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THE COMPOSITE SECTION ANALYSIS OF ENCASED BEAMS WITH CLOSED SHAPE

Plate bridges with encased beams are suitable for building bridges of a short and medium range. They have many advantages such as a low construction height, a clear static operation and a short execution time without the supporting scaffold. Their disadvantages are unthrift steel I sections used in most of the bridges of this type. Therefore, it is necessary to develop more appropriate design processes, a more efficient layout and use of steel beams. This paper presents experimentally validated composite steel and concrete beams using a modified form of the closed section steel with static load tests.

Key words: composite beam, encased hollow sections .

Плитні мости з замонолiченими жорсткими балками придатні для зведення малих та середніх по довжині мостів. Вони мають багато переваг, таких як мала будівельна висота, проста статична робота і швидке зведення без додаткових риштувань. Недоліком є неефективне використання сталі у двотаврових балках, що найчастіше використовується у мостах цього типу. Тому необхідно розробити кращу методику проектування, ефективнішого використання сталевих балок. Подано результати випробувань композитних балок з бетону та сталевого модифікованого замкнутого профілю при статичному навантаженні.

Ключові слова: композитна балка, балки з жорсткою арматурою замкнутого профілю.

Introduction

A structural layout of the bridge plate with filler beams buried in concrete didn´t change very significantly from the beginning of their use. Nowadays, the design and assessment method is used to limit states. Standardized requirements for composite bridges are given in Eurocode 4, Part 2: General rules and rules for bridges. This standard allows for the assessment of plasticity in the ultimate limit state. It also allows the bridge plate to be used as I beams – section. Taking into consideration these bridges showed that the use of steel is ineffective. The top flange of the beam is close to the neutral axis, and thus its contribution to the bending resistance is minimal. It serves only to ensure the coupling. The research at the Faculty of Civil Engineering TUKE is aimed on the deck bridge encased beams that would reduce the steel consumption while maintaining the same bending strength and stiffness. Carried out static tests showed that the T beams – sections are able to meet these requirements. The results suggest that special attention should be paid to the way of coupling, which may be for the use of alternative critical beams. Using beams T – sections may be up to 40% saving their steel. Plate bridges with such beams can make only as pre-cemented parts, which are then put up on the bearings [2,3].

Closed steel profile

Experimental tests were performed on composite steel-concrete beams with rigid steel reinforcement. N1 beams are made up of concreted steel sections with closed shape. The closed section was created by 6 mm thick welding sheet bent into a U shape that creates the top flange and the wall section to the lower flange of the overhanging ends. In the walls there are burned holes with a diameter of 50 mm in the axial length of 100 mm. Every third hole is dressed by concrete reinforcing bars with a diameter of 12 mm. The top flange is just made of burned holes with a diameter of 50 mm in the axial length of 100 mm. The holes are arranged so that in each section there are only holes in the walls or just in the flange. The cross and longitudinal section of the beam is N1 in Figure 1.

Samples were cemented in the laboratory of the Institute of Civil Engineering Faculty of the Technical University in Kosice. Steel formwork placed on a support beam ensured a coupled deflection during casting. Concrete reinforcement and steel beams in the desired shape and size were supplied by specialized companies. The actual values of material characteristics of the steel were determined from the stress-strain diagrams obtained by tensile tests. Three equivalent tensile tests were performed for a given type of steel beam. Subsequently there were determined their average values, which are considered as being nominal to calculate theoretical ultimate loads and evaluation of test results[1].

