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ANALYSIS OF THE THERMO-STRESSED STATE OF REINFORCE-CONCRETE MONOLITHIC BRIDGE SPAN

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Abstract. In the article describes the problem of the thermo stressed state during building the monolithic reinforce-concrete prestressed trestle. The calculations of trestle are shown. Described conclusions for the improvement of such type constructions design.

Keywords: Prestressed concrete, girder deck span, trestle, thermal stressed state, account of boundary conditions, computer calculations.

Introduction

For the increase of longevity of bridges in obedience to the norms of design (DBN V.2.3.–14:2006) since 2006 in Ukraine the bridges spans on the general use highways can be built only from the prefabricated-monolithic or monolithic reinforced concrete. In Ukraine there is considerable experience of design and building of span structures from the prefabricated prestressed reinforce-concrete constructions. Experience of bridge building in other countries indicates the efficiency of the use of monolithic prestressed deck slabs with the tense of armature on a concrete. Such constructions began to use in Ukraine and they are very perspective for bridge building. But experience of erection of such bridges in our country is moderate. There were certain problems during building process of a monolithic transport structure, for example formation of technological cracks.

Research

Trestle along a Naberezhno-Khreshchatytska Street in Kyiv is in composition of building of the Podyl’sky bridge transition through r.Dnipro in Kyiv, and it consists of ten continuous spans (fig. 1, a). Material of construction is post-tensioned monolithic reinforced concrete with the tense of armature on a concrete. The trestle scheme is combined: continuous deck beam, supports № 6 and № 7 are incorporated with spans and form a frame overlapping the maximal span in 36 m. A scheme of continuous monolithic span is a 24 m + 30 m + 4 × 33 m + 36 m + 33 m + 30 m + 24 m, length of 309 m.

Number of lanes: 2. Every lane has width of 3,75 m, and safety lane 1 m. Service pass is arranged at the right side and has width of 0,75 m. Profile on length has ascending and descending slopes of 60 ‰ and the inscribed vertical curve radius of 2000 m with length on a horizontal plane 240 m.

A height of span structure varies from thickness 1,1 m in central part 5m width, to 0,2 m on the edges on cantilevers (fig. 1, c). Such small thickness of deck (1/33, 7 maximal span 36 m) is conditioned by the requirement of achievement of minimum working trestle height. Working armature of reinforcement deck is a periodic profile of A-III class, structural – is an armature of periodic profile of A-I class.

Post-tension of spans structure is created by tensioning 28 bunches of rope armature (fig. 1, c). Every bunch consists of 19 K-7 ropes with a nominal diameter of 15,2 mm by EN 10138-98. According to project documentation force of tension of every bunch should be 352 t.

According to a project by LTD “Soyuztransproekt”, for concreting and arranging post-tensioning of the beam deck span structure is divided into 5 sections (fig. 2). The tension of ropes for every section came true after a set by the 70 % of concrete durability. At the junction of sections for continuous transmission of tension on all length of ropes is provided for the establishment of transient bilateral anchors-couplers. Also at the stage-by-stage tension of ropes on the cantilevers of sections loading (reservoirs with water) has been set for a counterbalance.

An examination of building research staff of Scientific and Research Institute Derzhdor several defects of span structure were discovered (fig. 2) (Stashuk *et al.* 2010). There were cracks with the width of opening of 0,1–0,3 mm among them. These cracks did not develop during static and dynamic tests, and filling of these cracks by injection materials and causing of sheeting will give an opportunity to provide project longevity of constructions.

To identify the causes of crack formation factors that could influence on cracks appearance were considered:

– On a joint of the 4th and 5th sections five bunches of ropes of post-tension armature were excluded from work at once (№ 9, 10, 12 on rice. 5), and that could substantially influence on the stress-deformation state of sections joint zone during the tension.

