A Review on Experimental Performance of Steel-Concrete-Steel (S-C-S) Composite Beam with Varying Stud Connectors

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Abstract - *The steel-concrete-steel composite beam is a new concept for the design of composite structures, which consist of a concrete core that is inserted between two steel plates connected to one another with connectors. The use of these connectors and the normal concrete composite core reduces the overall weight of the SCS sandwich system to enable the construction of ship and ship structures. The performance of a composite SCS structure depends on the efficient interaction and transfer of stresses between the components of steel plates and concrete core. This can be achieved with mechanical shear connectors, which in addition to longitudinal sliding also prevent vertical separation The steel-concrete-steel composite system developed on the basis of reinforced concrete (RC) structures is characterized by high load-bearing capacity, good ductility and integrity, as well as excellent impact resistance and tightness. The panels can effectively limit the crack width of the concrete in all directions. The steel skins also act as formwork during concreting and promote construction efficiency. Therefore, in recent years SCS structures have been used in large structures such as bridges, pipe tunnels, nuclear power plants, and central tubes of high-rise buildings. This paper aims in exploring scope for studying the new materials provision inside S-C-S beam without increasing its weight.*

***Key Words*: SCS Beam, Sandwich System,Novel Connector**

1.INTRODUCTION

Steel-concrete-steel (S-C-S) sandwich composite beam is a construction system that consists of a concrete core that is embedded between two relatively thin steel plates and connected to the concrete by shear connectors as shown in fig.1. This construction combines the advantages of steel and reinforced concrete systems for protection against impacts and explosions. It enables large panels to be prefabricated in the factory and allows for quick installation on the main structure, drastically reducing manufacturing costs and construction time. The two face plates serve as permanent formwork during the construction phase and provide waterproof coatings which are very suitable for marine and offshore application. In addition, flat steel surfaces can be easily protected, inspected and tested so that the integrity of the structure can be guaranteed throughout its useful life and it has demonstrated its superiority over conventional technical constructions in applications that require strength, high ductility and high energy absorption capacity.

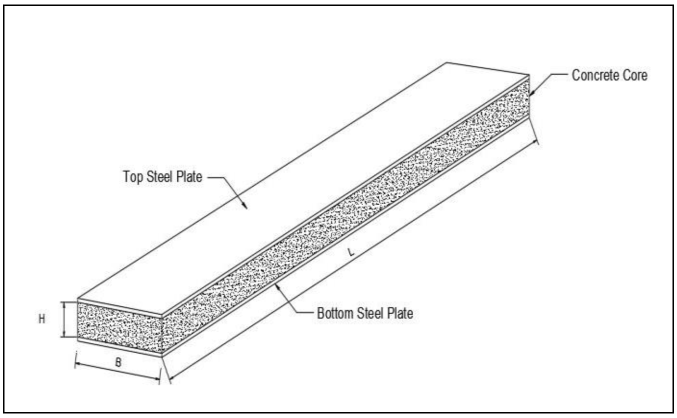

Fig -1: Steel-Concrete-Steel Sandwich Beam

The possible uses of the SCS sandwich construction are diverse, including underwater tunnels, protective structures, building cores, basements of multi-storey buildings, bridge decks, weight dams, floating breakwaters, anti-collision structures, nuclear structures, liquid containers, ship hulls. and on the high seas. Structures where resistance to impact and explosive charges is of the utmost importance; However, the possible uses of this form of construction are currently limited by the thickness and weight of the concrete core, which makes it less suitable for offshore applications. [2]. The performance of a composite SCS structure depends on the efficient interaction and transfer of stresses between the steel plates and the concrete core. This can be achieved through the use of mechanical bond anchors which, in addition to longitudinal sliding, also prevent vertical separation. The types of compound connectors used for sandwich composite construction include headed studs, angle shear connectors, and mechanically fastened bi-steel dowels [21]. The use of headed stud anchors is not suitable for lightweight concrete cores due to the low load-bearing capacity. Sohel et al. [22] carried out impact tests on SCS sandwich beams with angular shear connectors welded to the end plates. Most of the samples failed prematurely due to tensile separation of the end plates, local buckling of the end plates and crushing of the concrete core, which led to poor impact performance. Then a further improvement was made with J-hook connectors and the behavior of the static flexural strength was investigated by Liew and Sohel [2]. Based on the failure modes of simply supported SCS beams observed in Ref. [23] as well as the in-continuous beam tested in this article, a mechanical model is proposed to take into account the shear failure of deep SCS beams under concentrated loads. The model deals with (1) the power transmission mechanism of deep SCS girders after critical diagonal crack; (2) the possible modes of failure of deep beams; and (3) maximum shear strength after critical diagonal crack.

