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Lateral Load Resisting Performance and Seismic Behaviour of Glass Fiber Reinforced Polymer Wall Panels

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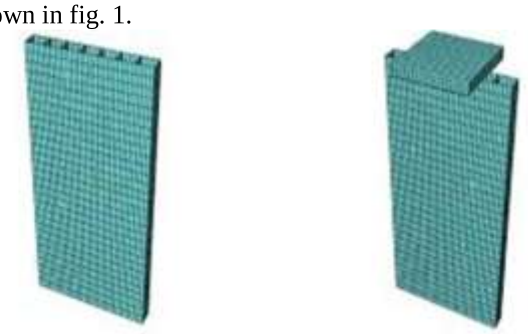
Abstract- *Glass Fibre Reinforced Polymer (GFRP) composites have attracted increasing attention in civil applications due to their light weight, high strength, and excellent corrosion resistance and durability. In structural applications, GFRP composites are mostly used to repair and strengthen existing steel and concrete structures. GFRP wall panels can be potentially used in low rise buildings in seismic areas. Considering the aspects of GFRP, in this thesis considering lateral load resistance the best model of a wall panel will be obtained by varying its geometry using finite element software ANSYS16.1. Lateral resistance and seismic performance of the obtained model without infill, concrete with microbars and concrete without microbars will be carried out. The comparison of GFRP wall panels and conventional wall panels were also conducted.*

Keywords*- GFRP wall panels, Lateral resistance, Ultra-lightweight cement composite.*

I. INTRODUCTION

Glass Fibre Reinforced Polymer (GFRP) materials have been widely used in civil engineering. They are more commonly used to strengthen existing structures. They have gained popularity in recent years because they are easy to retrofit and reduce the overall selfweight of the structure, yielding design flexibility. Compared to traditional RC walls, FRP wall panels have some advantages. Due to its high strength to weight ratio, easy application, and resistance to corrosion, FRP materials have been applied to enhance existing structural walls strength and ductility. However, the light weight nature of FRP structures also raises concern with respect to their dynamic response. Due to its light weight nature, a FRP structure has a high live load to dead load ratio, which makes the structural response more live load dependent. Furthermore, the lighter weight combined with the lower level of material damping can lead to excessive structural vibrations. GFRP can be applied to strengthen the beams, columns, and slabs of buildings and bridges. It is possible to increase the strength of structural members even after they have been severely damaged due to. GFRP are best suited for any design program that demands weight savings, precision engineering, finite tolerance and simplification of parts in both production and operation. GFRP wall panels can be potentially used in low rise buildings in seismic regions. GFRP rebar is non conductive to electricity and heat making it an ideal choice for facilities like power generation plants and scientific installations. GFRP is gaining commercial value because it is resistant to corrosive agents and does not let concrete rust or weaken. GFRP wall panels are shown in fig. 1.



(a) (b)

Fig. 1. GFRP wall panels (a) without mass (b) with mass

II. SCOPE AND OBJECTIVES OF THE STUDY

A dynamic analysis will help to check whether these panels will resist or have sufficient strength to take care of the earthquake force. It will also help to estimate how much stresses are going to effect the structure during an earthquake. The past studies are limited to the comparison of seismic performance of GFRP wall panels and conventional wall panels. The main objectives of this study are follows

- To find out the best geometry of the panel by varying the dimensions using lateral load resistance method.
- To determine the lateral load resistance of the best panel geometry without infill, concrete without microbars and concrete with microbars.
- To analyse the seismic performance of the best panel geometry without infill, concrete without microbars and concrete with microbars.
- To carry out a comparative study between GFRP wall panels and conventional wall panels.

III. FINITE ELEMENT OF GFRP WALL PANELS WITH VARYING GEOMETRY

A. Geometry

Three dimensional models were developed to demonstrate the behaviour properly. The model that is selected for the thesis can be as follows

- GFRP wall panels without infill and varying geometry: In this study, GFRP wall panels with varying

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thickness and breadth by width ratio are taken. The thickness varied from outer rib to middle. The actual thickness is 5mm.The actual breadth by width ratio is 7.5.

