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WHITE PAPER

DELTABEAM® SLIM FLOOR STRUCTURE
WITH TRANSFER BEAMS

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DELTABEAM® Composite Beam is known to be a cost effective solution for slim floor construction. Building projects can be small or large, they can be simple box-like two-bay office buildings, or very demanding shopping malls or concert halls.

The requirements vary; in some areas a slim floor solution does the job but then there are places where something else is needed – for instance a transfer beam with long span. DELTABEAM® Composite Beam is selected for this application because of its lower weight compared to concrete beams, making it easier to install and handle, and because it does not require fire protection like steel structures.

A transfer beam is used for instance in cases where a column is discontinuous i.e. it does not extend to the foundation and the load from it must be transferred to the surrounding structures.

This paper shortly describes the load tests made for the deepest DELTABEAM® Composite Beam type – D70-800 (h=700mm).

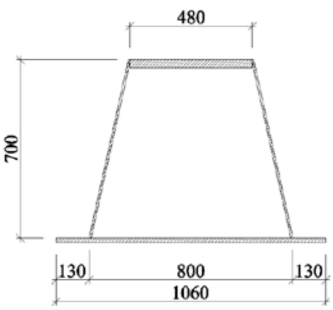


FIG. 1 STEEL BEAM CROSS-SECTION

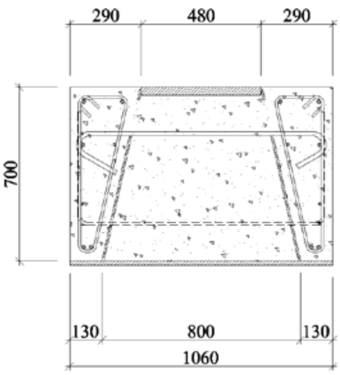


FIG. 2 COMPOSITE BEAM CROSS-SECTION

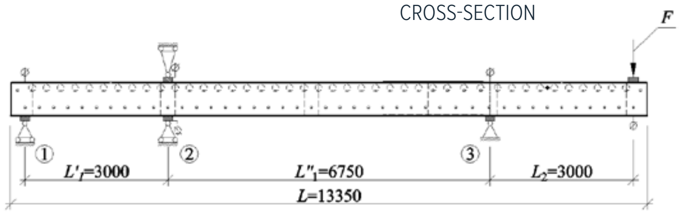


FIG. 3 STATIC SYSTEM OF THE CANTILEVER TESTS

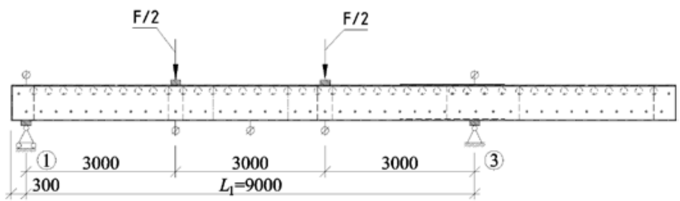


FIG. 4 STATIC SYSTEM OF THE SIMPLE BEAM TESTS

SPECIMENS AND TEST SETUP

DELTABEAM® Composite Beams were tested with two setups: cantilever setup and simple beam setup, see figures 3 and 4 below. Specimens were designed so that one specimen could be tested twice, first the cantilever test and, after reorganizing the setup, the simple beam test.

The specimen was quite big with a total length of ~13.4 meters and weight of the steel part approximately 6 tons. The total weight of the composite beam specimen was approximately 30 tons. Because of the size and weight, the setup had to be designed so that both tests for both specimens could be done without moving the specimen.

The loading was arranged so that there were main loading jacks installed with substitute jacks to enable their use without removing the load from the system.

The effects in the cantilever tests were analyzed with the FE method to find out the extent of the local strains and deformations. This in turn helped to define the locations for the support points in the cantilever and simple beam tests to ensure that the results of the tests were not affected by each other.

Both specimens were designed so that local effects at the loading points were prevented. The composite specimen was designed to simulate an intermediate beam with slabs on both sides without compression flanges in the ULS (ultimate limit stage).

FAILURE MODES – EXPERIMENTAL TESTS

First loading test – cantilever of the steel cross-section. The behavior of the specimen was stable. It can be observed from the measured data that the top plate started to yield but eventually the global failure was due to the buckling of the bottom plate just in front of the support.

Second loading test – simple beam test with the steel cross-section. The behavior of the specimen was stable until the failure. Also, in this test tension fields could be observed in the webs. The global failure was the buckling of the top plate. As can be seen in the figure, also the webs buckled locally outwards.

Third loading test – cantilever test with composite cross-section. The behavior of the specimen was stable throughout the test until loading had to be stopped due to technical problems with the loading system. The behavior of the specimen was ductile due to the yielding of the top plate. Externally, it could be seen that cracks, marked with numbers 1 and 2 in the figure on the right, continued to grow in width and length.

