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Testing of a Full-Scale Composite Floor Plate

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ABSTRACT

A full-scale composite floor plate was tested to investigate the flexural behavior and in-plane effects of the floor slab in a grillage of composite beams that reduces the tendency for longitudinal splitting of the concrete slab along the line of the primary beams. This is important in cases where the steel decking is discontinuous when it is orientated parallel to the beams. In this case, it is important to demonstrate that the amount of transverse reinforcement required to transfer local forces from the shear connectors can be reduced relative to the requirements of Eurocode 4. The mechanism under study involved in-plane compression forces being developed in the slab due to the restraining action of the floor plate, which was held in position by the peripheral composite beams; while the secondary beams acted as transverse ties to resist the forces in the floor plate that would otherwise lead to splitting of the slab along the line of the primary beams. The tendency for cracking along the center line of the primary beam and at the peripheral beams was closely monitored. This is the first large floor plate test that has been carried out under laboratory conditions since the Cardington tests in the early 1990s, although those tests were not carried out to failure. This floor plate test was designed so that the longitudinal force transferred by the primary beams was relatively high (i.e., it was designed for full shear connection), but the transverse reinforcement was taken as the minimum of 0.2% of the concrete area. The test confirmed that the primary beams reached their plastic bending resistance despite the discontinuous decking and transverse reinforcement at the minimum percentage given in Eurocode 4. Based on this test, a reduction factor due to shear connectors at edge beams without U-bars is proposed.

1. Introduction

Steel-concrete composite structures are the most common forms of flooring system used in steel-framed structures and have been widely used for many years all over the world [1–6]. Composite action generated between the steel beams and concrete slabs through the use of shear connectors could increase the load-bearing capacity and stiffness of the composite beams, which would lead to a significant saving in steel weight and construction cost.

The composite floor plate test presented in this paper investigated how the in-plane or membrane effects of the composite floor slab reduce the tendency for longitudinal splitting of the concrete slab along the line of the primary beams, and therefore increase the load capacity of the structural system. The floor plate test consisted of a grillage of primary beams, secondary beams, and columns. A series of tests was conducted. The first test was carried out with two-point loads applied to each of the internal secondary beams so that the primary beams were loaded via the secondary beams, as would be the case in practice. This test was repeated over a few cycles of working load and factored load, followed by an increase up to a load; this resulted in an acceptable maximum deflection that would not cause serious damage to the floor plate, which might affect subsequent tests. The second test series that was carried out focused on the edge beams by applying load directly onto these beams; this investigated the tendency for splitting of the concrete slab near its edge. On one edge, U-shape reinforcing bars (U-bars) were used to provide local anchorage, whereas on the other edge, no additional reinforcement other than the mesh was used. Finally, a robustness test was performed on the side of the secondary edge beams without U-bars in which the support to the column was removed.

2. Details of the full-scale composite floor plate

2.1. Design of the composite floor plate

The dimensions of the composite floor plate were chosen to be 10.6 m long × 4.0 m wide, since these dimensions have the correct

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aspect ratio and easily fit in our laboratory. The composite floor plate consisted of nine beams (three primary beams and six secondary beams) and six columns, as shown in Fig. 1. All the primary beams (one central primary beam and two edge primary beams) were IPE270 in S355 steel and spanned 3.6 m between the flanges of the two columns. The two internal secondary beams were IPE300, also in S355 steel, and spanned 5.2 m between their connections to the web of the supporting beams. The other four edge secondary beams were IPE270 in S355 steel with a span of 5.2 m. The central primary beam (IPE270) was designed to be 10% weaker than the internal secondary beams (IPE300) so that failure would occur first in the central primary beam.

2.2. Composite frame setup

The floor beam and column arrangement is shown in Fig. 2. The columns were 1.0 m high and the two central columns were designed to be 200 mm shorter than the other four corner columns, so that load cells could be placed underneath them to monitor the loads transferred to the central columns. The two central columns were tied to prevent outward movement, since it is possible that a small moment might be generated in the columns through the connections. An endplate with the dimensions 180 mm × 220 mm × 10 mm was welded to the web of the internal secondary beams (IPE300, sections were notched to fit) and bolted to the web of the primary beams (IPE270) using six No. M20 Grade 8.8 bolts (the bolt spacing was 70 mm in the vertical direction and 100 mm in the horizontal direction). An endplate with the dimensions 140 mm × 220 mm × 10 mm was welded to the web of the secondary edge beams (IPE270) and bolted to the web of the HEA200 columns using six No. M20 Grade 8.8 bolts (the bolt spacing was 70 mm in both the horizontal and vertical directions). An endplate with the dimensions 170 mm × 220 mm × 10 mm was welded to the web of the primary beams (IPE270) and bolted to the flange of the HEA200 column using six No. M20 Grade 8.8 bolts (the bolt spacing was 70 mm in the vertical direction and 90 mm in the horizontal direction). Fig. 3 shows details of the beam-to-beam and beam-to-column connections.

