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Experimental verification of secondary effects of prestressed beam at ULS[☆]

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Summary The paper deals with secondary effects of prestressing at ultimate limit state when statically indeterminate structure has changed its structural form due to development of plastic hinges in critical cross-sections. The article presents results of an experimental program which was carried out at Slovak University of Technology in Bratislava on two span continuous beams post-tensioned by two single-strand tendons subjected to experimental load which has changed structural system into kinematic mechanism.

Introduction

Application of prestressing is based on more effective use of concrete cross sections compare with sections reinforced by reinforcing steel. Reinforcing steel is passive reinforcement because stresses develop here after loading of a structural member. Opposite, prestressing tendons transfer actively compressive forces and bending moments into concrete members thanks to its prestrain. This increases flexural stiffness of prestressed elements at SLS and after cracking we can usually utilize full tensile capacity of prestressing units to the bending capacity at ULS (Navrátil, 2014).

In a case of post-tensioned structural members, tendon layout usually complies distribution of internal forces due to the load, e.g. in simply supported beams tendons are located in the bottom part of the structure and in continuous beams they have usually polygonal arrangement (Moravčík et al., 2014). It means in areas with sagging moments are located in the bottom while in areas with hogging moments in the top part of a member. It is because bending moments due to the prestressing are proportional to the prestressing force ''P'' and distance ''e'' between center gravity of prestressing unit and the beam. Product $P \times e$ represents primary effects of prestressing. In case of

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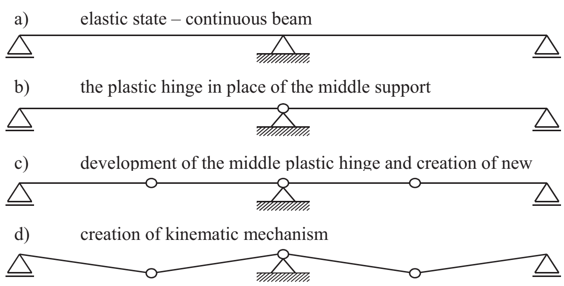

Figure 1 The scheme of a change of structural form from statically indeterminate beam to kinematic mechanism.

statically indeterminate structures prestressing may generate additional internal forces so called secondary (parasitic) effects which can significantly influence distribution of stresses in the structure (Andrew and Witt, 1951). The secondary effects develop due to the restraining of by tendons imposed deformations by hyperstatic restraints. Therefore they depend mainly on the structural system and as well as on the geometry of the tendon. The secondary effects can be equal to zero if suitable tendon layout is used (concordant tendon). Because the secondary effects depends on the structural system the question is how to treat with these internal forces at ULS when the structure changes structural form due to formation of plastic hinges in critical cross-sections with ultimate state — kinematic mechanism?

Description of the experimental program

Detailed analysis of above mentioned issue was the main part of experimental program. The samples of the experiment were post-tensioned concrete beams laying on three supports. This resulted in a form of two-span continuous beam with the same span length. With gradual increase of the external forces, bending capacity of critical cross sections was reached which finally resulted in development of the kinematic mechanism. The statically indeterminate structure (Fig. 1a) has been transformed into the statically determinate structure (Fig. 1b) after plastic hinge formation at internal support. Further growth of external load led to the development of plastic hinge in the spans (Fig. 1c) and to the kinematic mechanism as final stage (Fig. 1d) — destruction of the structure.

Together 6 concrete beams were cast for the purpose of the experiment with same cross section dimensions 0.25×0.4 m and the length of 10.5 m. Concrete strength class of C35/45 has been used. Beams were produced in specialized factory ZIPP Bratislava, s.r.o., Sered' division. Pictures taken during preparation and execution of the beams are in Fig. 2.

All beams were reinforced with reinforcing steel B500B and with two single strand tendons ϕLs15.7 mm/1860 MPa with different geometry. The first tendon had polygonal shape and geometry produced zero secondary effects (concordant tendon). The second tendon was designed to reach maximum secondary effect. Tendon layouts of each tendon are shown in Fig. 3. Plastic ducts with diameter of 22 mm were used for each tendon.

Elasto-magnetic sensors placed in characteristic cross sections for each tendon on opposite side of the beam were used for detailed recording of prestressing force. Experimental beams were prestressed by tendons with different bond. All together there were 3 groups of samples. The first one were beams prestressed by tendons with bond N1 and N2, the second one were beams prestressed by tendons coated with emulsion for protection against corrosion

Figure 2 Preparation and realization of the experimental beams.

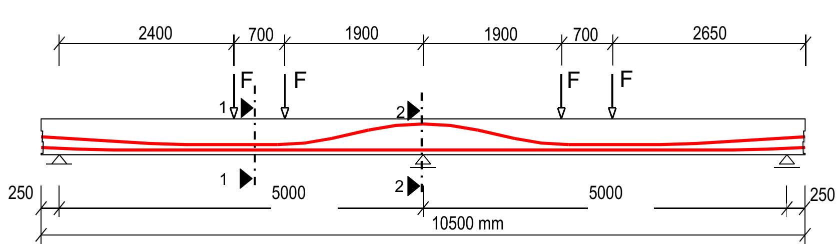

Figure 3 The tendon lay-outs.