THIN SANDWICH COMPOSITES: A REVIEW

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Abstract -Sandwich composites have its wide spread of use in construction industry due to its easy installation, high thermal insulation and sound insulation characteristics. The major advantage of using a sandwich composite is its high strength to weight ratio. The materials required and the fabrication or manufacturing technique is chosen based on the application and industry it is used. Besides its advantages in construction industry its disadvantage is the thickness of concrete wythe when casted using steel reinforcement. As it is in contradiction with its basic property of sandwich i.e, thin face sheet and thicker core it can overcome by using textile reinforcements without scarifying the strength and other characteristics. So, this review mainly focuses on the works carried out by researchers in thin sandwich composites.

Keywords -Sandwich composite, textile reinforcement, cores, stiffness, light weight.

I. INTRODUCTION

Precast technology is now commonly used in construction industry due to its advantages. In this technique the structural elements are manufactured at factory and then transported to the site and assembled so to the skeletal system hence, the time required for construction is drastically reduced. And when the elements are casted at factory higher degree of quality control can be attained with proper supervision. Sandwich composites has wide area of application due to its high strength to weight ratio. But the materials used in manufacturing varies based on the application and are used in various construction due to its high insulation characteristics.The application of sandwich composites can be extended to various fields by reducing its size. Lot of advanced research activities are now concentrated on developing a thinner section. But while reducing its density and thickness its structural characteristics should not be affected. [1,2]. The minimum thickness of a normal reinforced concrete wythe is 80 mm and the required cover has to be provided to avoid the corrosion of the steel reinforcement embedded in the panel.The wythe thickness can be reduced than the standard one by using the non-corrosive reinforcement [3]. It can be implemented in sandwich construction to achieve the thinner section without affecting its other characteristics and leading to an advancement in the construction of sandwich composites[2,4].The non-corrosive reinforcement will be in the form of mesh which helps in reducing the cracks occurred due to loading and it behaves similar to the ferrocement panel. Specific surface and volume ratio of the reinforcement will affect the behavior of sandwich composites[5].

II. ELEMENTS OF SANDWICH COMPOSITE

In general sandwich composite consists of two face sheets of high strength to stiffness which are separated by a thick core material of low density. The sandwich face sheet and cores are of different materials and can be chosen based on its requirements as per the industrial standards. The figure.1 indicates about the elements of a structural sandwich panel.

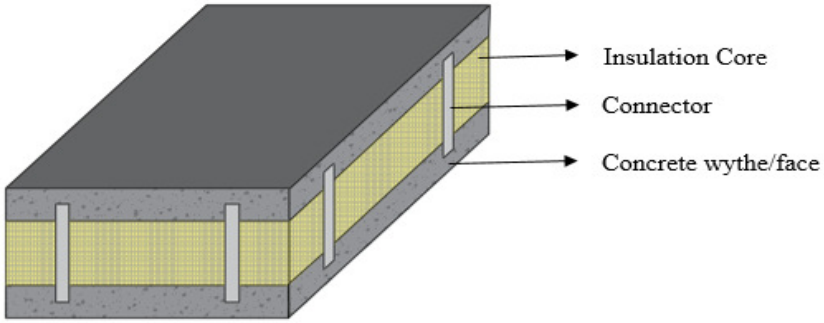

Figure 1. Elements in a sandwich panel.

2.1 Wythe

In construction industry the face sheet/skin of a sandwich composite made of concrete is called as wythe. It can be made with or without reinforcement. Face sheet in sandwich composite is commonly made of aluminium, steel, aluminium and Fiber reinforced polymers[10]. The general property of the wythe is it should be of lower thickness with high flexural performance. But when concrete wythe is made with steel reinforcements proper cover has be provided to protect the reinforcement from corrosion. The diameter of the steel rods and the clear cover will in turn increase the thickness of the sandwich panel. Textile reinforcement can be used in place of steel reinforcements to make the section thinner with good structural performance. When glass fiber is embedded in the mix of high performance concrete thinner wythe can be achieved. The flexural strength can be improved and the inclusion of fibers will reduce the plastic shrinkage and cracking [7].Using Textile reinforced concrete (TRC)with finer mixed concrete and textile reinforcements such as glass fiber, basalt fiber, carbon fiber etc… gives higher tensile and compressive strength than the plain concrete mix. So, it is considered as an alternative to steelreinforced concrete in lightweight sandwich panelsdue to their fire resistance and incombustibility[8]. Textile reinforcement helps in improving the load carrying capacity at both the wythes in tension and compression zone [8, 9].

