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## My Papers

   [Experimental Tests on Composite Beam with Various Slab Systems \(978-3-03785-421-1\)](#)

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## Experimental Tests on Composite Beam with Various Slab Systems

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**Keywords:** composite beam, metal decking floor, pre-cast floor, solid floor

**Abstract.** This paper presents the structural behaviour of composite beams with various floor systems tested in full-scale arrangement. Six full-scale specimens with staggered and non-staggered arrangement of studs on the composite beams were tested until failure. The moment capacities obtained from the experiment are compared with the theoretical values established from BS 5950 and Eurocode 4. The experimental results showed good agreement with theoretical predictions while no significant influences were found between staggered and non-staggered arrangement of studs.

### Introduction

The use of composite beam in buildings has known to be more economical against bare steel beams, which the composite action between steel and concrete has results in significant savings in steel weight and reduce the beam depth [1]. The advantages of composite beam contributed to the dominance of composite beam in the commercial building in steel construction industry. To date, the advantages of composite beam have been further extended with the use of pre-cast floor and metal decking floor, to minimized or eliminate the use of formwork. The performance of such floor systems depends on the interaction of the concrete slab and the steel section connected together by shear connectors. This interaction depends on the strength of the studs, the concrete strength, and the continuity preserved along the horizontal interface so that the concrete slab and the steel section respond as one unit. This paper presents the experimental investigation on composite beam with three types of slab system namely solid slab (in-situ slab), pre-cast slab (half-slab system) and profiled metal decking slab. The shear studs are 19 mm in diameter and were positioned either as staggered or non-staggered arrangement. A total of 6 full-scale composite beams were tested until failure and the performance of each floor system will be discussed based on the maximum moments and deflections.

