Influence of concrete slabs on lateral torsional buckling of steel beams

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ABSTRACT: The use of pre-cast concrete floor slabs in steel framed structures is quite common. A non-connected concrete slab on top of a beam will provide some restraint to the beam. It may even be that the restraint provided by the floor slab prevents lateral torsional buckling. To investigate the restraining effect of a concrete slab on the top flange of a steel beam subject to lateral torsional buckling, two experimental load tests were performed. The first test is a test where a steel beam with lateral restraints at the supports only (fork conditions), was loaded in four point bending. In a second test, a single 1.2 m wide non-connected concrete slab was placed on a strip of rubber at mid span of the steel beam. The tests were carried out on 7.2 m long IPE240, S235 beams subject to the same loading conditions. The test results have been compared with results obtained from Finite Element simulations and theoretical analyses.

1 INTRODUCTION

To investigate the restraining effect on the lateral torsional buckling behaviour of a non-connected concrete slab on top of a steel beam, two four point bending tests were performed. The first test is on a steel beam with lateral restraints at the supports only (fork conditions). In a second test, a single 1.2 m wide pre-cast concrete slab was placed on a 20 mm thick, 10 cm wide strip of rubber at mid span of the steel beam. The tests were carried out on 7.2 m long IPE240, S235 beams.

The test results have been simulated by making use of the Finite Element Method (FEM) and they have been compared.

Also, the test results have been compared with results obtained from theoretical analyses.

2 EXPERIMENTS

Both four point bending tests had a span length of 7.2 m with IPE240 sections of steel grade S235.

For test 1 without concrete slab, the test was carried out by applying the two point loads in tension, testing the beam in upside down position. (Figure 1)

For test 2 with concrete slab, it turned out to be easier to apply the point loads in compression and test the beam in normal position (Figure 2).

Load versus vertical displacements are shown in Figures 3 and 4 for test 1 and 2 respectively, together with Finite Element results. Test 1 failed in lateral torsional buckling; test 2 did not show lateral torsional buckling.

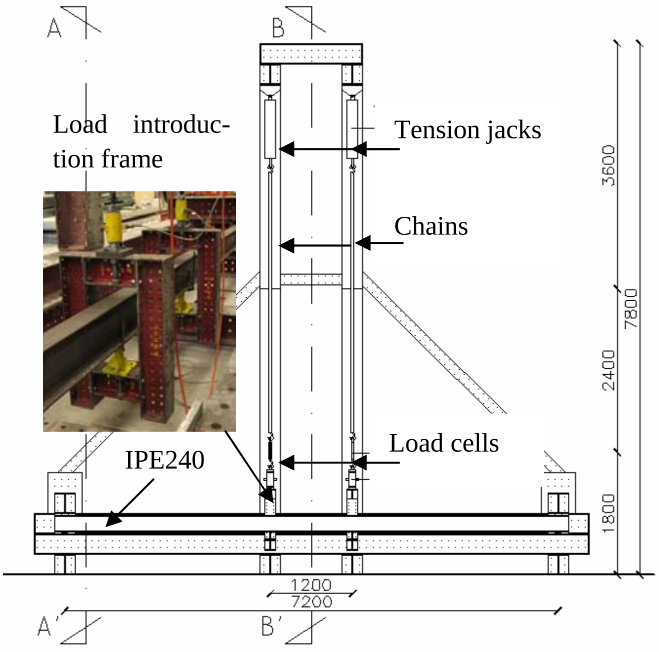

Figure 1. Test set-up for test 1 without concrete slab.

3 FINITE ELEMENT SIMULATIONS

The tests are simulated using the Finite Element Method. The simulations are carried out as a geometrical and material non-linear analysis on a beam

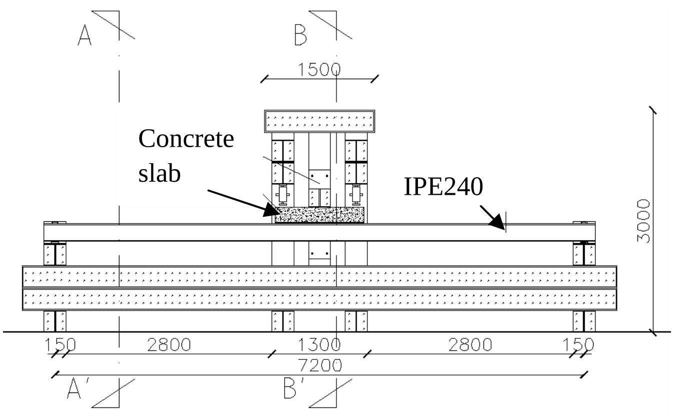

Figure 2. Test set-up for test 2 with concrete slab.