The GFRP panel used in the study is 61 cm wide by 122 cm long and 5mm thick made of glass fiber using pultrusion process. The weight of the whole panel is 13.6 kg. The GFRP wall panels with varying geometries are taken for analysis. Models with varying thickness and B/W ratio are taken. In the first case thickness is varied from outer ribs to middle, that is 3mm to 5mm keeping breadth by width ratio constant. In the second case thickness at centre is 3 mm and for outer one it is 8mm, keeping B/W ratio constant. In the third case thickness is kept uniform, that is 5 mm. In the fourth case thickness is kept constant , that is 4mm and B/W ratio is 6.In the fifth case also thickness is kept constant , that is 6mm and breadth by width ratio is 9.In above all cases weight remain constant. From this best geometry is found out. The cross section of GFRP wall panel with varying geometry is shown in fig.2.

B. Material Properties

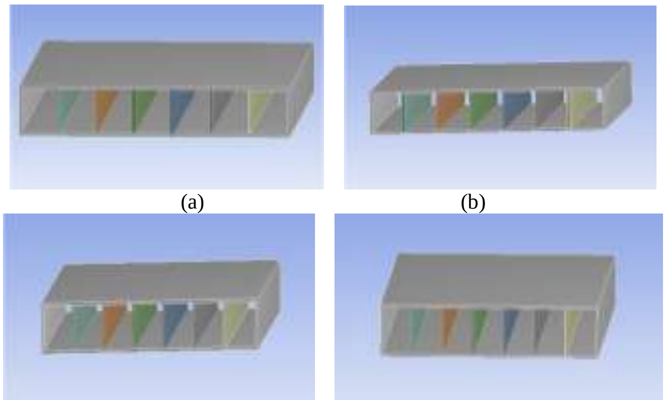
They are made of steel material with yield stress of 250 MPa, Poisson's ratio of 0.3. Bilinear isotropic hardening is used to reproduce the plastic behaviour of materials. The properties are given below in Table I.

TABLE I. Material Properties

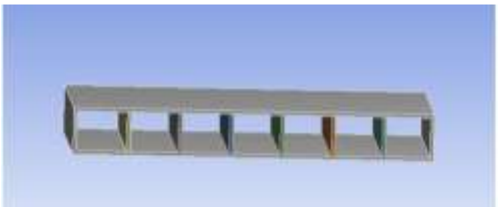
PROPERTY	VALUE
Yield strength	250MPa
Young's modulus in X direction	3650MPa
Young's modulus in Y direction	3650MPa
Young's modulus in z direction	1800MPa
Poisson's ratio	0.3

C. Modelling and Analysis

The GFRP wall panel is modelled using ANSYS Workbench16.1. A surface contact was used to explain the interaction between the wall panels. A friction coefficient of 0.1 was used to resemble a sliding greasy surface, and hard contact in the normal behavior. Pushover analysis and modal analysis are carried out. The material properties were assigned, support and loading conditions were provided. The crosssection of GFRP panels is shown in Fig. 2.



(a) (b) (c) (d)



(e)

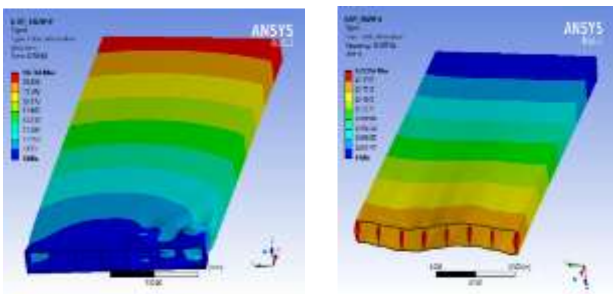
Fig. 2. Cross section of GFRP wall panels-varying thickness &breadth by width ratio (a)varying thickness 3-8mm (b) varying thickness 8-3mm (c) uniform thickness 5mm (d) uniform thickness 4mm and breadth by width ratio 6 (e) uniform thickness 6mm and breadth by width ratio 9

Every model was meshed using 20 noded Hexahedron element [Solid 186] to achieve better accuracy in nonlinear analysis. In pushover analysis, the load deflection curve were computed for each and every model .From this maximum load were found out .In modal analysis the frequency and time period computed for each model and less vibration model were noted.

D. Results and Discussions

After analysis of the structures, the results are noted. The load deformation values and frequency time period values are shown in table II and table III respectively. The fig. 3 and fig. 4 shows total deformation and load deformation curves.