– Also the possible factor of crack formation is heat release at the reaction of hydration in the monolithic concrete array. The chemical level of the heat release depends on cement, its mineral composition, chemical composition, consumption of cement per 1 m^3 of concrete, chemical additions entered in concrete mixture, initial temperature of the nested mixture, concrete temperature at insetting (Solov'yanchak *et al.* 2003; Korotyn 2005; Sokolov 2006). The technological reasons of crack formation in the monolithic reinforced concrete depends of the uneven temperature gradient in an array as a result of contiguity of the inlaid monolithic concrete structure to the concrete, that already collected its durability. Other reasons can be limitations of concrete mass movement (support elements, rigid connections, difference in geometric sizes and in the plan of array) or the presence of external heat sources.

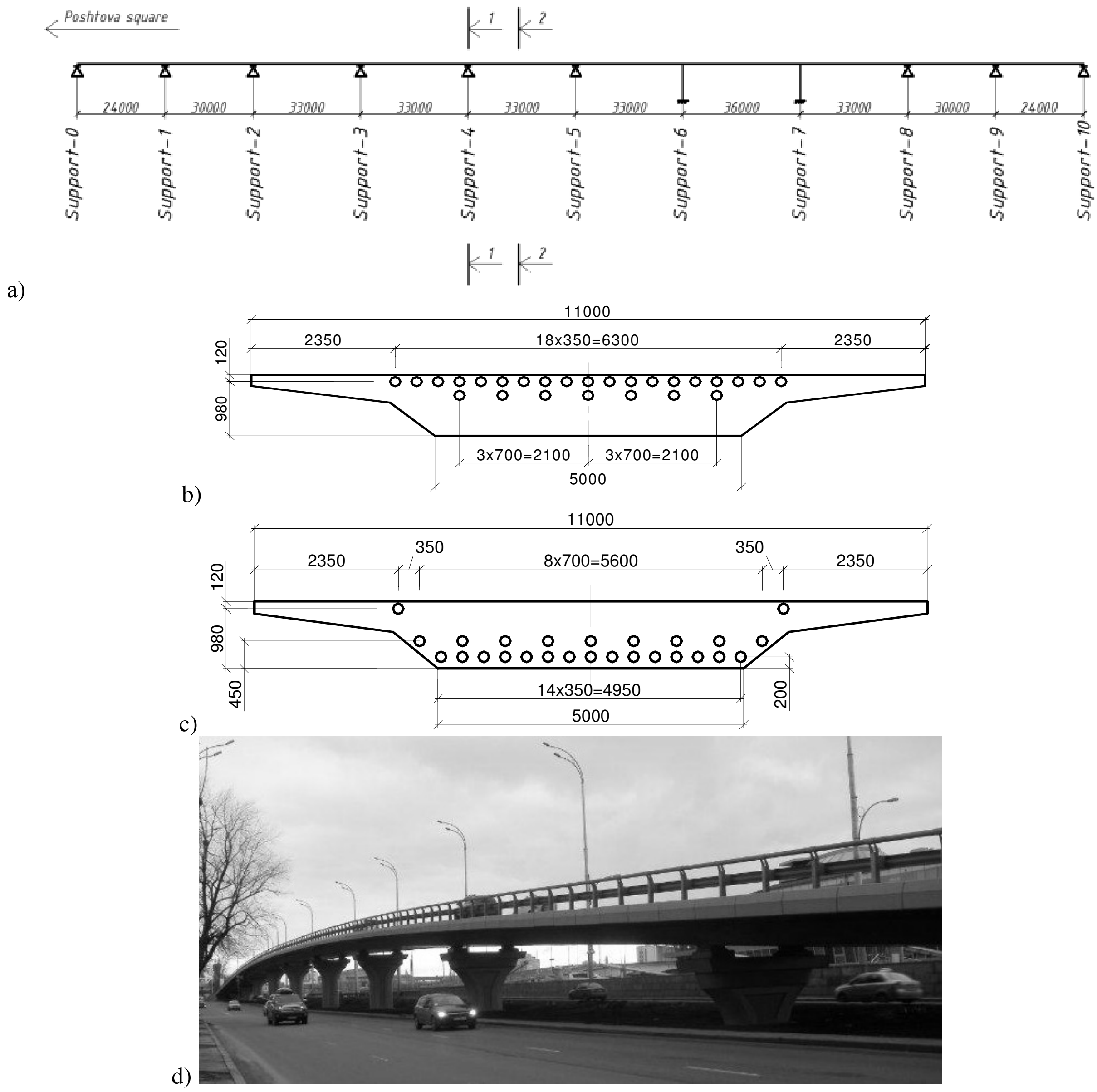


Fig. 1. a) – trestle scheme; b) – cross-section 1-1; c) – cross-section 2-2

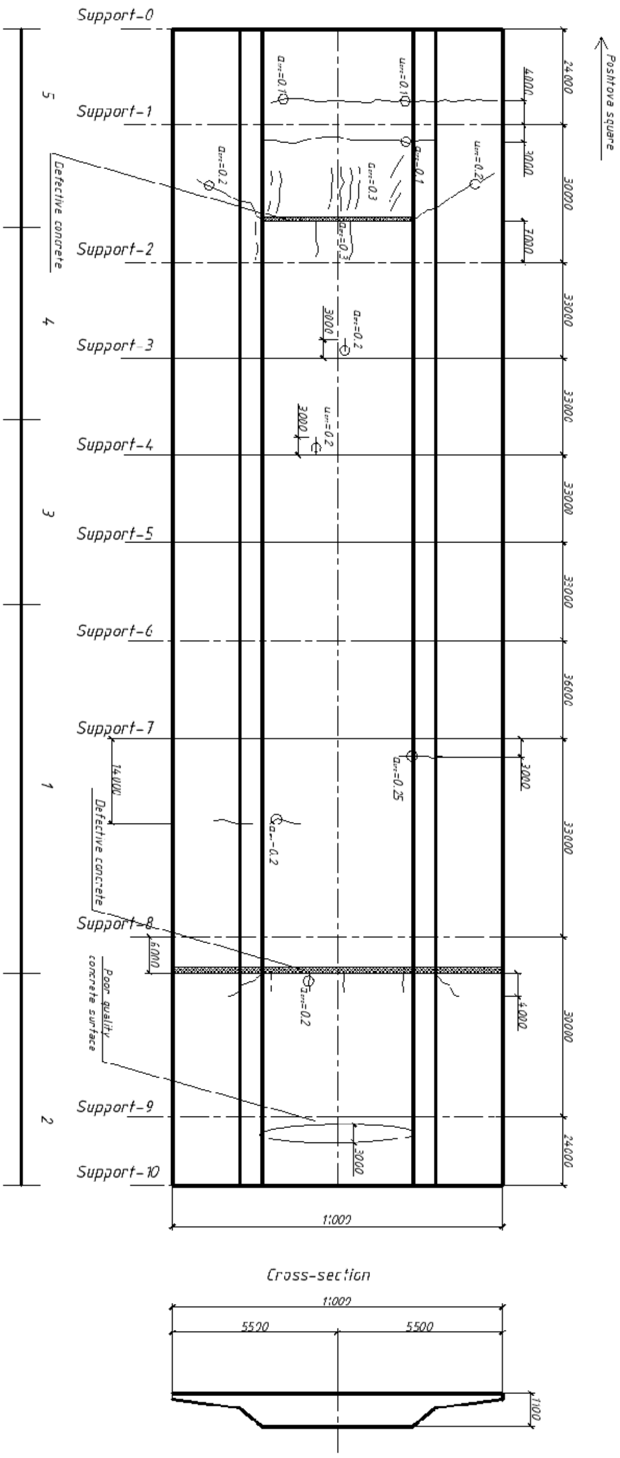


Fig. 2. Defects chart of span structure and its dividing into the section of concreting

