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HOGGING REGION BEHAVIOUR OF CONTINUOUS COMPOSITE GIRDER

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Summary: *Experimental verifications of flexural behaviour of a composite steel-concrete girder-bridge are presented. The subject of a study is especially a modification of stiffness of continuous superstructure above piers. The comparison of experimentally obtained values with theoretical results is given in the paper. For the global analysis, numerical models based on FEM were applied. The concepts of simplified modelling of the concrete part in the regions of hogging moments, where the slab is influenced by effects as concrete cracking, tension stiffening and reinforcement yielding is investigated in the paper.*

Keywords: *experimental testing, composite structure, deck in hogging region*

1. INTRODUCTION

Real behaviour of a composite steel-concrete structure has been principal topic of our research, whose partial results are presented in this paper. Especially, the hogging moment region of deck slab influenced by concrete cracking, tension stiffening and reinforcement yielding has been investigated in the previous investigation, based on bridge-site experimental measurement, theoretical results [1] and laboratory testing [2]. Appropriate approaches could outcome from the research, able to take into account by linear analysis reduced stiffness of concrete slab due to concrete cracking, as conclusion also in the paper.

2. EXPERIMENTAL STUDY ON BRIDGE STRUCTURE

Composite steel bridge [3], whose roadway deck is supported on two girders and slim piers, carries roadway, 8.5 m wide between barriers and the total deck width is 9.5 meters. After consideration of the technical and architectural aspects, it was decided that the bridge structural system would consist of a total of four spans with lengths in the

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bridge longitudinal axe 18 + 22 + 22 + 18 metres. But these values varies in the centre-line of main girders due to rather complex road alignment (Fig.1). The left side main girder has theoretical spans 20.295 + 21.980 + 22.016 + 16.155 m, while in the case of right girders the corresponding values are 15.647 + 22.055 + 22.005 + 19.812 m.

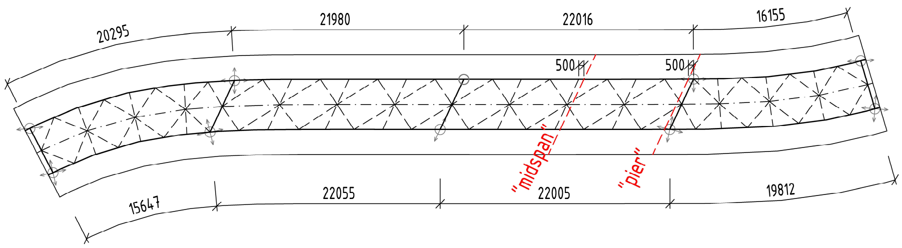

Figure 1. Concept of four span continuous composite bridges

Thus, this composite superstructure defines the two-lane overcrossing of its whole 103 metres length (Fig.2). A typical bridge cross-section consisting of the concrete slab and only two built-up plate girder of I-section axially 4.80 m spaced is illustrated in Fig.3. The steel plate composite girders were selected for the bridge having the slender 20 mm thick web and variable depth from 0.82 to 1.10m with parabolic haunches over piers. The inconstant area of flanges was used to save material where the bending moment would be smaller or larger in a span. Especially, the top flanges that act with the concrete slab are of the constant 400 mm width and proportioned by varying thickness from 20 to 40 mm. For increasing the flexural strength of cross-sections, the bottom flanges are 40 mm thick, and vary in the width from 650 to 75 mm.