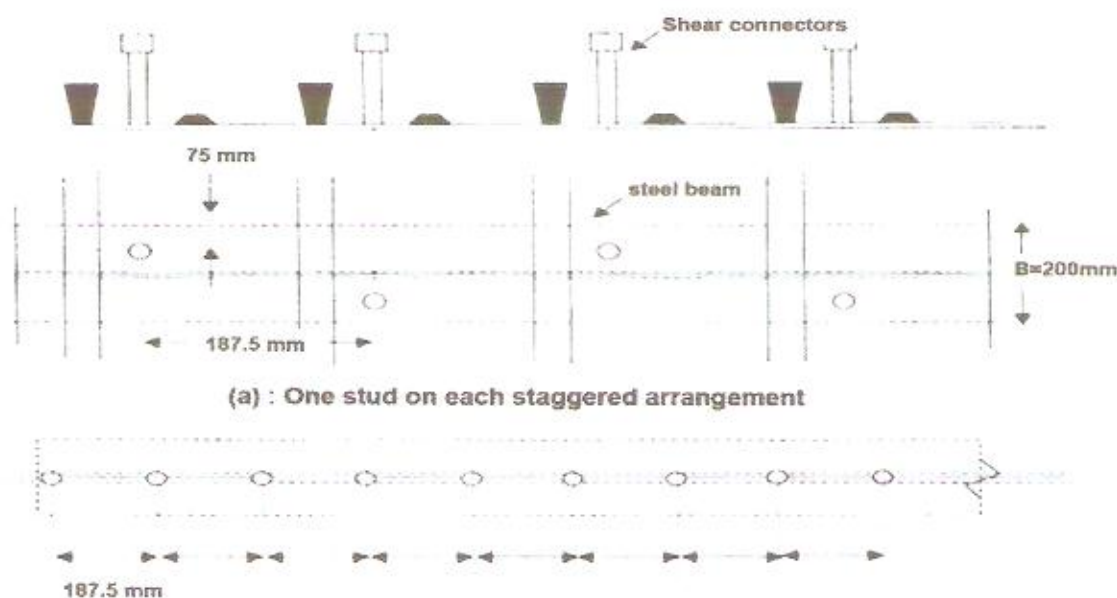
### Experimental Programme

**Mechanical Properties of the Materials.** The concrete grade of C30 was used in the slab system throughout the specimens and 9 pieces of cubes were tested for compression to verify the concrete strength [2]. The cube tests have shown an average value of 36.78 N/mm<sup>2</sup> which has achieved the minimum requirement of 30 N/mm<sup>2</sup>. A total of 12 coupon specimens were cut from the web and the flange of the steel section to obtain the mean values of yield strength ( $f_y$ ), ultimate strength ( $f_u$ ) and the elastic modulus ( $E$ ) [3]. From the tensile test, the mean values for  $f_y = 324$  N/mm<sup>2</sup>;  $f_u = 392$  N/mm<sup>2</sup>; and  $E = 202$  kN/mm<sup>2</sup>. The values obtained from the material tests are then used to calculate the moment capacities of the composite beams in accordance to BS 5950 [4] and Eurocode 4 [5].

**Full-Scale Bending Test.** 6 full-scale composite beams consist of 3 different types of slab system and 2 types of stud arrangement were tested until failure. The slab systems used are solid slab, pre-cast slab and steel decking slab while the studs are positioned either in staggered or non-staggered arrangement. The detail dimensions of each specimen are summarized in Table 1 and Fig. 1. The arrangement of the test rig and measuring equipments are shown in Fig. 2. The DARTEC hydraulic actuator was used to exert 2 point loads on the specimen at a distance of 1 m from the mid span of the beam. This distance is to represent an area for a pure bending moment developed in the beam. The LVDTs were placed at the mid span of the beam and also the loading point. Strain gauges are also installed along the beam depth as shown in Fig. 2. An increment of 10 kN is applied to the composite beam so that a uniform data and gradual failure of the specimen can be monitored. The specimen is further loaded until substantial deflection of the beam can be observed. At this point, the loading sequence is controlled by the increment of deflection as a small increment of load has resulted to substantial increase in the deflection. The failure condition is considered to have reached when an abrupt or significantly large reduction in the applied load.

**Table 1** Details of specimens full-scale bending tests

Model Name	Steel Beam Size	Slab System	Slab Dimension	Stud Arrangement
CB SSD	400x200x65.4 kg/m Length = 6 m	Steel Decking	Slab thickness = 125 mm Width of Slab = 1.5 m Length of Slab = 6 m	Staggered at 187.5 mm
CB SSS		Solid Slab		
CB SHS		Pre-cast Slab		
CB PSD		Steel Decking		Parallel along the beam at 187.5 mm
CB PSS		Solid Slab		
CB PHS		Pre-cast Slab		



**(a) : One stud on each staggered arrangement**  
**(b) : Arrangement of studs in parallel to the central beam**  
**Fig. 1** Arrangement of shear studs in staggered and parallel to the beam