1.1 Key Concept

The binding force and the shear transmission mechanism between the cover plates and the concrete core are the two most important factors to consider when designing a lightweight sandwich system. In the anchor model of the SCS sandwich system [24], the lower steel plate acts as a tension element, the upper steel plate and the concrete in the compression zone as a compression element. Shear connectors welded to the top and bottom plate act as vertical tension members; the oblique compressive force is countered by the virtual concrete strut. In impact tests on sandwich beam samples with bolts and angled shear connectors, the concrete core was crushed and the pull-out strength of the shear connectors was lost causing the end plates to be pulled apart. and bottom panels through connectors to prevent the front panels from being pulled apart. However, if the sandwich depth is shallow, welding the straight bar connectors in ends to the steel face plates is not possible and therefore a novel connector is proposed in this study.[2]

1.2 Novel connectors for sandwich structures

In sandwich structures, mechanical connectors are required to create an effective connection between the steel decking plates and the concrete core, and the connectors must be designed to meet three basic requirements:

(1) slip resistance of the interface,

(2) prevent it from being complete be pulled out of the concrete core; and

(3) improve the shear strength of the cross-section to withstand vertical Several new types of connectors are proposed for composite SCS structures.

Different connectors which can be used in S-C-S beam are (a) Angle-Steel Bar-Angle (ASA); (b) Angle-T channel (AT); (c) Angle-Steel hoop-Angle (AHA); (d) Angle-C channel Angle (ACA); (e) U connector-Steel bar-U connector (USU); (f) Angle-I beam-Angle (AIA); (g) Angle–Angle (AA); (h) Root connector (RC); (i) U connector-Steel Cable-U connector (UCU). The new connection types proposed together with the J-hook connectors previously developed by the authors [2] are shown in Fig.2 Angle connectors or U-shaped connectors are welded to the outer steel plates to ensure that the interface is non-slip. Inserted steel rod (used in 'ASA' and 'USU'), steel rings (used in 'AHA'), C-channel (used in 'ACA'), beam 'I' (used in 'AIA' ') and the steel cable (used in 'UCU') all perform the same function, which is to connect the two steel plates of the face to avoid stress separation and to provide an improvement in the connection between the concrete core and the face. These connectors have their own merits in terms of ease of installation and the ability to withstand extreme loads without losing structural integrity. Cable and U-shaped connectors, as shown in Fig.2(i), require the least amount of steel and are relatively easy to install in a thin sandwich panel.[9]

