Numerical analyses and laboratory testing of concrete composite T-shaped beams without interface adhesion

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Abstract

Laboratory tests of concrete composite concrete T-shaped beams with variously arranged interface were performed. In the particular series the interface between concrete parts was reinforced or non-reinforced. Additionally the interface conditions varied as follows: adhesion existence, adhesion partly broken by chemical agent and lack of adhesion due to PVE membrane put in the interface. The paper presents the compiled results of all tests and the first stage of FEM analysis concerning the series of beams, where the adhesion was broken. Results of analysis are compared with the crack pattern observed during testing.

Keywords: concrete composite beams, T-shaped beams, adhesion, FEM analysis

1. Introduction

Two concrete parts are joint into one member in order to obtain *quasi-monolithic* structure of higher bearing capacity in comparison to bearing capacity of separate parts. It is possible only if the interface is properly arranged. Therefore the recognition of stress-strain characteristics of interface (crack resistance, bearing capacity and stiffness in relation to shear stress) should be done. The problem of concrete composite members of rectangular cross-section was the subject of quite a lot research, whereas T-shaped composite beams were analyzed in several papers, including the author's papers e.g. [2,3]. The last work presents the tests of beams with variously located interface.

In this paper the tests of T-shaped beams with variously arranged interface located between web and flange are reported . The compiled results of all tests and the first stage of FEM analysis concerning the series of beams, where the adhesion was broken, are presented. Results of analysis are compared with the crack pattern observed during testing.

2. Examination of T-shaped composite beams

2.1. Tested members

Five series of T-shaped composite beams were tested (Fig.1). The beams were designed to be damaged in the support zones. The procedure of beam production was divided into two stages. First, the concrete mix forming the web was placed in the mould. Next, after 14 days of concrete curing, the mould was completed with a layer of 'new' concrete after treatment of "old" concrete surface (moisturizing and roughening with wire brushes). The interface was variously arranged in particular series as follows:

- BZ/P+S – reinforced interface (ρ_i=0.21%) with adhesion,
- BZ/P – non-reinforced interface with adhesion,
- BZ/S1 – in reinforced interface (ρ_i=0.21%) the surface of „old" concrete was treated by chemical agent in order to limit the adhesion,
- BZ/S2 - in reinforced interface (series BZ/S2/A ρ_i=0.21%, series BZ/S2/B ρ_i=0.42%) the adhesion was entirely broken with utilization of PVE membrane.

The beams were tested as simply supported. In order to ensure stability, the beams were inverted upside down and the load was applied using a rigid traverse.

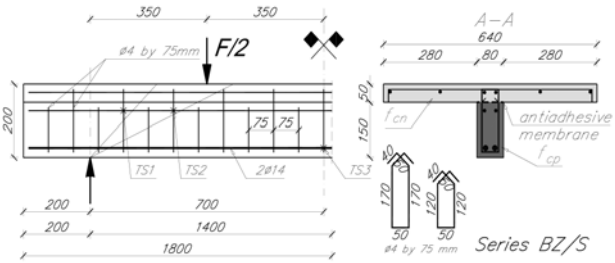


Figure 1: Details of tested beams: a) longitudinal section, b) cross-sections; TS1,TS2– strain gauges on the stirrups, TS3 – strain gauges on the main bar

2.2. Results

The test results are presented in Table 1. The crack pattern was different in particular series, although in all beams the perpendicular cracks appeared in the span middle first. Next the diagonal cracks appeared. After they reach the interface:

- in BZ/P+S beams the local crack in the interface was observed, then the crack propagated into the flange,
- in BZ/P beams (without reinforcement) the rapid delamination in entire interface took place.

In BZ/S1, BZ/S2/A and BZ/S2/B beams (limited or broken adhesion) cracks in the interface were observed since the beginning of loading. They propagated from the end of beam and joined the transverse cracks after they reach the interface. The deflections of BZ/S1 and BZ/S2 series were similar, but the ultimate load of BZ/S1 beams were higher. In "B" type of BZ/S2 beams there were more of perpendicular cracks.