- Results showed considering varying thickness and uniform thickness, the one having varying thickness shows greater strength.
- Among varying thickness, one having greater thickness for outer ribs has greater strength.
- Percentage increase of strength is 8.09 times uniform thickness. Comparing breadth by width ratio, one having higher B/W is having more strength.
- Percentage increase of strength is 27.37% times uniform thickness.
- Considering the frequencies of model with seismic mass, the frequency is less for varying thickness.
- Less frequency results in more time period which reduces vibration. Among varying thickness one having more thickness in the outer rib is having more vibration.
- Among uniform thickness one having higher B/W ratio 9 having more frequency.
- Also time period is less and hence vibration is less.



(a) (b)

Fig. 3. Total deformation (a) Pushover analysis (b) Modal analysis

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TABLE II. Load deformation values

		Deformation(mm)	Load(kN)	%Differences
T	VT_3-8	57.462	243.05	-4.16
	VT_8-3	41.13	274.16	8.09
	UT_5	52.863	253.62	1
BW	UT_5BW7.5	52.863	253.62	1
	UT_4BW-6	46.501	198.82	-21.6
	UT_6BW-9	37.89	323.04	27.37

TABLE III. Frequency and timeperiod

	Frequency(Hz)	Time period(s)	%Differences
VT_3-8	113.28	0.008827684	0.47
VT_8-3	113.84	0.008784259	-0.011
UT_5	113.83	0.00878503	1
UT_4BW-6	98.151	0.010188383	15.97
UT_6BW-9	124.94	0.008003842	-8.9

The table shows varying thickness and breadth by width ratio.That is VT_3-8 means varying thickness of 3 to 8mm.VT_8-3 means varying thickness of 8 to 3mm and UT_5 means uniform thickness of 5mm.UT_4B/W-6 means uniform thickness of 4mm and breadth bywidth ratio 6.also UT_6B/W-9 uniform thickness of 6mm and breadth by width ratio of 9.

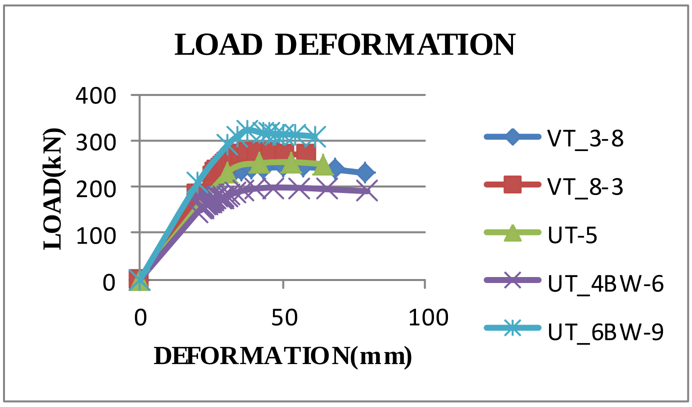


Fig. 4. Load deformation curve

IV. MODELLING OF GFRP WALL PANELS WITH INFILL

A. Geometry and Material properties

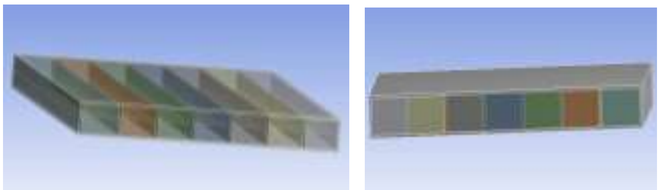
The best model was found out from varying geometry. The best model was uniform thickness of 6mm and breadth by width ratio of 9(UT_6B/W-9).

- GFRP wall panels with concrete and with microbars: The best model filled with ultra-lightweight cement composite and microbars of 4mm horizontally.
- GFRP wall panels with concrete and without microbars: The best model filled with ultra-lightweight cement composite
- A comparative study is carried out between conventional wall panels and GFRP wall panels.

They are made of steel material with yield stress of 250 MPa, Poisson's ratio of 0.3. Bilinear isotropic hardening is used to reproduce the plastic behaviour of materials.

B. Modelling and Analysis

The GFRP wall panels with infill & microbars and with infill and without microbars are modelled using ANSYS Workbench16.1. Pushover analysis and modal analysis are carried out. The material properties were assigned, support and loading conditions were provided.



(a) (b)
Fig. 5. Cross section GFRP wall panels (a) with rebar (b) without rebar

In this case both GFRP wall panels with infill and without infill are compared. Also they are compared with conventional wall panel. Here push over analysis modal analysis and time history analysis are carried out. From this best model is choosed that is one having higher load and less vibration. Fig. 5 shows cross section of GFRP wall panel with infill.