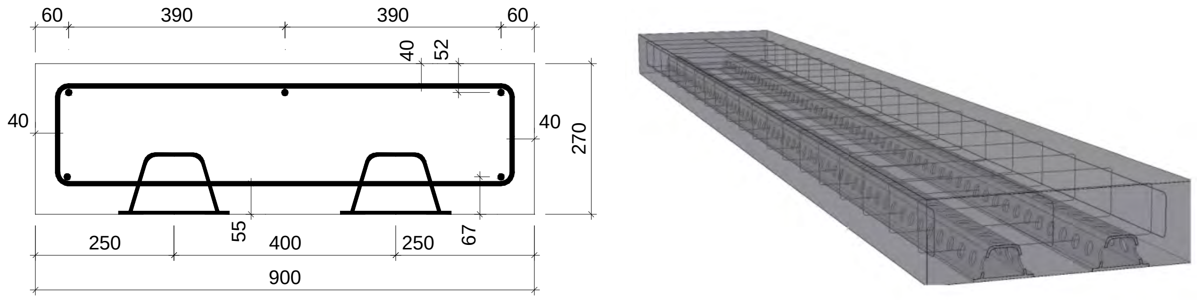

Fig. 1. Size and shape of beam N1

Table 1

Tensile test results of structural steel

Test No.	f_y [MPa]	$f_{y, priem}$ [MPa]	f_u [MPa]	$f_{u,priem}$ [MPa]	A [%]
1	317	315,3	397	396,0	41,7
3	313		397		41,7
4	316		394		40,0

Tensile tests of three samples determined the average yield strength of structural steel f_y = 315,3 MPa. Concrete was brought from the central mixing plant. Three pieces and samples for strength testing of concrete were produced. It was necessary to verify the actual compressive strength of concrete. That strength test was a part of the certificate from the supplier. Simultaneously, there were conducted cylinder and cube strength tests separately for each batch of concrete. Tests of concrete compressive strength were realized in the timeframe t = 28 days and then on the date of the test. The selected measured values are shown in Table 2.

Table 2

Compressive strength of concrete

Cube strength			
Test No.	**Weight [kg]**	**Max. load [kN]**	**$f_{ck,max}$ [MPa]**
1	7,726	870	38,76
3	7,636	895	40,06
4	7,608	900	40,35
Average			**39,72**

Cylindrical strength			
Test No.	**Weight [kg]**	**Max. load [kN]**	**$f_{ck,max}$ [MPa]**
1	11,18	680	32,78
3	10,91	685	31,55
4	10,75	670	32,18
Average			**32,17**

At the time of testing concrete compressive strength f_c = 32,17 Mpa was found out by the test of concrete compressive strength for cylindrical samples. Yield strength of reinforcement was considered by tabulated values f_{sk} = 490 MPa.

Experimental measurement

While casting the samples were placed on a support beam, because the zero state corresponded to the dead load. Size moment from the self-weight was Mg = 27,33 kNm. A load test of the sample was by two vertical forces distant from the edge of 2000 mm, the axial distance between the forces was 1800 mm and the free end was extended for support of 100 mm.

Samples were symmetrically loaded by spaced hydraulic presses so that the section between presses created a pure bending. Zero load condition corresponded to self-weight of beams. Another loading procedure was carried out stepwise with increasing pressure in hydraulic presses of 10 bars, corresponding to about 15 kN. Samples were twice lightweight.