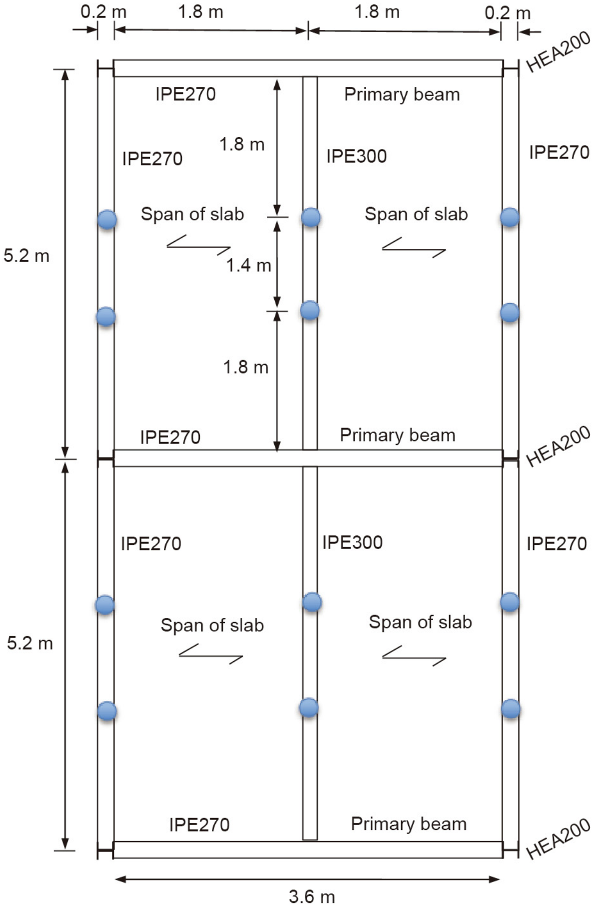


Fig. 1. Beam arrangement and floor plate dimensions. The blue spots represent the point load applied to the internal beam (test 1) and the external beam (test 2). The load cells were placed under the central columns.

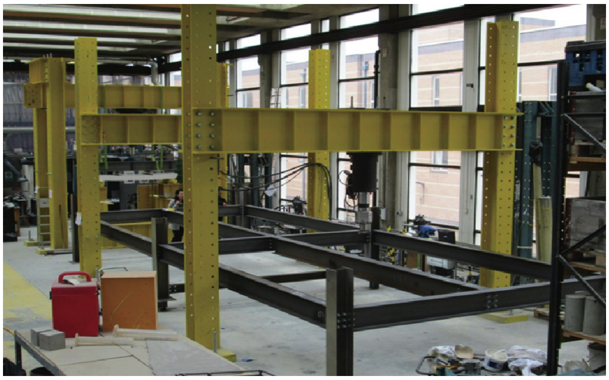
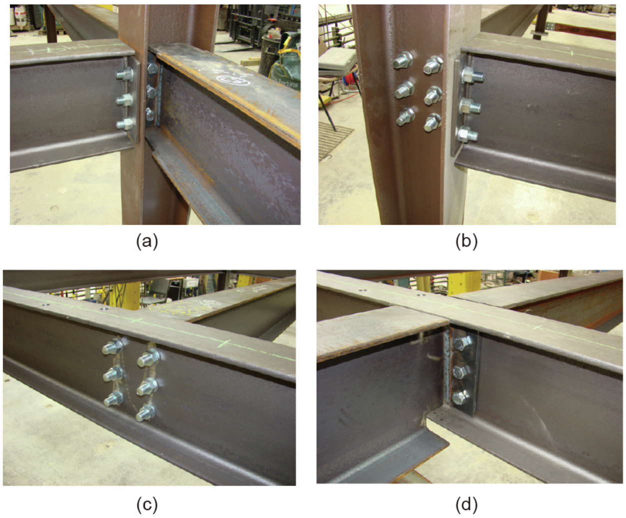


Fig. 2. Layout of the beams and columns in the floor plate test.

2.3. Details of composite slab and shear connectors

The composite slabs consisted of a 130 mm thick slab with a 0.9 mm thick, 58 mm deep profiled decking (Cofraplus 60 from ArcelorMittal S.A.). The deck profile had ribs spaced at 207 mm and allowed the welding of a stud in the middle of the rib. Single 19 mm diameter shear studs (100 mm nominal height) were used, and the spacing of the studs was chosen to be 200 mm for the primary internal beams and 207 mm for all the secondary beams. Since the profiled decking was discontinued at the primary beam, the shear connectors were welded directly to the primary beams while through deck welding was used for the secondary beams. The shear connector details are shown in Figs. 4 and 5.

The reinforcement adopted for the specimen was A142 mesh, as shown in Fig. 6, which was equivalent to the 0.2% minimum reinforcement in the concrete topping according to Eurocode 4. It was



(a) (b)

(c) (d)

Fig. 3. Details of beam-to-beam and beam-to-column joints. (a) Central column connections; (b) corner column connections; (c) primary edge beam connections; (d) primary central beam connections.