– Most local tensions in a concrete at a bent on a concrete occur in the tension transmission zone from an armature through anchors on a concrete (Sytnykov, Ananydze 2009). Their size quickly decreases along the longitudinal axis of span structure. Therefore, to determinate maximal tensions, small spatial elements are examined in the anchor zone on the state of which the anchor action and reinforcing clearly affects. Tensions are passed from anchors (or couplers) through pucks on a concrete. In accordance with (Sytnykov, Ananydze 2009) on the example of consideration of finite elements of the anchor real work model in the reinforced concrete it is shown that there are cracks in the concrete permitted under tension. These cracks are local and arise up only under supporting pucks and are suppressed to the second or third coil of anchor spiral. Trestle project included reinforcement of "butt" anchor zones of sections (fig. 3).

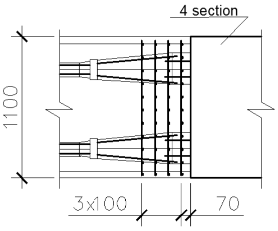


Fig. 3. Additional reinforcing of anchor zone

Due to this reinforce tensions of bent must be fluently passed on the body of span structure.

Methods of research

Analyzing possible reasons of crack formation it is decided to conduct next calculations of monolithic trestle:

1. Nonlinear spatial calculation of spatial production design spans structure in the PC Lira in obedience to the norms of designing (DBN V.2.3.–14:2006, DBN V.1.2–15:2009, DBN V.2.3–22:2009) to identify concrete tensile stresses that exceed the allowable. The created spatial model construction on that is executed by one by one editing of sections of span structure in obedience to project coordinates. On a calculation chart slopes and curve of span structure were simplified. The tension of ropes was occurred by groups between compensative at loading and unloading sections cantilevers. A span structure is divided into 0,5 m long elements. Coordinates of bunches of stressed armature are set according to project documentation in the cuts of sections joints, extra-supporting cuts, middles of spans and specific cuts. The spatial elements of span structure body are set, as the concrete of corresponding class, reinforced by the project coefficient. Anchors and couplers connections of sections are simplified to the area of cut of ropes bunch.

2. To identify tensions of stretching in a concrete and implementation of requirements for crack resistance calculation of cut of span structure on the joint of sections after the boundary conditions were executed in obedience to norms (DBN V.1.2 – 15:2009, DBN V.2.3 – 22:2009) and project documentation in the PC MathCad. The transversal cut of trestle was simplified to t-shaped (fig. 4).

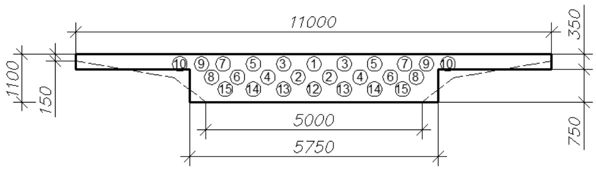


Fig. 4. The cut over of trestle at the beginning of 5th section for a calculation in the PC MathCad

3. Spatial calculation of span structure construction assembling with reinforcing and without it. The different percent of reinforce was taken into account in a butt-end (anchor) zone on the joint of sections 4 and 5 in span of Support – 1–Support – 2. On a linear spatial chart in the PC Lira tension of every pair of ropes with the compensative unloading of cantilever of the 4th section was taken into account. An experience fragment of model is indicated on fig. 5.

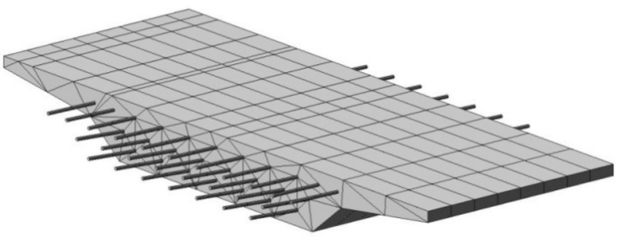


Fig. 5. Experience fragment of model (the 4m of beginning of the 5th section)