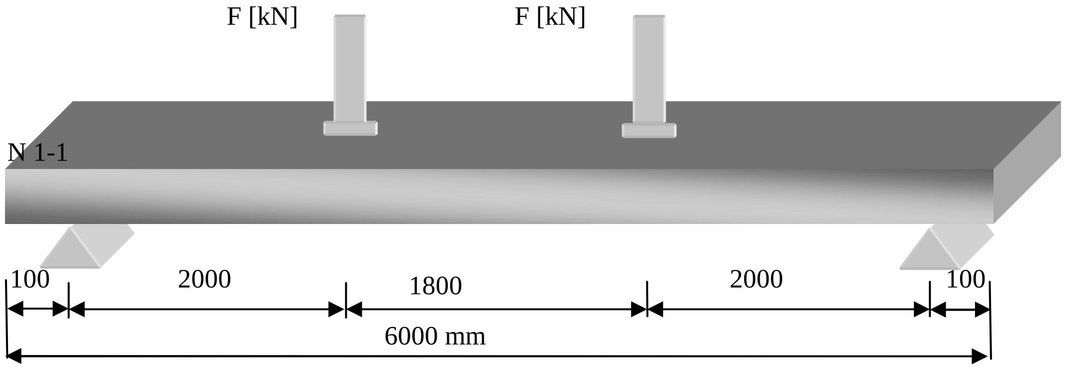

Fig. 2. Static scheme supported beam

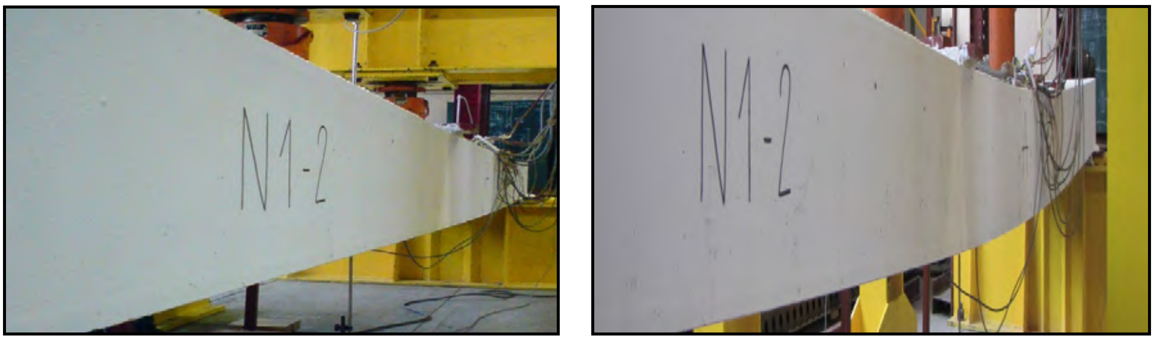

Fig. 3. Samples at the beginning and end of the test

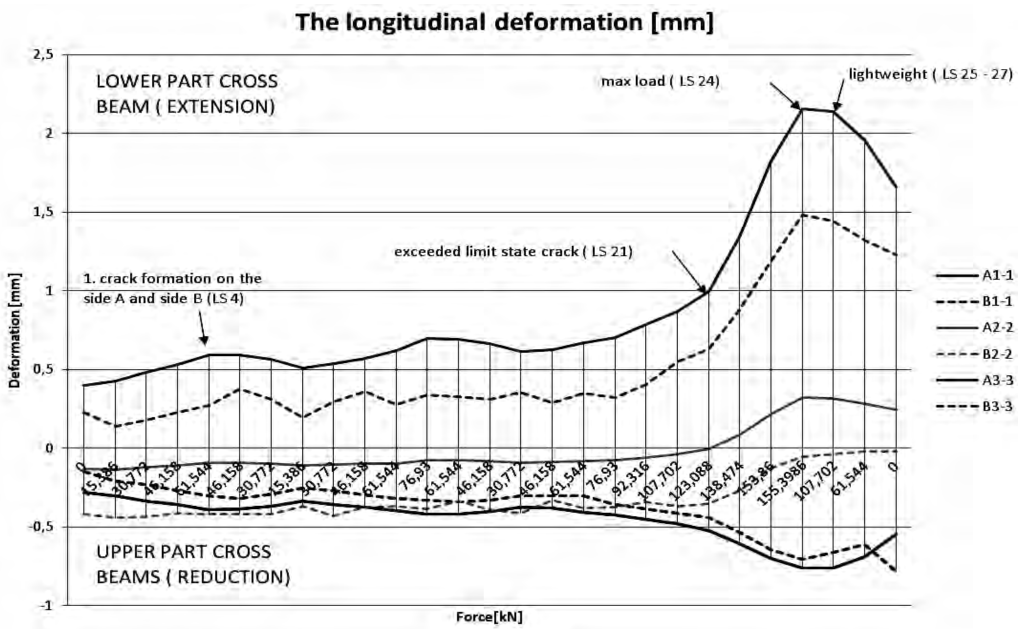

Fig. 4. Graph of longitudinal deformation and strength during loading

When loading above the tensile strength of the concrete, crack branching began to emerge in the towed concrete. These cracks were propagated and increased their magnification to reach a length of about 230 mm, which is the estimated position of plastic neutral axis. The tests were completed when it was not possible to increase the load transmitted by the samples. There was a significant widening of deflection without increasing the load. Dependence of longitudinal concrete strains on the size of load is plotted in the graph in Figure 4. On this chart there is a readable break in which a limit of state crack was exceeded and also the culmination of the load at its maximum value and the subsequent lightweight.