Fourth loading test – simple beam test with composite cross-section. The behavior of the specimen was stable throughout the test until loading was stopped due to capacity of the jacks when the deflection grew too large. The behavior of the specimen was ductile, and even the failure of the specimen was due to spalling of the external concrete. Externally, it could be seen that horizontal cracks started to grow and close to the end the concrete started to spall out, which resulted into reduced stiffness.

LOAD DEFLECTION BEHAVIOR – EXPERIMENTAL AND FE SIMULATION RESULTS

Prior steel beam tests were performed with SLS (serviceability limit stage) load cycles. They are not necessary for the steel beam, but they were performed to make sure that the specimen was laying properly on the supports.

Test 1: The result from the FE analysis is well in agreement with the experimental result, see the red and blue curves in the graph. Hand calculation gives a resistance of 91% of the maximum bending in the test.

Test 2: Also the result from the FE analysis of test 2 is well in agreement with the experimental result, see the gray and yellow curves in the graph. Hand calculation gives a resistance of also 91% of the maximum bending in the test.

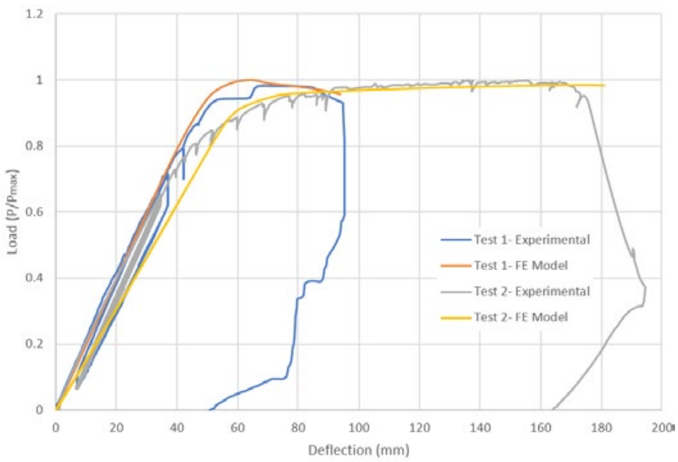
SLS load cycles were performed before the actual ULS loading also in composite DELTABEAM tests. In case of structures including concrete, it is important to run load cycles to release the bond between steel and concrete before the actual loading.

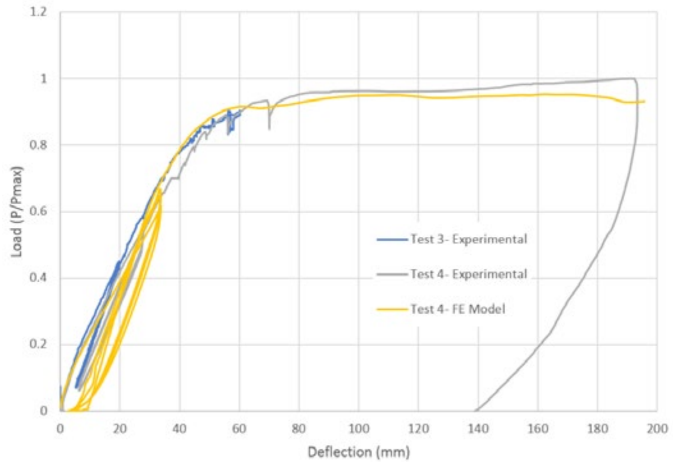
Test 3: The cantilever test had to be stopped prematurely due to technical problems with the loading system.

FE simulation was not done for this case either. However, the bending resistance given by hand calculation is 97% of the maximum bending moment in the test. It is obvious that the load in the test could have been increased.

Test 4: Both FE simulation stiffness and resistance are well in agreement with the experimental result, as can be seen in the graph. Hand calculation gives a resistance of 89% of the maximum bending in the test.

Material tests were performed for all concrete patches, different steel plate thicknesses, and reinforcement diameters which contributed to structural behavior of the specimens.





CONCLUSION

First of all, these tests prove that the behavior of DELTABEAM® Composite Beam is constant and safe apart from the cross-section size. Secondly, with the high load-bearing capacity and stiffness they are an economical solution for heavily loaded applications with long spans.

The behavior of all the specimens was according to the predictions of the current design methods, and the failure modes were as planned. The FE simulations predicted the behavior well, and the created FE modelling techniques are a reliable tool for simulating DELTABEAM® Composite Beam's behavior.

The results from the tests can also be used to further improve and develop the design methods of DELTABEAM® and develop new long span solutions with DELTABEAM®.

The tests were carried out in the FCE SUT testing laboratory in the Slovak University Technology of Bratislava.

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