BUCKLING AND BENDING PERFORMANCE OF CORRUGATED SANDWICH SLABS: ANALYTICAL INVESTIGATION

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ABSTRACT

A composite corrugated sandwich slab with rectangular, trapezoidal and triangular stiffeners was proposed. This innovative solution was developed using Glass Fiber Reinforced Polymer (GFRP) material formed by three components: Top and Bottom GFRP face sheets, GFRP stiffeners. Different types of slabs using different geometric conditions was studied and their behaviour was assessed. The results showed that the proposed composite corrugated sandwich slabs has more effect on bending failure than buckling failure.

INTRODUCTION

Sandwich structures are hybrid composites. Hybrid composites are those composites which have more than one type of fiber. These are used for improving the overall property of the structure. These composites also lower the cost of conventional composites. Engineers realised that introducing sandwich structures, the overall strength and stiffness can be dramatically improved. These can be achieved without compromising the light weight property. Hence Sandwich structures offer less material requirement along with minimum cost. A typical sandwich structure consists of top face sheet, bottom face sheet and core. Top and bottom face sheet are generally considered as thin but have high strength and stiffness. Core of sandwich structure will be thick but light weight and posses sufficient stiffness. These sandwich structures can be bonded either using adhesives or by mechanical fastening. Hence a sandwich structure act as a composite load bearing unit. The basic concept of sandwich system are the facings carry bending stress and core carry shear stress. Fibers in FRP used for sandwich structures can be glass.carbon,polyester.Whereas GFRP can be chosen preferably for lower comparative cost.

Applications of sandwich structures in construction are of many. The promising material properties of such structures result in introducing sandwich system in Housing and construction. Sandwich systems are also introduced in bridge and pedestrian decks. These are used in bridge beams, floating and protective structures. The sandwich systems are also used in railway sleepers in few countries.

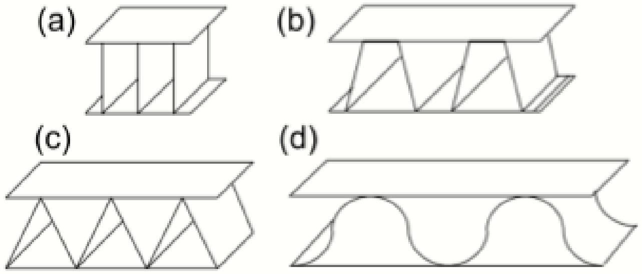

Fig.1.Types of geometry

METHODOLOGY

The innovative hybrid GFRP sandwich slabs proposed in the present paper have a GFRP panel on the bottom and top skin. Shear stresses in the proposed new hybrid sandwich panel are transferred by GFRP ribs, whereas bending stress taken by face sheets. GFRP ribs plays an important role in stress taking. Another important aspect related to the sandwich slab is the adhesive bond between layers. This adhesive bond introduced was for enhancing the shear forces transfer between layers, hence composite action maintained. According to the aforementioned reasons, these structural elements can be used in applications like slabs and beams, where a combination of relatively high flexural stiffness and low dead weight justifies the use of such materials compared to traditional ones.

Table 1 Details of specimen-1

Specimen	**L**	**b**	**h**	**ts**	**tw**	**V(m3)**
	(mm)	(mm)	(mm)	(mm)	(mm)	*10-4
RECT1	1000	225	50	3.2	2	5.5
TRI1	1000	225	50	3.2	2	5.6
TRAP1	1000	225	50	3.2	1.6	5.6
RECT1	1000	225	75	3.2	1.6	7.3
TRI1	1000	225	75	3.2	2	7.3
TRAP	1000	225	75	3.2	1.6	7.3
RECT1	1000	225	100	3.2	1.6	8.5
TRI1	1000	225	100	3.2	2	8.5
TRAP1	1000	225	100	3.2	1.6	8.5

Table 2 Details of specimen-2

Specimen	**L**	**d**	**h**	**ts**	**tw**	**V(m3)**
	(mm)	(mm)	(mm)	(mm)	(mm)	*10-4
RECT2	1500	337.5	50	3.2	2	1.2
TRI2	1500	337.5	50	3.2	2	1.2
TRAP2	1500	337.5	50	3.2	1.6	1.2
RECT2	1500	337.5	75	3.2	1.6	1.6
TRI2	1500	337.5	75	3.2	2	1.6
TRAP2	1500	337.5	75	3.2	1.6	1.6
RECT2	1500	337.5	100	3.2	1.6	1.9
TRI2	1500	337.5	100	3.2	2	1.9
TRAP2	1500	337.5	100	3.2	1.6	1.9