Table 3 shows the maximum power of presses F_{exp} in which the samples were loaded on completion of the tests, and also torques M_{exp} corresponding to the maximum load and the resulting average torque of resistance $M_{exp,priem}$ detected by the experimental test. The resulting torque is the percentage compared with numerical calculations.

Table 3

The test result

Sample	F_{exp} (kN)	M_{exp} (kNm)	$M_{teoret.}$ (kNm)	difference %	$M_{exp,priem}$ (kNm)	$M_{teoret,priem.}$ (kNm)	difference %
N1-1	154,0	335,33	317,48	+5,62 %	339,37	318,69	+6,48%
N1-2	155,5	338,33	318,71	+6,16 %			
N1-3	158,5	344,44	319,88	+7,68%			

During the tests relative deformations of steel were measured and recorded by strain gauges. Strain gauges were placed at the locations of highest stress bending and around openings. Inductive sensors captured the deflection at a mid-span and decrease of the supports. Dependence of strain composite beams on the size of the load is plotted in the graph in Figure 5.

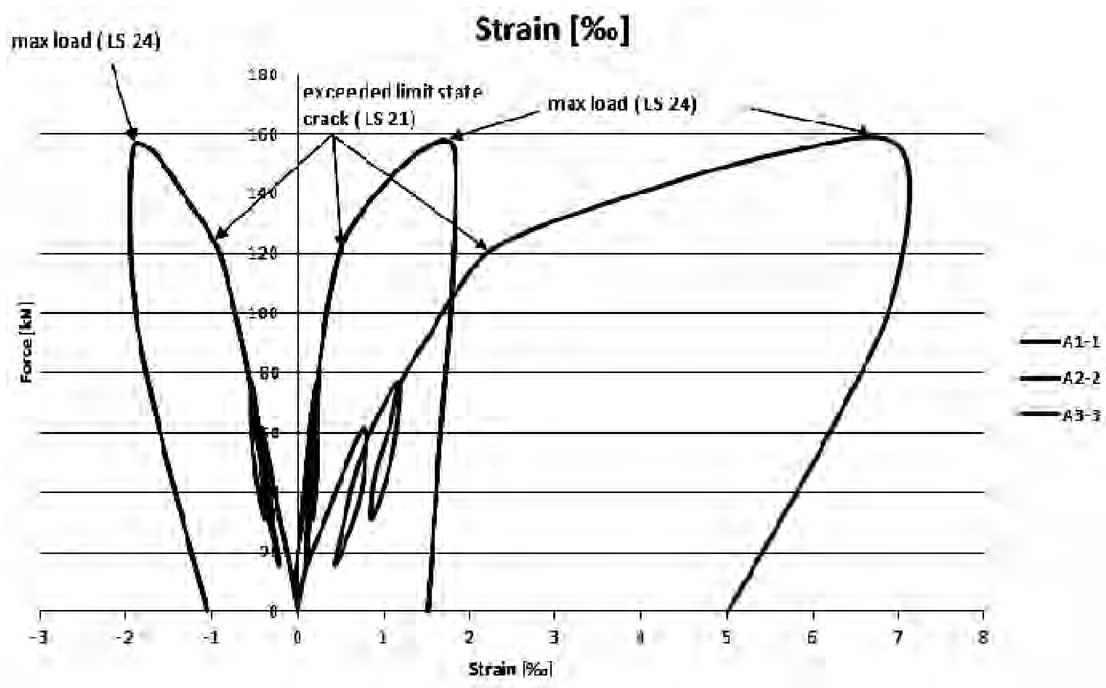

Fig. 5. Graphical dependence of strain and force during loading

When loaded with 60kN and 80kN the beam was lightweight, and even without any external beam load, a significant permanent deformation remained on the beam. The break, when exceeding a limit state of cracking in the concrete section, is clearly shown on the chart.

