Penetration Based Design of Double Skinned SCS Wall Panel under Bullet Impact

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This paper deals with the numerical study on double skinned SCS wall panel subjected to bullet impact. General purpose finite element software, ABAQUS, is used to carry out the collapse analyses. The wall panels are assumed to be made with trapezoidal profile steel sheet in their outer skins and the concrete is used as an infill material. In view of investigating the influence of various parameters, five different steel plate thicknesses such as 2, 4, 6, 8 and 10mm, three different concrete infill thicknesses such as 50, 75 and 100mm, three different bullet hitting angle such as 0^o, 25^o and 50^o and three different hitting locations are subjected to investigation. Wall panel of size 1.2m x 1.2m is considered with simply supported condition along two opposite edges and other two edges are considered as free. Damage plasticity criterion is used to simulate the concrete behavior and the matrix failure where as elasto-plastic behavior is considered for steel plate. From the parametric study, it is observed that the critical angle of impact for maximum depth of penetration of bullet is 25^o from normal of surface. For 0^o angle of impact, the depth of penetration of bullet is less. This may be due to the full composite action achieved by the composite panel and the back side steel plate comes in action; whereas, for 25^o angle of impact the front steel plate alone comes in to action. For angles of impact more than 25^o, the bullet enters in to the higher thickness part of SCS panel and becomes less effective and; critical location of impact for perforation of bullet with minimum impact energy is minimum thickness section of panel. Critical angle of impact for maximum deflection of the panel and maximum deformation (bulging) of the back plate is 0^o from normal of surface because normal component of force is maximum for 0^o angle of impact as compared to that of other impact angles. It is also observed that as the thickness of back side plate is increased there is a small increment in impact load carrying capacity of panel whereas, when the thickness of front side plate is increased, there is a large increment in impact load carrying capacity of panel. This paper presents the details of the investigation, observations and the final conclusion.

Keywords: Bullet impact; Depth of penetration; Finite element analysis; Steel concrete steel composite, Impact Load,

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1. Introduction

Steel-Concrete-Steel (SCS) sandwich composite construction, otherwise called as double skinned composite, is a basic framework comprising of a concrete core, sandwiched between two relatively thin steel plates, connected to the concrete by mechanical shear connectors. The combined effect of steel and reinforced concrete system enhances the performance under impact and blast loading. As the components can be prefabricated, which helps in rapid installation in the structure leads to reduced fabrication cost and time. SCS structure is highly suitable for marine and offshore structures due to the presence of impermeable outer steel plates which also behave like permanent formwork during construction. SCS have a superior structural performance where high strength, high ductility and high energy absorption capacity is expected compared to conventional engineering structures (Sohel et al. 2003).

Low velocity and large mass impacts may be expected for civil, marine and offshore structures in their service life. For this reason, there is an increasing awareness of the effect of foreign object impacts is required, termed as low-velocity impacts on structures used in marine, offshore and other civil structures. In SCS composite structure, steel has high fracture toughness and therefore such structure offers a high level of resistance against impact loads. But concrete offers very little resistance to an impact load, yet the inclusion of randomly oriented discrete discontinuous fibers improves many of its engineering properties, especially against impact or abrasive loading (Shah 1987). The concept of using fibers for such purposes is an old one and has been reported to be in existence for 3500 years (Bentur and Mindess 1990). Use of natural fibers, namely coir, cellulose, sisal, jute, etc. for structural purposes in concrete has been studied extensively. However, due to concerns about their long-term performance (Zollo 1997), metallic and polymer fibers are widely used in fiber reinforced concrete.

The potential uses of SCS composite construction are diverse, including submerged tube tunnels, protective structures, building cores, basement of multi-storey building, bridge deck (Bowerman et al. 2002, Xie et al. 2007, Zhao and Han 2006), gravity seawalls, floating breakwater, anti-collision structures, nuclear structures, liquid containment, ship hulls and offshore structures, in which resistance to impact and explosive loads is of prime importance. Structural applications where there are constraints over the thickness and weight of the concrete core, SCS proves to be disadvantageous especially in offshore uses. The lightweight core concrete in SCS has better fire resistance and acoustic property compared to traditional stiffened plate construction.But for better penetration resistance and impact resistance conventional normal weight concrete is preferred in case of high-velocity impact. SCS composite framework can be further enhanced by decreasing the thickness of the core and maintaining the overall structural performance of the composite systems. The present research work explores the use of conventional normal weight concrete for SCS construction.

Currently, there are three types of mechanical connectors used in SCS composite construction. The first type is the routine headed stud development in which the studs are welded with the steel plates before concrete is cast. The resistance of the two steel confront plates against tensile detachment relies upon the pull out strength of the headed studs. The conventional headed studs are installed on the steel plate and thus there is no restriction on the core thickness and thus making the casting of concrete easier. The second type is a Bi-Steel connector in which steel round bar is rotated at high speed and opposite external force is applied to the steel face plates generating frictional heat that fuse the bar and the plates together (Bowerman et al. 2002). The Bi-Steel SCS provides a better quality of construction due to reduced site work as the system can be shop fabricated. The direct connection between the two face plates harnesses shear transfer even in the absence of an intermediate concrete core. The only disadvantage of such method is that the core thickness must not be too thin (≥ 200mm) to restrict the placement of the Bi-Steel cross connectors. To overcome all these disadvantages of using headed stud and Bi-Steel connectors in SCS composite structures, it is necessary to use the third type i.e. ‘J-Hook’ shear connector which can interconnect both top and bottom steel face plates and their use will not be restricted by the concrete core thickness.

Most of the previous studies have been focused on the strength capacity of composite structures under static and quasi-static loading (Oduyemi and Wright 1989, Narayanan et al. 1994, Xie et al. 2007, McKinley and Boswell 2002). Design and construction guides for SCS composite with headed stud and Bi-Steel are available in the literature (Bowerman et al. 1999, Narayanan et al. 1994). However, the performance of the SCS composite structures under impact load has not been explored extensively. The very limited literature on impact behavior of SCS composite structures is available (Sohel et al. 2003, Corbett 1993). Sohel et al. (2003) conducted impact tests on SCS composite beams with angle shear connectors welded on the face plates. The test specimens were failed by tensile separation of the face plates, local buckling of face plates and crushing of concrete core leading to poor impact performance. Alexandre et al. (2015) studied the influence of end anchorage mechanism on the ultimate load behavior of composite slabs. Yong Yang et al. (2016) studied the mechanical performance of composite beams with innovative composite deck slab. The composite slab in their study was composed of concrete slab and normal flat plate which were connected by perfobond shear connectors. Longitudinal shear behavior of composite floor slab was experimentally investigated by Marcela et al. (2017). Free vibration response of precast composite slab was investigated by