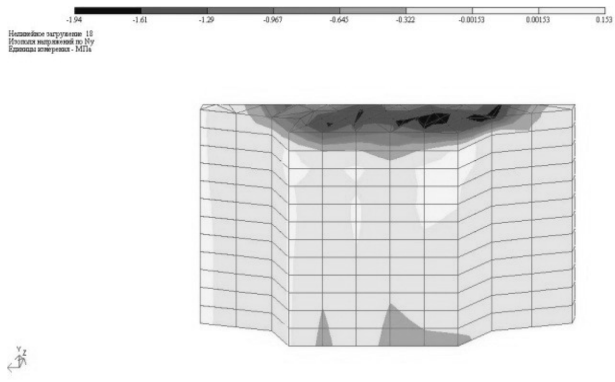
4. For determination of stretching tensions in a concrete as a result of reaction of hydration, that exceed the allowable values during the set of durability in PC MIDAS, there were executed calculations of the thermo stressed state at hardening in the array of concrete of part of span structure (beginning of the 5th section). In obedience to project geometrical sizes array of concrete with supporting connection and formwork has been set. The function of set of durability and function of heating has been set for a concrete. External surfaces have different coefficients of heat transfer (a surface is covered with pellicle, formwork and joint with the 4th section).

Research result

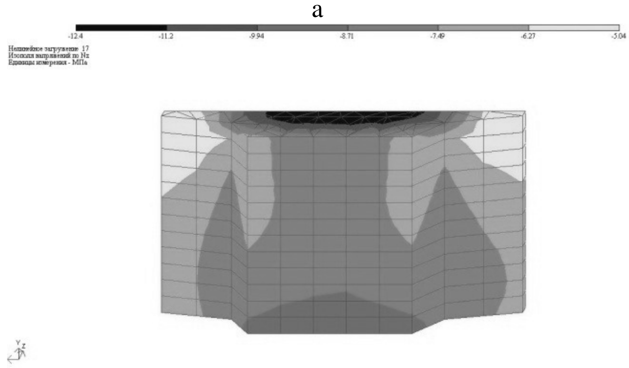
1. According to the fragment of nonlinear spatial model of calculation in the place of formation of cracks (beginning of the 5th section between Support – 1 and Support – 2) stretching maximal effort in the concrete of flag of span structure during the pull of armature of 0,153 MPa (fig. 6). Maximal squeezing effort –1,94 MPa. But tensions do not exceed allowed concordantly (DBN V.2.3. – 14:2006) 0,8 R_{btsr}, that equals 1,28 MPa for this construction.

2. According to results the linear calculation of cut (fig. 6) of the same zone in the PC MathCad, it was set, that at the simultaneous tension of all ropes on the top and the bottom of the trestle cut there are squeezing efforts in a concrete – 2,15 MPa and – 9,37 MPa accordingly, that does not exceed allowed value of R_{bmc1} = 17 MPa (DBN V.2.3. – 14:2006).

3. When calculating without the account of reinforce at the tension of pair of ropes № 4 on the bottom part of model tensions in a concrete arise up more than allowed value of R_{bt} = 1,1 MPa (fig. 7a). At the tension of every next pair of ropes there were new zones with tension in a concrete that exceed allowable.

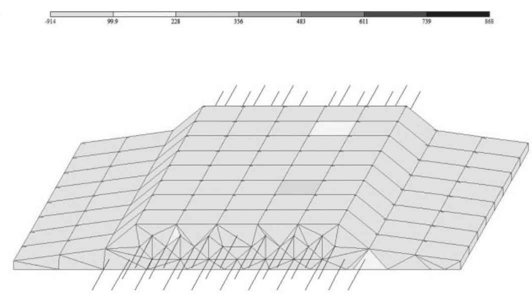


a

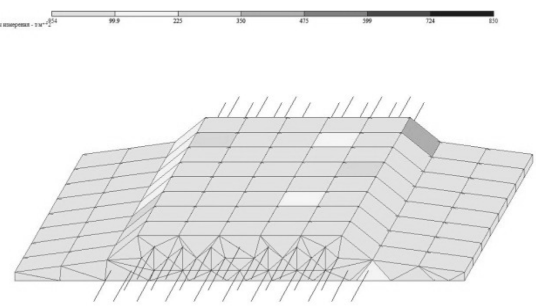


b

Fig. 6. Fragment of calculation model at the beginning of the 5th section of concreting with tensions of concrete: a – on global axis *x* (bottom view); b – on global axis *y*, along the trestle (bottom view)