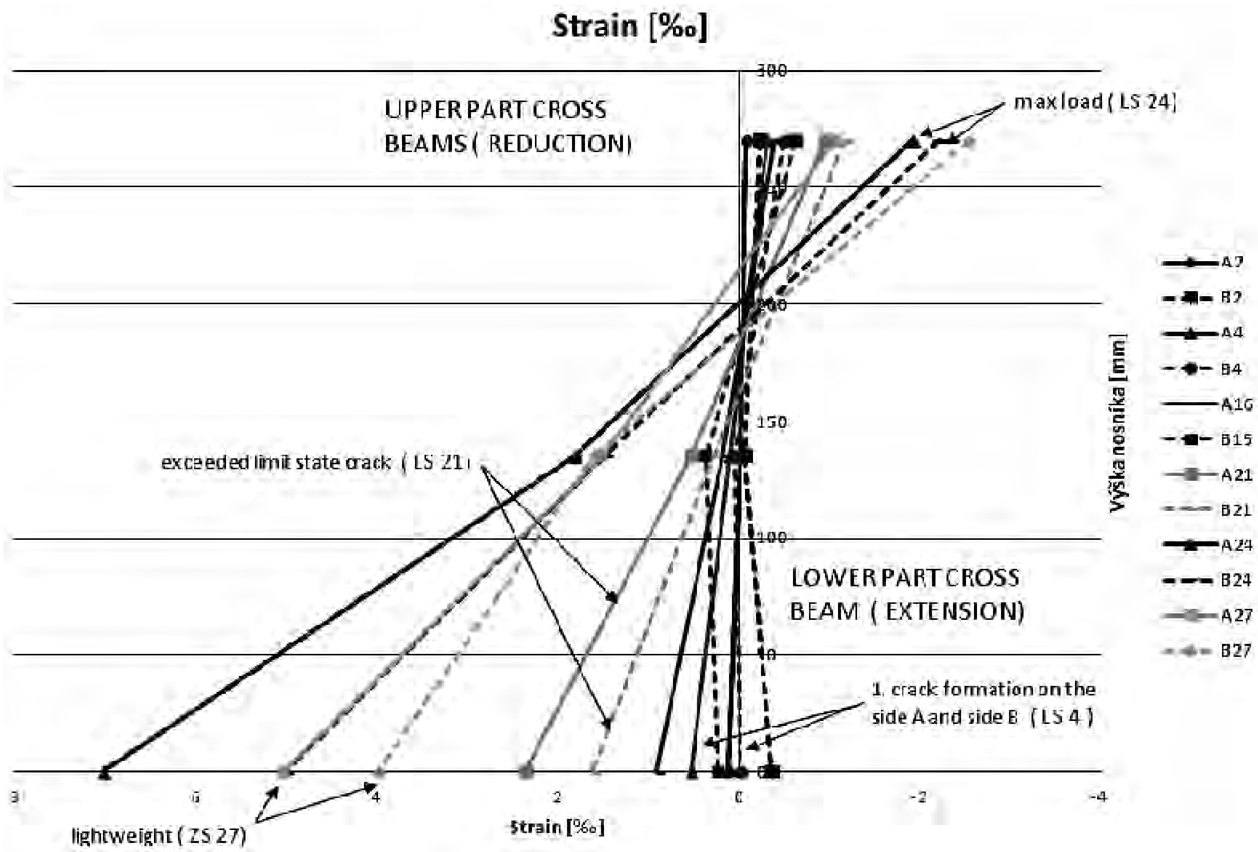

Fig. 6. Graphical representation of strain during the height of the beam

Conclusion

The paper presents the measured values of longitudinal deformation and strain of the tested beam with gradual change of load. The individual load cases represent an additional load or lightweight of the samples during the experimental tests. When unloading, there was recorded a permanent deflection which was due to changes in bending stiffness after cracking in concrete.

Acknowledgements

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