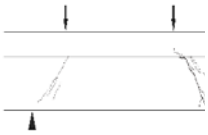
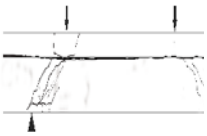
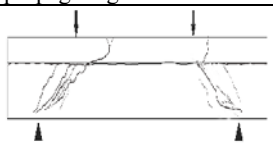
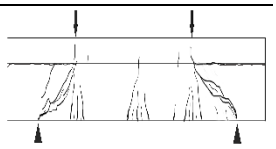
The load of	BZ/P+S	BZ/P	BZ/S1	BZ/S2/A	BZ/S2/B
mode of failure	shear	delamination	shear and interface cracking propagating from beam end		shear and bending
					
failure	136.0 149.0 142.0	136.0 149.0 142.0	143.2 137.5 127.3	126.0 112.0 113.0	138.0 138.0 134.0
first diagonal crack	no data 60.0 60.0	50.0 50.0 57.0	50.0 50.0 50.0	50.0 50.0 40.0	no data 70.0 50.0
interface crack	no data 70.0 70.0	78.0 72.0 68.0	60.0 80.0 60.0	79.0 50.0 50.0	no data 100.0 80.0

Table 1: Compiled results of test

3. FEM analysis

3.1. FEM model and analysis results

In the first stage of FEM analysis, presented below, the beams of series BZ/S with broken or limited adhesion were modelled. The *ABAQUS/Standard* software was used. The *Concrete Damaged Plasticity* in built model of concrete was adopted, whereas for steel as an elastic-ideal plastic model was used.

The model of concrete beam (Fig. 2) was built of the C3DR8 standard linear solid elements and B31 beam elements for the reinforcement. *Embedded* function of Abaqus was used. The dimensions of all elements were approximately of 20 mm, which was optimal for the FEM mesh. There was no adhesion between the web and the flange of the beam, the parts were independent, but the *normal and tangential behaviours* function were involved as the parameters of the cohesive surface. The friction coefficient of 0.7 was adopted.

In the fig. 3 the deformation and crack pattern of FEM analysis results are presented.

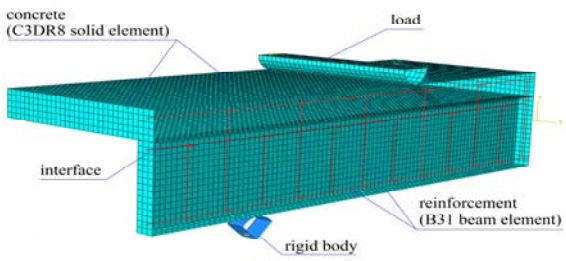


Figure 2: View of the beam FEM model

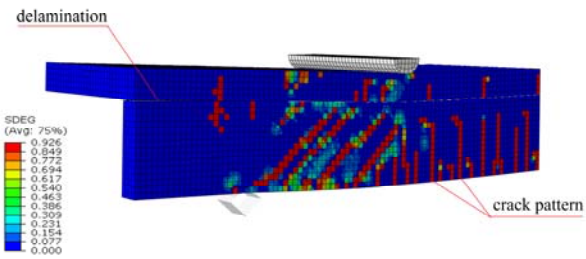


Figure 3: Deformation and the crack pattern obtained from FEM analysis under ultimate load.

3.2. Comparison with the real crack pattern

The performance of support zone was registered gradually in steps of 10 kN increasing until the ultimate load. In the Fig.4 the image obtained during testing is presented. It can be noticed that the FEM analysis results are close to the real beam performance.

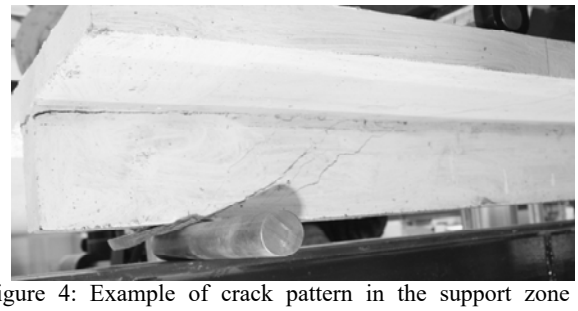


Figure 4: Example of crack pattern in the support zone of a BZ/S beam at the ultimate load.

4. Conclusions

On the basis of the test results and the FEM analysis, the following conclusions may by drown:

a) The FEM with the Concrete Damage Plasticity Model of ABAQUS leads to reasonable and sound results in terms to deformation and crack pattern of the concrete composite T-shape beams.
b) Defining the interface of concrete composite as a cohesive surface seem to be suitable for the global static work analysis.
c) FEM model well calibrated with the tests results is the source of many essential analysis.

References

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