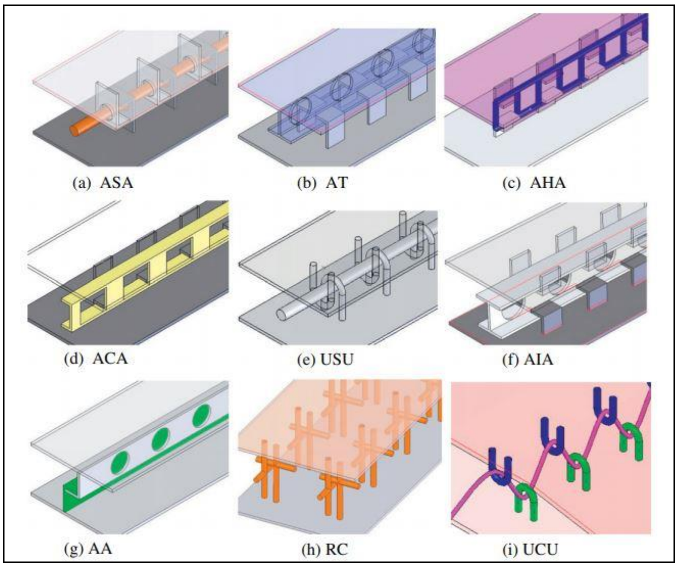

Fig -2: Proposed mechanical connectors used in SCS panel: (a) Angle-Steel bar-Angle (ASA); (b) Angle-T channel (AT); (c) Angle-Steel hoop-Angle (AHA); (d) Angle-C channel-Angle (ACA); (e) U connector-Steel bar-U connector (USU); (f) Angle-I beam-Angle (AIA); (g) Angle–Angle (AA); (h) Root connector (RC); (i) U connector-Steel Cable-U connector (UCU).[9]

2. LITERATURE REVIEW

Steel-Concrete-Steel sandwich composite structure is a relative new type of system that combines the advantages of steel and reinforced concrete structure. Due to its excellent strength to cost performance, it exhibits versatile potential applications in building and offshore constructions. Following is the brief review of researches in the Steel-Concrete-Steel (SCS) composite beam.

J.Y. Richard Liew et al. (2015) [1], considered numerical and analytical models to predict the response behavior of steel-concrete-steel multi-layer beams (SCS) subjected to light and heavy impact loads. An explicit non-linear finite element analysis was performed, and the results were verified with impact test data to determine their accuracy in predicting permanent deformation, vertical displacement over time, and impact force. The type of damage predicted by the FE model is exactly the same as the failure mode observed during the test. The J-hook connector can effectively prevent the steel plate from separating.

J.Y. Richard Liew and K.M.A. Sohel (2009) [2], examined a new concept for the design of composite structures with a lightweight concrete core between two steel plates connected by J-hook connectors, and lightweight concrete and J-hook connectors have been specially developed for this purpose. are able to withstand tensile and shear forces and their use is not limited by core thickness. Shear testing confirms that the shear transmission ability of the J-hook connector is superior to the conventional headed stud connector to provide a bond between steel plates -Samples have been tested to evaluate the bending and shear behavior under static point loading. The parameters of the degree of partial composite, concrete with and without fibers, and concrete strength are examined. On the basis of Eurocodes as the basis of assessment, a theoretical model is developed to predict the bending and shear load-bearing capacity, taking into account components that allow the construction of sandwich structures with J-hook connectors. Compared to the test results, the predicted load-bearing capacity is generally conservative if a brittle failure of the connector can be avoided. in the concrete core increases the bending ability of the beam as well as its post-peak ductility.

N. Foundoukos and J.C. Chapman (2007) [3], The finite element model is used to model the static behavior of the double steel beam, and the model is compared with the test results showing good consistency, and then it is used for the parameter study of the section strength and distributed load. -Steel beams. To isolate the transverse shear failure mode and prevent the finite element model from being used for other failure modes. In this way, the proposed lateral movement design equations can be compared and verified. On the basis of parameter research, the UDL case was also considered, and the design method was changed.

X.X. Dai and J.Y. Richard Liew (2010) [4], The test data shows that considering only the load range without considering the maximum applied load will lead to overestimation of the fatigue life of the structural multilayer system. When the difference between this value and the load range is large, the maximum applied load will have a significant impact on fatigue performance. This paper studies the static and fatigue strength of a composite sandwich system consisting of a lightweight concrete core sandwiched between two steel plates and connected by a J-connector. Finally, based on the regression analysis of the test data, a fatigue equation with three parameters considering the load range and the maximum applied load is proposed.

N.E. Shanmugam et al. (2002) [5], In the DSC panel, shear fasteners in the form of welded studs are used to transfer shear force between the outer skin of the steel plate and the concrete core. In the experimental procedure performed by the author, only 12 DSC panels were tested against the concentrated load fracture used in the intermediate cell method. The analysis showed that these panels have high bending properties, tensile strength and ductility.