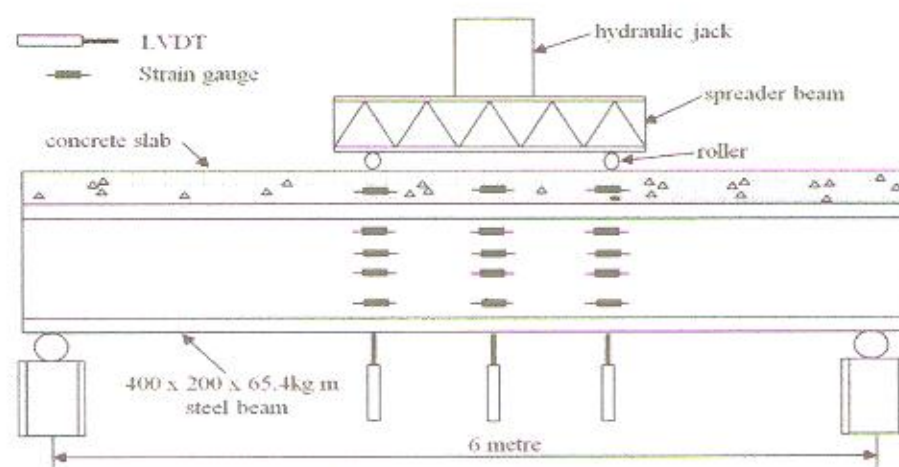


Fig. 2 Test arrangement

### Results and Discussion

The test results were presented based on the ultimate moment capacity, initial stiffness and the maximum deflection, which derived from the moment-deflection curves as shown in Fig. 3. The test results were summarized in Table 2 and the ultimate moment capacities were compared to the theoretical predictions, which calculated in accordance to BS 5950: Part 1 Section 3.1 [4] and Eurocode 4: Part 1.1 [5]. The comparison shows good agreement between experimental results and theoretical predictions where the ratios are in the range of 1.05 to 1.11. The maximum deflection at mid span of the beam corresponding to the ultimate moment ( $\delta_{max,exp}$ ) and the initial stiffness of the beam at linear elastic region ( $S_{ini,exp}$ ) obtained from the moment-deflection curves are also recorded in Table 2, and the values are in the range of 40.0 mm to 125.7 mm for deflections and 30.6 kNm/mm to 48.9 kNm/mm for initial stiffness.

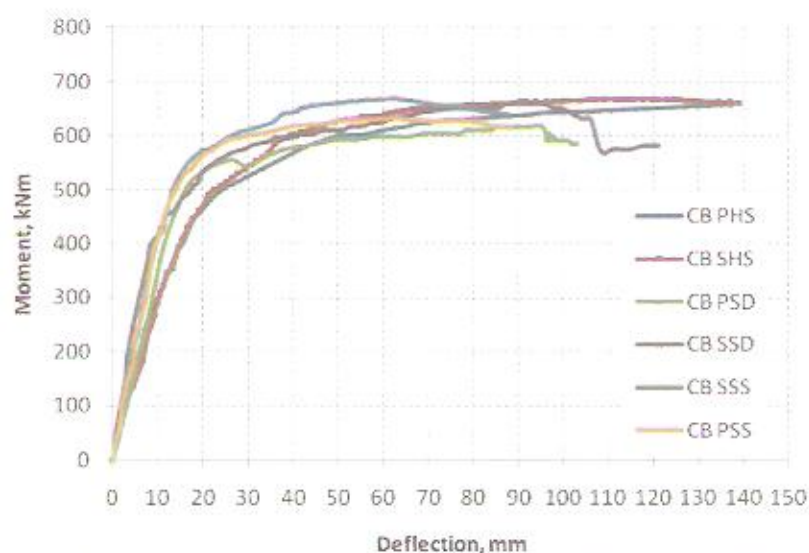


Fig. 3 Moment-deflection curves for tested composite beams

**Table 2** Comparison of experimental results and theoretical predictions

Model Name	$M_{u,theo}$ (kNm)	$M_{u,exp}$ (kNm)	$M_{u,theo} / M_{u,exp}$	$\delta_{max,exp}$ (mm)	$S_{int,exp}$ (kNm/mm)
CB SSD	587.6	650.3	1.11	93.9	48.9
CB SSS	603.0	670.1	1.11	40.0	43.8
CB SHS	630.5	677.3	1.07	122.8	32.4
CB PSD	575.2	608.8	1.06	85.2	36.0
CB PSS	601.5	633.9	1.05	45.9	41.7
CB PHIS	601.8	638.3	1.06	125.7	30.6

By observing the failure modes of the specimens, shear studs are dislodged from its position on the specimen and showed significant deformation, which demonstrate the characteristics of partial shear connection between steel and concrete. Slippage between steel and concrete was recorded at about 10 mm that did not contribute significantly to the failure of the composite beam. Composite beams with staggered studs arrangement are slightly higher in both moment capacity and initial stiffness as compared to non-staggered studs. Both theoretical and experimental results showed the performance of composite beams with metal steel decking are low in moment capacity as compared to solid slab and precast slab system, while the composite beam with precast slab system showed largest values in the maximum deflection as compared to the other 2 slab system.

### Conclusions

The concluding remarks from the experimental results of the composite beam with 3 different slab systems and stud arrangement are listed as follows:-

- 1) BS 5950: Part 1 Section 3.1 [4] and Eurocode 4: Part 1.1 [5] are suitable to be used to predict the moment capacity of composite beams for the tested slab systems and stud arrangement.
- 2) No significant difference in terms of moment capacity was found between staggered and non-staggered stud arrangement in a composite beam.
- 3) Composite beam with precast slab systems showed higher capacity in bending and high ductility, but relatively low in initial stiffness as compared to solid slab system and metal decking system.

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