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Steel-concrete-steel sandwich composite structures-recent innovations

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ABSTRACT

Steel-concrete-steel (SCS) sandwich structures consisting of two steel face plates infilled with lightweight cement composite material has been developed. This paper reviews the recent innovations of SCS sandwich structures subject to blast, impact, fatigue, and static loads. Novel J-hook connectors, high strength steel plates and new lightweight cement composite materials have been considered for the development of the SCS sandwich products to improve their strength-to-weight performance. Extensive tests have been conducted to investigate the effectiveness of J-hook connectors to achieve better composite action to resist flexural, shear, impact, blast and fatigue loads. Flat and curved SCS sandwich plates under patch loading are also investigated. The experimental results are essential to understand the structural behaviour of the SCS sandwich structures and to provide data for the development of analytical models for design implementation. Design equations have been proposed to predict the shear and tensile resistances of J-hook connectors and to determine the flexural, shear, impact, blast and fatigue resistances of SCS sandwich beam. The punching shear resistance of sandwich shells and compression resistance of sandwich walls are also investigated. The accuracy of the design equations are validated by the test data and finite element analysis results.

1. Introduction

Steel-concrete-steel (SCS) sandwich composite structures consist of two steel face plates and a sandwiched concrete core which are bonded together by mechanical connectors to form an integral unit to resist external loads. In the early days, SCS sandwich structures were developed for infrastructures and tunnels to resist loading due to accidental impact and vehicular loading. With the recent investigation on their performance under static impact, fatigue and blast load [1–6], the applications of SCS sandwich structures have been extended to offshore decking, protective structures, oil storage containers and ice-resistant walls [7,8]. Steel-concrete-steel sandwich structures have also been proposed for structural walls in nuclear facilities [9,10].

Different types of SCS sandwich composite structures have been developed by using different bonding techniques at the steel-concrete interface. Cohesive materials, such as epoxy, were used in the SCS sandwich composite structures [11]. Compared with the mechanical shear connectors, brittle bond failure tended to take place at the steel-concrete interface due to the imperfection of the bonding material which would compromise the structural integrity of the SCS sandwich structure. A double skin structure with overlapped stud connectors to bond the concrete and steel plates was initially proposed for tunnel liner [12]. However, the bond between the steel plates and concrete core depends greatly on the spacing and the lapped length of the connectors. Once the concrete core failed under the action of extreme loads, the steel plates and the concrete core may separate and affect the structural integrity of the sandwich plate. One novel way to improve the structural integrity of SCS sandwich structure is to connect the two steel face plates with straight steel bar connectors using friction welding [13]. However, the installation of the connectors using the friction weld apparatus limits the thickness of SCS sandwich structure within the range of 200 to 700 mm. Angle-section connectors were also proposed for SCS sandwich constructions in Japan [14]. Owing to the shallow embedment of the angle-section connectors, bond failure tended to occur at the service load level unless additional stiffener plates were provided. To develop a slim deck for offshore platforms, J-hook connectors were developed by Liew et al. [1] as shown in Fig. 1(a). Experimental studies showed that SCS sandwich structures with J-hook connectors exhibited excellent performances under impact, blast, and fatigue loadings [2,3]. This type of structure is suitable for applications in shear walls, protective structure, ship hulls of cargo tank, bridge/offshore decks, and ice-resistant wall in Arctic offshore platform as shown in Fig. 1(b–e).

To reduce the self-weight of the SCS sandwich structure, lightweight concrete (LWC) has been proposed by the authors [13]. LWC with different strength to weight ratio offers more choices to design SCS sandwich structures to achieve higher strength-to-weight ratio. LWC with a density of 1450 kg/m^3 and compressive strength of 30 MPa has been

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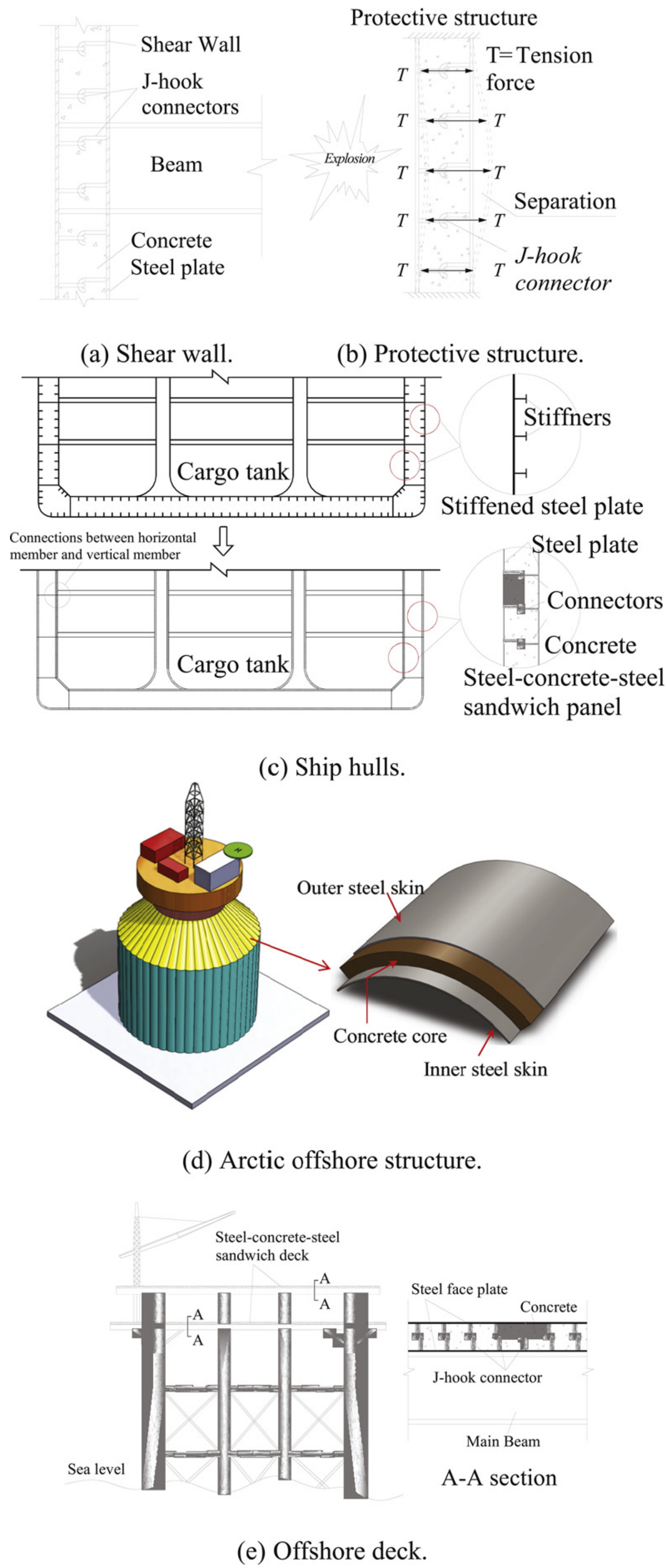

Fig. 1. Applications of the SCS sandwich structure.