be very interesting to see a next evolution of textile reinforcement.

Acknowledgement

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References

[1] KULAS, Christian. *Zum Tragverhalten getränkter textiler Bewehrungselemente für Betonbauteile*. Phd thesis, Aachen Technische Hochschule, 2014

[2] JESSE, Frank, CURBACH, Manfred. *Verstärken mit Textilbeton.* Beton-Kalender 2010: Schwerpunkte: Brücken, Betonbau im Wasser, 2010 Ernst & Sohn Verlag für Architektur und technische Wissenschaften GmbH & Co. KG

[3] LORENZ, Enrico, ORTLEPP Regine. *Berechnungsalgorithmus zur Bestimmung der Verankerungslänge der textilen Bewehrung in der Feinbetonmatrix,* 4th Colloquium on Textile Reinforced Structures (CTRS4), Dresden, Germany, June 3-6.