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Steel–Concrete–Steel sandwich slabs with lightweight core — Static performance

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ABSTRACT

This paper investigates the static performance of Steel–Concrete–Steel (SCS) sandwich slabs which consist of an ultra-lightweight concrete core sandwiched between two steel plates. Special J-hook connectors have been developed to develop composite action between the concrete core and the two steel plates. The core is made of lightweight concrete of density less than 1450 kg/m^3. Laboratory tests were carried out on eight SCS sandwich slabs under centrally applied patch load. Test results showed that the mode of failure and crack pattern of SCS sandwich slabs were very similar to those of reinforced concrete slabs especially when the concrete core and steel plates act in a fully composite manner. Flexural and punching are the primary modes of failure. After flexural yielding, membrane action developed in the slab due to the effectiveness of J-hook connectors in maintaining composite action which further increases its load carrying capacity after flexural yielding. Theoretical models are proposed to predict the flexural and punching resistance and a good correlation with test results is obtained. A large deflection analysis considering plate membrane action is also proposed to predict the force deflection relation of SCS sandwich slabs.

1. Introduction

Steel–Concrete–Steel sandwich structures which consist of a concrete core sandwiched in between two steel face plates, has been applied to port and harbour facilities since the early 1980s [1], and since then has found further applications for submerged tube tunnels, protective structures, building cores, bridge deck, gravity seawalls, floating breakwater, anti-collision structures, nuclear containment, liquid containment, ship hulls and offshore deck structures, in which resistance of impact and explosive loads is of prime importance [2–4]. Zuk [5] and Bergan et al. [4] carried out further work to realize its potential for application as lightweight deck structures and for strengthening of weakened areas in ship structures. The apparent advantages of the system are that the external steel face plates act as both primary reinforcement and permanent formwork, and also as impermeable, impact and blast resistant membranes.

In general, mechanical shear connectors are required to develop composite action between steel plates and concrete core. Three types of shear connector are commonly used in sandwich construction, (1) angle shear connector [1,2], (2) headed shear stud [3] and (3) mechanically fixed connector such as Bi-steel [6]. One of the drawbacks of the headed shear stud and angle shear connector used for SCS sandwich construction is their relatively poor performance under high shear force [1,2] and the possibility of tensile separation under impact loading [7]. The headed stud and angle connectors have poor performance because their pull out strength in cracked concrete is very low compared to Bi-Steel connectors which are welded directly to the top and bottom steel plates. However, Bi-Steel connectors require a minimum height at least 200 mm for it to be spun and friction welded to the top and bottom plates [6]. Moreover, for shallow core depth particularly for ship hull, deck-like structures or overlays on exiting floor use of welded headed stud connector may not be suitable due to low shear resistance of the core.

After consideration of all these factors, a sandwich system with a J-hook shear connector has been developed and its use is not restricted by the depth of the panel. The top and bottom J connectors are hooked against each other as shown in Fig. 1 and concrete is filled between the plates to form a sandwich structure. Studies carried out by Liew and Sohel [8,9] on sandwich beams under impact loads show that the double J-hook connectors increase the overall structural integrity and lead to a good structural performance under different loading conditions. This paper extends the study to sandwich slabs under static load.

Most of the previous studies have been focused on the flexural strength of SCS sandwich beams under static and quasi-static loading [3,6,8,10–12]. The primary modes of failure in the beams were tension plate yielding and slipping and pull out or tension failure of the shear connectors. A sandwich slab is different from that of beams, columns and beam–columns as it resists lateral load by flexural bending in two directions. Information available on SCS sandwich slabs is limited and full scale tests are required to understand the behavior of such a structural system. Shanmugam et al. [13] conducted tests on SCS sandwich slabs with headed studs. The SCS panels were supported on four sides thus their

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