2.2 Core

The core material is also called as insulation layer in case of a concrete sandwich composite. The basic property of the core material in a sandwich composite is it should be thicker, rigid and lighter in weight. Core material provides insulating properties to the sandwich element. So, the material chosen should be of low thermal conductivity. The core material can be of honeycomb cores, truss core,corrugated cores, truss,Z-cores, I-cores, C-cores [6].The space between two wythe can be designed using rigid foam core or as anvacuum insulated panel to provide thermal insulation.The core materials can be of rigid foam, rubber, plastic, expanded polystyrene, polyurethane, extruded polystyrene and phenolic foam. Insulation materials differ in mechanical properties and their thermal resistance depends on the type of insulation used. The type of insulation in sandwich composite system not only depends on thermal insulation, but also on various properties.[10].

2.2.1 Polymeric cores

The polymeric foam cores are more suitable for a sandwich composite due to its excellent load bearing capacity, stiffness, sound and thermal insulation characteristics. The elastic and shear modulus of core can be improved by raising its density but it interns affects the insulation characteristics[11]. The thermal conductivity of various polymeric foam cores is given in the Table 1.[12]

Table 1. Thermal conductivity of polymeric foams [12].

S.No	Polymeric core	Thermal conductivity (Wm/K)
1	Expanded Polystyrene (EPS)	0.037 – 0.038
2	Extruded Polystyrene (XPS)	0.033 – 0.045
3	Mineral wool	0.032 – 0.044
4	Polyurethane (PUR)	0.023-0.026

2.2.2 Light weight concrete

The light weight concrete and ultra-light weight concrete can be also used as a core material of a sandwich other than polymeric foams. Autoclaved aerated concrete (AAC) has distinct cellular structure with very low density and higher compressive strength. The entrained air bubbles present in it is the main cause for its improved physical properties. It is of low density with good sound and thermal insulation properties. The bonding between the textile reinforced concrete and the autoclaved aerated concrete helps in transferring the load without using shear connectors [13]. Foam concrete can also be used as core material due to its characteristics.

2.3 Connectors

The major failure mode in sandwich composite is delamination. Delamination occurs at the interface between the wythe and insulation material. Connectors are provided to avoid these types of failure.The flexural behavior of the sandwich panels gets changes in its behavior in the presence or absence of shear [5].The analytical and experimental studies done by Amran et al. [14] on the behavior of foam cored sandwich panels. And found the behavior similar to conventional RC slabs.The pin connectors used did not help in increasing the strength or stiffness but provides strength after cracking of the specimen[15]. But when shear grid made of CFRP is used it helped in increasing the ductility, load carrying capacity and stiffness. In hybrid truss system compression was mainly due to stiffness of the insulation provided and not due to the CFRP strands. Providing large number of grids than the required does not improve the ductility after cracking.

III. MANUFACTURING

The form work made of steel or timber can be used in manufacturing of a composite section with required dimension. First bottom layer of concreting has to be done to a certain height and then bottom reinforcement can be placed and remaining thickness for first layer is laid. If shear connector was used it should be placed in position while placing the bottom reinforcement. Then before setting of the concrete the insulation layer is laid. So, it helps the insulation layer to bind up with the mortar. Either it can be allowed to set and after setting of the first layer top wythe can be laid or it can be also lad in fresh state. This is the hand layup method using which the sandwich composite can be manufactured without the use of any special equipment's[16].

IV.BEHAVIOUR OF THIN SANDWICH PANELS

It is important to study the behavior of sandwich composite. The studies have been carried out by researchers in flexural behavior, shear behavior and thermal performance of a sandwich panel.