Table 3 Details of specimen-3

Specimen	**L**	**d**	**h**	**ts**	**tw**	**V(m3)**
	(mm)	(mm)	(mm)	(mm)	(mm)	*10-4
RECT3	2000	450	50	3.2	2	2.2
TRI3	2000	450	50	3.2	2	2.2
TRAP3	2000	450	50	3.2	1.6	2.2
RECT3	2000	450	75	3.2	1.6	2.1
TRI3	2000	450	75	3.2	2	2.1
TRAP3	2000	450	75	3.2	1.6	2.0
RECT3	2000	450	100	3.2	1.6	3.5
TRI3	2000	450	100	3.2	2	3.5
TRAP3	2000	450	100	3.2	1.6	3.4

Each component considering separately, they are relatively weak by itself, but when combined together they provide a strong and lightweight structural system. Furthermore, proper transfer of stress from the GFRP skin through GFRP rib ensured while modelling using contacts. The main aim of the paper was to obtain the bending and buckling performance of corrugated sandwich slabs.

DESCRIPTION OF SPECIMEN PARAMETERS

In this study, three set of specimens were modelled. Three geometries were used for the study Rectangle, Triangle and Trapezoid. The GFRP and HS-2101-G100 unsaturated polyester resin were used for face sheets and corrugations. Table 1,Table 2 and Table 3 lists the geometry of the components forming the sandwich panel developed. All three set of specimens were identical in face sheet thickness and web height.

Table 4 Material Properties

Mechanical property	Value
Modulus of elasticity (GPa)	20.9
Poisson’s Ratio	0.5
Tensile yield Strength (MPa)	322.9
Compressive yield Strength (MPa)	55.3

FINITE ELEMENT MODELLING

The corrugated sandwich slabs were modelled using ANSYS/WORKBENCH, which allows simulating linear and nonlinear large deformation effectively. A geometrical model with a lower number of elements, which leads to a lower numerical computation and a shorter processing time generated. Both face and core sheets were made of GFRP, which was characterized as a orthotropic material with material properties listed in Table.

The core and face sheet were meshed using SHELL 181 element. Thickness of core was assumed to be normal along its length. This rectangular element with four nodes and 6 degrees of freedom at each node can be used to analyse thin to moderately thick shell structures. Although SHELL 181 is a two-dimensional element, the sheet thickness can be added or alternated to the element properties in ANSYS. The displacement of all nodes were restricted to in-plane movements.

RESULT

BUCKLING AND BENDING LOAD LIMIT

Buckling and bending load was calculated in order to study, out of the two loads which load was having more influence on the panels. For this the buckling study was performed, and the result was compared with the bending load and its corresponding deformation.

Table 5 Buckling and Bending load limit for span 1

Specimen	**tw**	**h**	**Bending**	**Buckling**
	(mm)	**(mm)**	**Load Limit(kN)**	**Load Limit (kN)**
	1.6	50	8	25
RECT 1	1.6	75	9	22
	1.6	100	14	18
	2	50	4	8
TRI 1	2	75	8	13
	2	100	15	10
	1.6	50	13	27
TRAP 1	1.6	75	19	24
	1.6	100	16	16

Table 6 Buckling and Bending load limit for span 2

Specimen	**tw**	**h**	**Bending**	**Buckling**
	(mm)	**(mm)**	**Load (kN)**	**Load (kN)**
	1.6	50	5	21
RECT2	1.6	75	30	32
	1.6	100	76	**56**
	2	50	5	7
TRI 2	2	75	8	11
	2	100	13	20
	1.6	50	5	39
TRAP2	1.6	75	28	32
	1.6	100	76	**27**

Table 7 Buckling and Bending load limit for span 3

Specimen	**tw**	**h**	**Bending**	**Buckling**
	(mm)	**(mm)**	**Load (kN)**	**Load (kN)**
	1.6	50	4	17
RECT3	1.6	75	20	21
	1.6	100	4	6
	2	50	3	6
TRI3	2	75	7	10
	2	100	10	10
	1.6	50	5	26
TRAP3	1.6	75	56	**30**
	1.6	100	77	**30**

CONCLUSION

This paper presents the analytical studies on the sandwich panels with GFRP face sheets and webs. The buckling and bending performance of sandwich panels with GFRP face sheets and core was studied.It can be concluded that the buckling load exceeds the bending load in most of the cases except for three cases.The exception was due to the increase in span and web height which resulted in the buckling nature of specimen.Hence the specimen will be subjected to failure due to bending in those specimens where bending load is less than buckling load.Increase in ultimate bending strength of sandwich panels can be achieved by improving the performance of webs

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