Yu-Bing Leng et al. (2015) [7], In the case of deep steel-concrete-steel sandwich structural elements (SCS1), the shear behavior becomes quite critical and the failure pattern is different from that of reinforced concrete members. Tests show that the shear resistance is highly dependent on the steel plates and shear connectors, and the membrane effect of the steel plate outer sides gives the beams excellent strength and ductile performance.

Alexander Rossi and Renato Silva Nicoletti (2020) [8] pointed out that due to twisted lateral bending (LDB), local bending, or a combination of these stability modes, mixed concrete beams may fail when subjected to negative moment loads. By using ABAQUS software to develop advanced physical and geometric nonlinear numerical analysis, the negative moment resistance of mixed reinforced concrete beams is studied. The influence of several parameters is analyzed, such as the cross-section of the steel profile, the speed of the longitudinal reinforcement, the infinite length, the existence of wall stiffeners, and the distribution of negative bending moments along the span. Compare the results with standard procedures and analytical methods. It can be concluded that the cross-section and the presence of lintel reinforcement are the parameters that have the greatest impact on the strength of LDB.

Jia-Bao Yanet al. (2020) [10], has done a new type of SCS sandwich beam with improved C-channel connectors (SCSSB-ECs). Next, a nonlinear finite element (NFEM) 3D model was developed that takes into account the nonlinearities of geometry and materials as well as the complex interactions between improved C-channels (EC) and the concrete core. Parametric FE studies show that all SCSSB-ECs have a ductile flexural failure mode and a four-stage operating mechanism. the examined parameters of the final resistance behavior of SCSSBECs were reported, analyzed and compared, they showed that the thickness of the slab had the most significant influence, the concrete resistance and the shear light ratio showed mean influences and the distance of the ECs, length of C- The gutters in EC and the installation direction of the C-channels have marginal influences on the final strength behavior of the SCSSB-EC.

J. B. Yan et al. (2012) [11], This work uses new shear connectors, such as J-connectors and split connectors. In order to achieve the bond strength of SCS composite beams, its performance must be considered. Static testing was performed on a multilayer SCS beam with J-hooks and cable with U-Connector. Observe their maximum intensity values and corresponding failure modes. An analytical method was developed to predict the ultimate strength of steel-concrete-steel multi-layer beams of different types of shear connectors, and the accuracy was checked by comparison. Design guidelines for the minimum spacing between connectors are provided to avoid shear cracks and local cracks in the concrete core.

Zhang Jing et.al (2020) [13], In this paper various studies have been performed on the flexural behavior of steel-concrete composite (SCC) beams. This paper focuses on an experimental study of the longitudinal shear behavior of SCC beams, including eight SCC beam specimens and six push-out specimens. The investigated parameters were the transverse reinforcement ratio, shear connection degree, longitudinal single-row and double-row studs and stud diameter. The failure modes, concrete slab strains, steel beam strains, load-deflection and load-slip curves were investigated. In addition, the effect of the test parameters on composite beams was also compared and analysed.

K.M.A. Sohel and J.Y. Richard Liew (2014) [20], has done study of the impact performance of sandwich slab using lightweight concrete cores. The concrete core is located between two steel plates connected by a J-connector. Lightweight concrete was used and an impact test was carried out. The obtained results are compared with the test results so that the model can be used to evaluate the impact behavior of the hybrid sandwich panel.

3. CONCLUSIONS

From the literature review, the following conclusions can be drawn:

i. Novel shear connectors have been proposed for the Steel-Concrete-Steel composite beam to enhance the interfacial bond between the face plate and internal core.
ii. Test on sandwich beam subject to concentrated point load at the mid length shows that it is necessary to provide adequate shear connectors in order to delay the formation of shear cracks in the concrete core to ensure ductile failure mode.
iii. There is scope to perform experimentally, the effect of flexural behavior on S-C-S beam under four-point loading by using IS3935(1966) of composite structures.
iv. Also, there will be consideration of different parameters such as Stress -Strain behavior, Load vs deflection in the experimental performance of S-C-S beam by using U-Connector & Headed Stud Connector at varying spacing. Also, these experimental results obtained from above experimentation can be validated with finite element-based tool.

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