Topic: Limit states of hybrid steel-concrete structures with external reinforcement

Keywords: composite structures, hybrid structure, composite, composite dowel, shear resistance, Strut-and-Tie model, composite bridges, hybrid bridges

Summary:

Elements with a hybrid cross-section using the CD are more and more often used in designed structures. Within the shear design methods used so far, some conservative simplifications have been introduced. Depending on the geometry of the cross-section, the contribution of the steel or reinforced concrete part in transferring the transverse force was omitted. However, this approach has significant limitations and does not give full freedom in shaping the cross-section geometry. In the face of this, there was a need to formulate an universal shear design method. Therefore, in recent years, the theoretical foundations of the general shear design method have been formulated.

As part of this dissertation, the assumptions of the general method were verified, supported by literature recognition, numerical analysis and destructive tests of beams with a hybrid cross-section.

The preliminary tests of the beam with external reinforcement (SRCD-1) confirmed the development of the ST mechanism in the beam with a small share of the steel part in the section height. Due to the fact that it was an extreme case of a hybrid section, a basic research program was prepared on the basis of the obtained results.

Numerical analysis were started with edge-loaded sectional models of reinforced concrete slabs to verify the influence of selected effects on the failure mechanisms of reinforcing steel and concrete. On the basis of these analysis and the results of preliminary tests, models of beams for testing were prepared. The results of the conducted analysis confirmed the development of the theoretical mechanism of cooperation between the reinforced concrete and steel parts of the cross-section, assumed in the general method. The convergence of the value of the lateral shear force in shear connection determined on the basis of the aforementioned method with the forces obtained in the models was also confirmed. In addition, the influence of the position and stiffness of the shear connection on the values of forces and deflection of the beams was analysed. All the models mentioned above were made in the SOFiSTiK program.

Two beams (S1-200, S2-300) were used for the main tests, in which the height of the steel and reinforced concrete parts were comparable. The aim of the tests was to demonstrate

the appearance of the ST mechanism also for the high steel web used and to verify the value of the angle of inclination of the concrete struts. According to the rules of the general method, the inclination angle θ should decrease in relation to the beam with external reinforcement (SRCD-1). Vertical displacements of beams, slippage between steel and concrete, horizontal separation between steel and parts of concrete web and strains in reinforcing steel, structural steel and the surface of the reinforced concrete flange were measured. For both tested beams (S1-200, S2-300) lower values of the struts inclination angle θ were observed than for the SRCD-1 beam, confirming the formulated thesis. This was also confirmed by the results from the numerical models of the beams. On the basis of the obtained results of the slip in the composite, calibration and validation of the computational models were carried out, obtaining a satisfactory convergence of the results.

In addition to verify the assumptions of the general method, the results of the conducted tests indicate that the two types of stirrups used as reinforcement of the connector and passing below the dowel cooperate in transferring the transverse force in the cross-section. Destructive tests also indicate that the thickness of the web and the location of the connection in the tension or compression zone significantly affect its stiffness and load capacity. Both the results from the models and the tested elements indicate a significant impact of the stiffness of the connection and shear deformations on the deflections of the tested beams.

At the end of the doctoral dissertation, conclusions were presented that confirm the correctness of the assumptions of the general shear design method, both in terms of the shear transfer mechanism and the value of the lateral shear force determined on the basis of the lever arm of internal forces. The analysis and tests carried out confirm the possibility of using the above-mentioned method in the dimensioning of real structures using hybrid cross-sections.