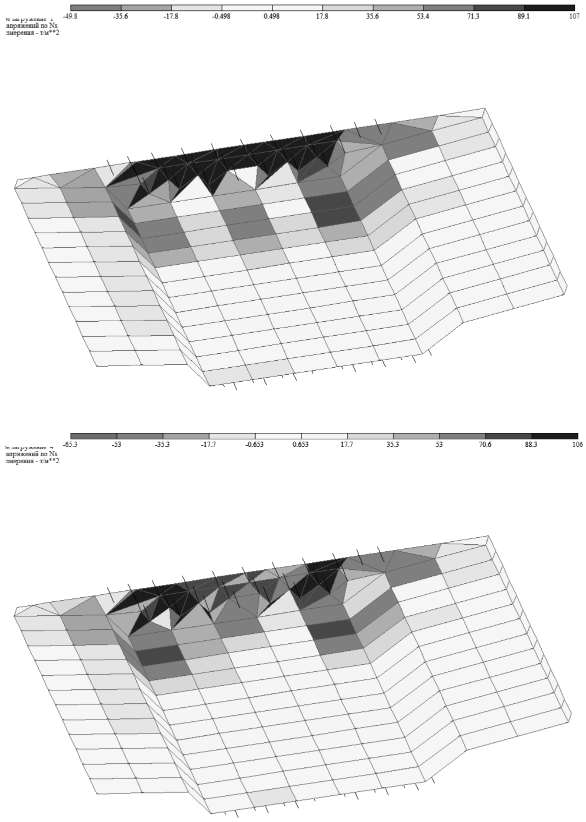
a)



b)

Fig. 7. Tension in a concrete at the pull of pair of ropes: a – № 4, b – № 15

When calculating the joint section with taking into account reinforcing of anchor zone there were no stretching tensions in a concrete, that would exceed values allowed. Maximal stretching were recorded at the pull of the first three pairs of ropes (fig. 8). As a result of those calculations it is possible to select the real required percent of anchor zone reinforcing.



a)

b)

Fig. 8. Tension in a concrete at the pull of pairs of ropes (rice. 5): a – № 1, b – № 2

4. When analyzing obtained data of calculation model in PC MIDAS, it is detected, that tensions, that exceed allowed values on stretching forming by hardening of concrete on the 80th hour (2,12 MPA) in the zones of the formed cracks, indicated on a chart on fig. 2 (fig. 9).

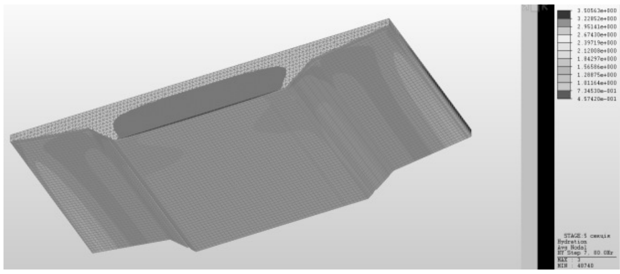


Fig. 9. Temperature tensions on the 80th hour at hardening of butt-end part of span structure of the 5th section on a joint with the 4th one

Conclusions

In the research of the causes of cracks in span deck it was set, that cracks appeared because of tensions as a result of thermal tension in a monolithic concrete that exceed allowed values at hardening.

At planning of monolithic reinforce-concrete constructions it is necessary to calculate not only the maximum states during exploitation and installation of construction, but also the thermo-stressed state at hardening of concrete at building. If necessary, it is needed to take measures to regulate the temperature in the array of concrete by technological or chemical methods.

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