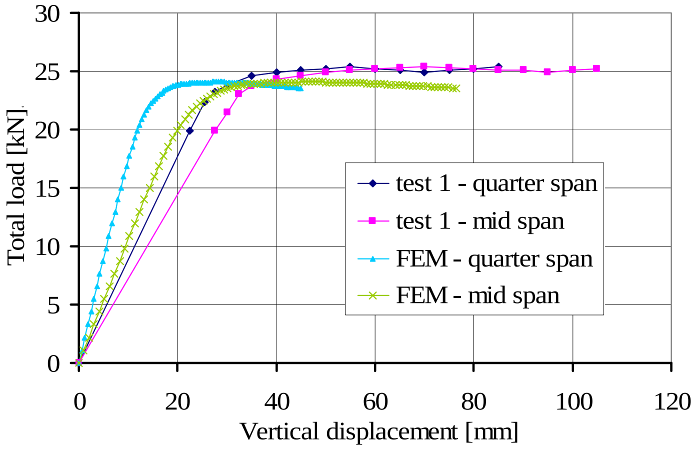

Figure 3. Load versus vertical deflection – test 1.

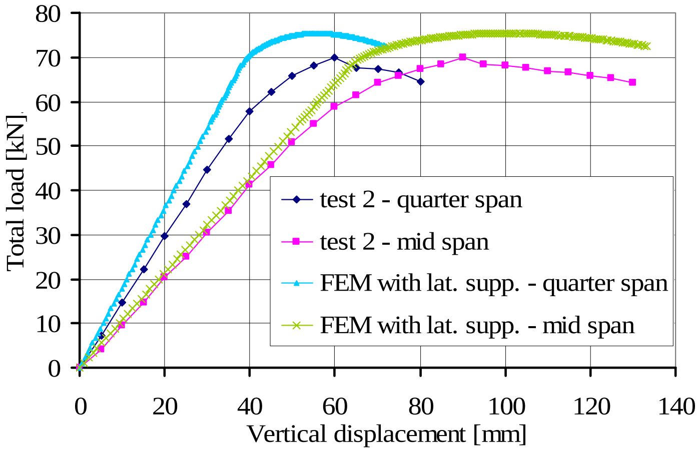

Figure 4. Load versus vertical deflection – test 2.

with imperfections (GMNIA) with DIANA (Witte & Schreppers 2005). Two FE models are used for test 2 giving an upper and lower bound of the ultimate total load. The Finite Element model behaves stiffer with respect to vertical displacements than the specimen of test 1 (Figure 3) but in general, there is a reasonable agreement between Finite Element and experimental results.

4 THEORETICAL ANALYSES

The ultimate load is calculated using the lateral torsional buckling design rules of EN1993 (EN1993-1-1 2006) and plastic mechanism theory (Figure 5).

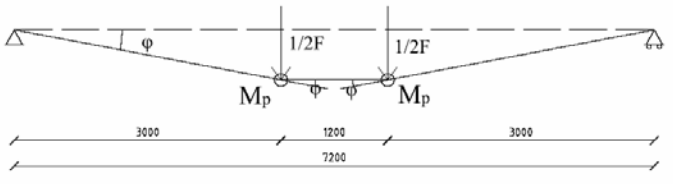

Figure 5. Plastic mechanism.

Table 1. Ultimate total loads (kN)

	Experiment	FEM	Theory	
			LTB	PMT
Without slab	25.4	24.1	21.3	75.3
With slab	70.0	57.7 (lb)	62.4	75.5
		75.4 (ub)		

LTB=Lateral Torsional Buckling, PMT=Plastic Mechanism Theory, FEM= Finite Element Method, lb=lower bound, ub=upper bound

5 DISCUSSION

The ultimate total loads are summarised in table 1.

For the case without concrete slab, the FEM predicts the experimental ultimate load well. The theoretical lateral torsional buckling load is closer to the experimental ultimate load than the value obtained with plastic mechanism theory.

For the case with concrete slab, the upper bound FEM ultimate load is close to the experimental ultimate load and corresponds well with the plastic mechanism ultimate load.

These results indicate that the concrete slab is almost able to completely restrain the beam against lateral torsional buckling such that the beam almost reaches its plastic mechanism capacity.

6 CONCLUSIONS

It was observed that the non-connected pre-cast concrete slab, placed on top of the steel beam, performed as a partial lateral support against lateral torsional buckling such that the beam almost reached its full plastic mechanism capacity. This preliminary study shows promising results. Further research is planned to quantify the restraining effect of floor slabs on the lateral torsional buckling behaviour of steel floor beams.

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