4.1 Flexural Behaviour

The flexural behavior of a sandwich element can be found using two-point loading, three point, four-point loading or six-point loading conditions. The sandwich panel can be designed as load bearing or non-load bearing element. It is mainly used as cladding so it can be retrofitted easily. And in both the cases windload acts as a uniform load on the panel so it is required to examine its flexural behavior by applying uniform pressure at the face of the panel and it acts similar to wind load [17]. In the experimental study carried out by Gopinath et al., the strain and deflection are measured at different locations and LVDT was used. The crack pattern was observed for increase in load. And strain gauges were used to determine the strains and is fixed at the top to determine the compression strains. The strain gauge fixed at the flexure side helped in determining the tensile strains. While testing the insulation buckled and got separated from the bottom wythe due to the improper bonding between two. As self-tapping screws are attached to the top bearing failure occurred [18].From the four-point bending tests conducted it is clear that it eliminates shear between both the loading points and it helps in investigating the pure bending [19].Chen et al., [20] has carried out four-point bending which resulted in failure at the ends supports due to shear. Three-point bending was conducted and found that

when the panel thickness is increased about 20% by mass the flexural rigidity and ultimate load bearing capacity of the panel was improved [21].

4.2 Shear Behaviour

The bonding between the wythe and the insulation layer can be found using the shear test. The load is to be applied to anyone layer and the slip occurs has to be recorded with respect to the load applied. When the insulated concrete sandwich panelswere connected with corrugated GFRP shear connectors in-plane shear behaviorwas studied. The pitch, width and embedded length of shear connectors is taken into account for two types of insulationmaterial.by increasing the width of the connector the strength and stiffness is increased [22].The comparative study on w shaped GFRP connectors with shear GFRP connectors and found the shear capacity was two times than the w shaped connectors and was almost approximately 2 times of truss connectors made of stainless-steel for reduced diameter and approximately 2.5 times than GFRP pin connectors [23]. The failure mechanism of the panel was shear sliding and the panel behaves as deep beam in shear analysis [24].

4.3 Thermal performance

It is important to study the thermal performance of a sandwich composite. Hot plate apparatus was used to determine the thermal performance.And Finite element modelling was used to investigate in detail about the common features in design of thin panels and potential heat loss areas. The major source of heat loss is thermal bridging about 71% of the total thermal transmittance of thin sandwich panel the tested. In normal brick masonry walls this is less than 20%. Few features of the tested design help to significantly reduce the thermal bridging effect and reduce the U-value in an optimized panel design [25]. By providing vacuum insulation with phenolic core high thermal performance for modest insulation thickness of 90mm can be achieved [7].

V. APPLICATIONS

Sandwich panel is used in the application of façades for industrial buildings and factories has gained importance in the past five decades due to the prefabrication. It can be done irrespective to several weather conditions in a reduced time during assembly [26]. Precast concrete panels are used as a common cladding to enclose the façade of structural systems, by providing the desired architectural expression, in aneconomical and practical way by uniform finishes and special shapes[27]. FRP with foams or other light weight material make the most efficient panel system due to the high thermal conductivity of conventional concrete and steel. For non-load bearing application, the existing system is sufficient for use, as it requires only minimum shear connection. But, for structural application, excellent composite behavior is required to minimize the effect of minimum thermal bridging. In order to achieve composite action in a sandwich panel using the alternative materials, economy, safety, and durability are important in line with the basic design principle. Bond slip, low shear strength, brittleness, and un-economical sections makes it uneconomical [28].

VI. SUMMARY

Sandwich panels are used mainly as claddings and wall panels due to its improved performance. The construction time is reduced as the elements are fabricated in factory and then transported to the site and assembled. The major advantage of using sandwich element is due to its high thermal insulation. It can either be load bearing or non-load bearing element. The usage of the sandwich panels can be increased by reducing the size of the section by introducing textile reinforced concrete as the face sheet without disturbing its other properties. Textile reinforced concrete improves the performance of the sandwich panel by resisting the cracks and improving the durability with proper finishing. Sandwich construction helps in constructing an energy efficient structure so the external energy used can be reduced. From the review it is clear that only limited number of studies has been done in the thin sandwich panels and its performance so, further detailed study in this field is required.

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