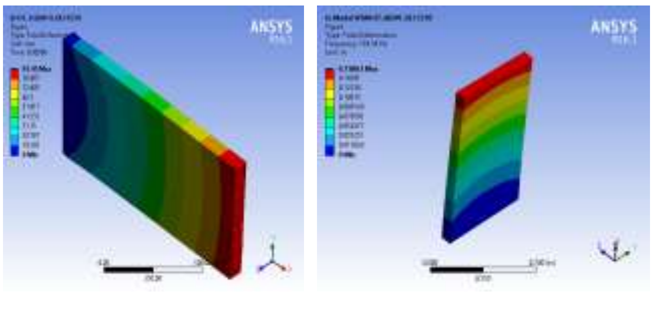
C. Results and Discussions

After the analysis of structures, the results are noted. The maximum load deformation, frequency timeperiod and directional deformation are shown in table IV, table V and table VI .Fig. 6 and fig. 7 shows total deformation and load deformation curve.

- Result showed that considering GFRP wall panels without infill, concrete with microbars and concrete without microbars, concrete with microbars shows more strength.
- Percentage increase of strength is 26.4 times than GFRP wall panels without infill.
- Considering the model, the frequency is more for GFRP wall panel with microbars.
- More frequency results in less time period and vibration.
- Comparing both this best performance is given by GFRP wall panels with microbars.
- Comparing GFRP wall panel without infill, concrete with microbars and concrete without microbars, maximum vibration exhibited by without rebars.
- Hence less vibration for concrete with microbars.

TABLE IV. Load deformation values

	Deformation(mm)	Load(kN)	%Difference
WITHOUT INFILL	37.89	323.04	1
WITH OUT REBARS	96.34	388.6	20.29
WITH REBARS	93.063	408.33	26.4



(a) (b)
Fig. 6. Total Deformations (a) Pushover analysis (b) Modal analysis

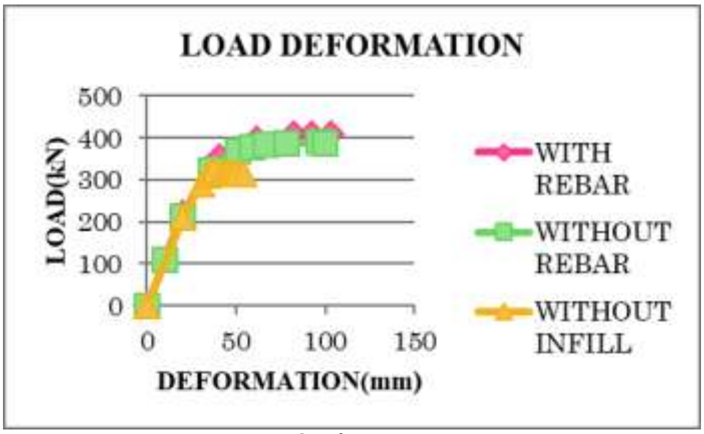


Fig. 7. Load Deformation Curve

TABLE V. Frequency and Time period

	Frequency (Hz)	**Time period (s)**	**% Difference**
WITHOUT INFILL	124.94	0.008003842	1
WITH REBAR	139.24	0.007181844	-10.27
WITHOUT REBAR	138.59	0.007215528	-9.8

TABLE VI. Directional Deformations

	POSITIVE (m)	**NEGATIVE (m)**
WITHOUT INFILL	1.87E-06	-1.77E-06
WITH REBAR	1.43E-06	-1.56E-06
WITHOUT REBAR	1.16E-06	-1.85E-06

V. CONCLUSIONS

- Considering varying geometry like thickness and B/W ratio, pushover analysis and modal analysis are carried out.
- Considering varying thickness and uniform thickness, the one having varying thickness shows greater strength and less vibration.
- Comparing breadth by width ratio ,one having higher B/W is having more strength and less vibration
- Among varying geometry ,best geometry is found out
- The best geometry is UT_6B/W_9, having more strength and less vibration.
- This geometry is filled with concrete and rebars, and also concrete without rebars
- Among various analysis like pushover analysis modal analysis and time history analysis, best results exhibited by GFRP wall panels with concrete and rebars
- It shows high strength and less vibration.
- Since light weight concrete is used it has less weight and young's modulus and hence more strength.
- Normal GFRP panels has less stiffness and mass and when concrete is filled, weight added hence strength increases and vibration decreases.
- Since ultra-lightweight cement composite is used, GFRP wall panels filled with concrete have more strength and less vibration.

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