Figure 2. Concept of four span continuous composite bridges

Low-alloy structural carbon steel S355J2 has been used for steel bridge structural parts. Cross frames consisting of rectangular hollow diagonals and horizontal channels and acting as a truss provide lateral stability of the girder bridge and distribute vertical loads. End cross frames and diaphragms at piers and abutment are provided to transmit lateral loads to the bearing. Reinforce concrete with 28-days compressive strength 35 $N.mm^{-2}$ was used in slab, 330 mm thick reducing to 300 mm at girders and next to 200mm at its cantilever edge. Shear stud connectors Ø 19/150 from steel grade S235J2 at the interface between the concrete slab and structural steel should ensure a full composite action.
The extra field measurements have been executed in centre of the third span and at the adjacent pier bridge cross-section. For this purpose, six strain gauges (indicated from 1s to 6s) were used as presented in Fig. 3 to register stress distributio in the steel girders at the pier area. Five wire strain gauges (specifid from 1c to 6c) were also encased in the deck to record streesses in the concrete as well as two strain gauges (1r,2r) located on reinforcement bars before slab casting. The stresses in the mid-center span section were recorded using four strain gauges (7s,8s) put at the bottom flanges. The monitorimg of stress progress started the day after the final phase of deck concreting and still continues.The results examined in the paper correspomd to period of 281 days after concrete casting.

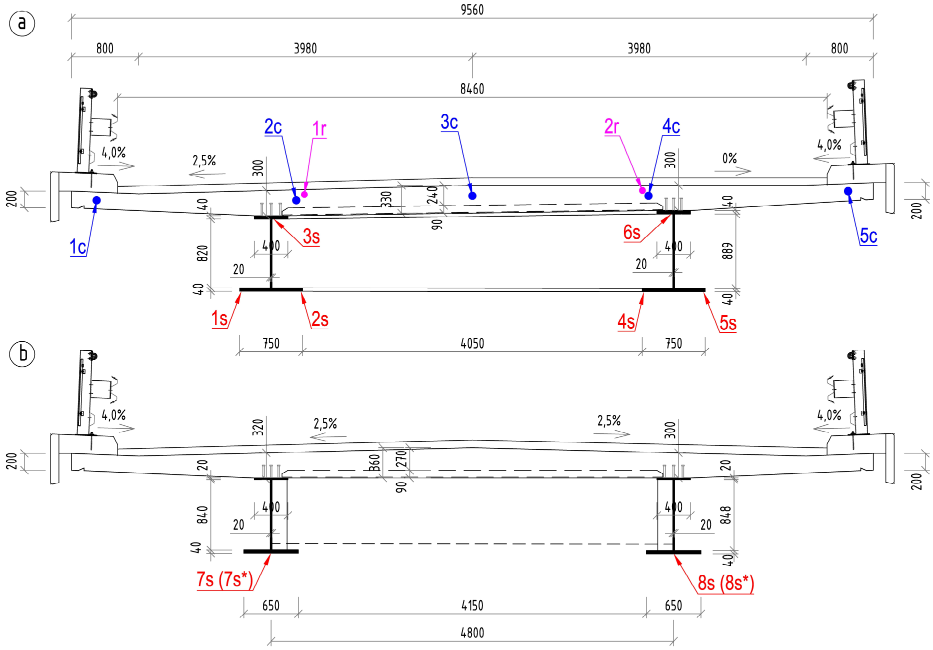

Figure 3. Strain gauge position at support and in the middle of the 3rd span

Applied test load should produce deformation and internal forces large enough to satisfy given criteria of relevant codes, e.g. STN 73 6209 [4]. Generally, an efficiency relation η is specified, as a ration between elastic experimental values S_e of any observed parameter activated by testing loading and calculated values S_{cal} produced by code ideal load scheme $\eta = S_e/S_{cal.}$ In the case of this bridge structure, the four trucks weighty 42.8 tons (Fig.4), as testing load were imposed in the third largest span for achieving a deflection S_e = 14.4 mm and corresponding $\eta = 0.87$. In the forth span this four tracks configuration LC4 has produced deflection S_e = 11.8 mm and $\eta = 0.75$.

3. TRANSFORMATION MODEL

Curvature and real direction of bearing displacement had to be appropriately implemented into the model. The concrete deck was approximated with shell finite elements. Several different thicknesses of elements were adopted for better account of variable deck. Steel girders and cross truss beams as well as support diaphragms were meshed by member elements, including real eccentricities from bridge slab. The truss bracings were considered also as beam elements respecting their characteristics including corresponding eccentricities. As precaste concrete slabs were used as the deck formwork, orthotropy was introduced to the deck elements in the relevant areas by two different heights in the orthogonal directions.

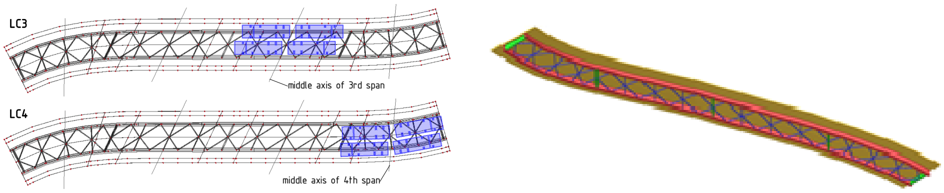

Figure 4. Testing load configuration, bridge finite element modelling

In continuous composite beams, the extent of the hogging moment region at the internal supports depends on the conditions of loading. Three concepts of simplified modelling of the concrete deck in the regions of hogging moments were used. Firstly, the *uncracked* elastic global analysis takes into account unchanging deck area in hogging region, despite the fact that concrete is subject to cracking for a number of reasons, including direct loading and shrinkage. Alternatively, the *cracked* elastic global analysis was made using the cracked cross-section over 15% of the span on each side of internal support, as given in EC 4 [5] and keeping the uncracked cross-section elsewhere. The deck stiffness was determined by neglecting the concrete in tension but considering reinforcement on the support. The fixed ratio hypothesis for the cracked length greatly facilitates the analysis as it avoids any iterative methods to determine this length. Lastly, the slab stiffness can be supposed deteriorated simply in the deck axial behaviour. Thus only longitudinal reinforcement was taken into account and the concrete in tension ignored. At the same time, the transversal flexural stiffness of slab remained unaffected. The results provided by this analysis are specified as *reduced* ones.

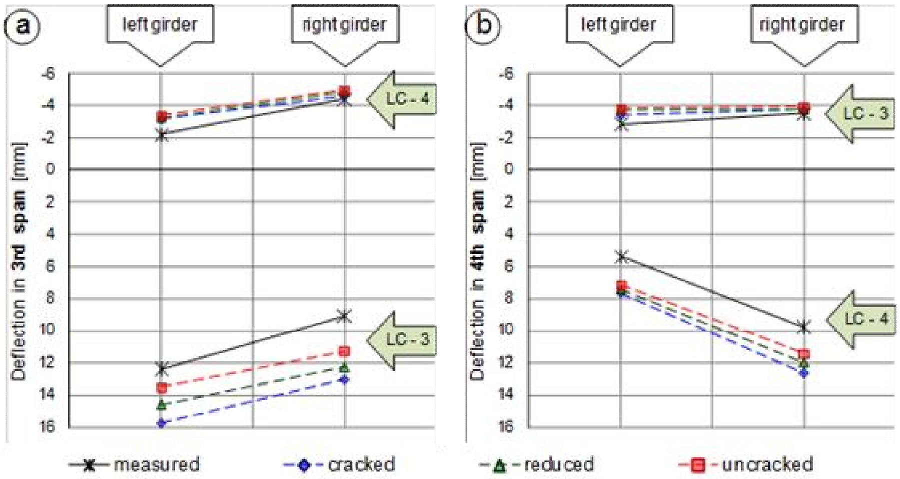

Figure 5. Mid-span deflections in the third and fourth spans

The deflection values in the bridge mid-spans indicate that *uncracked* numerical model, considering constant concrete effective area of the deck could provide results closer to the measured values (Fig.5). The investigation confirmed evidence that, when transverse reinforcement appropriate to the shear connector spacing is provided, even the cracked slab may be able to transfer shear to longitudinal reinforcement at a distance of several slab thicknesses on either side of the steel girders. This uncracked method gives sufficiently accurate results. However, reverse mid-span deflections of the adjacent unloaded spans could be found more closely to tested values, vhen considering certain decrease of concrete stiffness above the intermediate support. But the differences can be seen as insignificant.

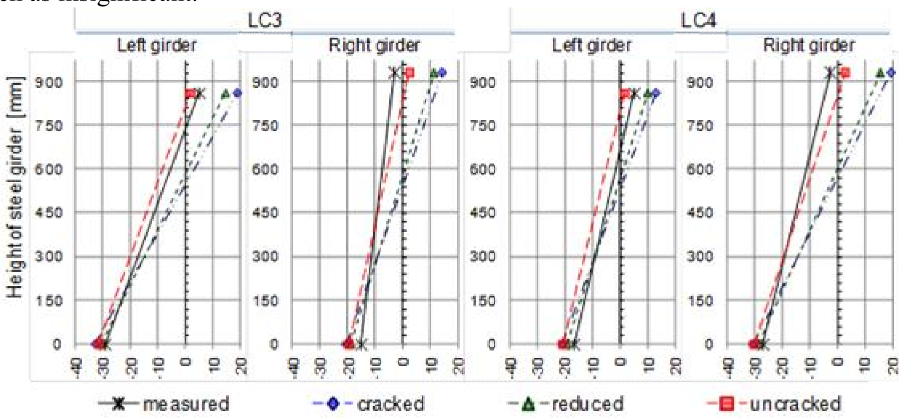

Figure 6. Stresses distribution through the steel girder cross-section at the pier

The stress distributions testify, too, that *uncracked* numerical model, considering constant concrete effective area of the deck could reproduce suitably a real flexural bridge behaviour (Fig.6).

4. CONCLUSIONS

Experimental and theoretical values of strains and stresses over the cross-section above the intermediate support confirm that concrete cracking in the hogging area influence insignificantly the slab stiffness. The reinforce concrete deck can transfer further tensile forces. Approximation of composite bridges by spatial model, even in the case of skew supports and complex arrangement can provide actual structural behaviour. Morever, the uncracked analysis with the constant stiffness of the reinforce bridge deck may be introduced in this analysis. Morever, the flexural behaviour of the structure can be influenced by bridge equipment and non-structural parts, ignored in the analyses. In this way, minor result differences can be explained.

Acknowledgments

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REFERENCES

[1] Bujňák J, Odrobiňák J. “On design of composite beams with concrete cracking”, COST C12 Final Conference Proceedings (Pub.: A.A. Balkema Publishers), Innsbruck, Austria, 441-446, **2005**.
[2] Bujňák, J, Odrobiňák, J.: Theoretical and experimental study of bridge superstructures of special conception.Proceedings of the conference „EUROSTEEL 2014, September 10-12, **2014**, Naples, Italy
[3] Bujňák, J, Odrobiňák, J.: Report from proof load test: The bridge SO 218-00 in km 9,060 over the highway D1 Dubná skala - Turany”, University of Žilina, Slovakia, **2014**
[4] Slovak Technical Standard - STN 73 6209.: Proof load tests of bridge, SUTN Bratislava, **1993.**
[5] Eurocode 4: Design of composite steel and concrete structures. Part 2: General rules and rules for bridges. Brussels, CEN; **2005**.
[6] Eurocode 1: Actions on structures - Part 2: Traffic loads on bridges, CEN; **2003**.

ПОНАШАЊЕ ЗОНА СА НЕГАТИВНИМ МОМЕНТОМ САВИЈАЊА КОД КОНТИНУАЛНИХ КОМПОЗИТНИХ ГРЕДА

Резиме: *Приказана је експериментална верификација понашања композитне челично-бетонске греде при савијању. У раду је нагласак на модификацији крутости континуалног горњег строја изнад стубова. Извршено је поређење експерименталних резултата са теоријским вредностима. Глобална анализа је обезбеђена применом нумеричког модела заснованог на МКЕ. У раду се изучава поједностављено моделисање бетона у областима негативних момената савијања где је плоча под утицајем ефеката појаве прслина у бетону, прерасподеле напона и граничне носивости арматуре.*

Кључне речи: *експериментално испитивање, композитне конструкције, плоча у зони са негативним моментом савијања*