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Pushover Analysis of Glass Fiber Reinforced Gypsum Panel as an Infill Material.

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Abstract:

Glass fibered reinforced gypsum (GFRG) panels are made from gypsum plaster reinforced with chopped glass fibers used as a rapid wall structure construction. Generally at present India country some parts considered as a high seismic zone so different methods of construction and materials are finding out which increases earthquake resistance of structure. This review paper explains the behavior of glass fibered reinforced gypsum (GFRG) panels as an infill material replaced by brick in different lateral resisting tall structure building. GFRG panels are laterally stiffened and light weight material which reduces the dead load of a building structure as compare to brick masonry. The pushover analysis using ATC-40 and FEMA-440 to glass fibered reinforced gypsum (GFRG) panel showed a lateral deformation feature and the distribution of axial forces and shear forces.

Keywords

Pushover analysis, tall structure, seismic effect, plastic rotation, lateral stiffness, lateral deformation etc.

1. Introduction

Performance of building in the recent earthquake shows that's the presence of infill wall has an important structure implication therefore in the structure role of infill cannot be neglected in the region of high seismic zone. The frame infill interaction shows increases in both lateral stiffness and strength of structure. Glass fibered reinforced gypsum (GFRG) wall a new composite wall product known as a rapid wall in construction industry first developed in Australia. The glass fibered reinforced gypsum (GFRG) panels are manufactured with size of 12m in length, 3m in height and 124mm in thickness. The density of panel is generally 1.14gm/cm^3 which are 10.12% of the weight of brick masonry. Micro beams and RCC screed (acting as T-beam) can be used as floor/ roof slab. The GFRG Panel is manufactured in semi-automatic plant using slurry of calcite gypsum plaster mixed with certain chemicals including water repellent emulsion and glass fiber roving's, cut, spread and imbedded uniformly into the slurry with the help of screen roller. The wall panels can be cut as per dimensions & requirements of the building planned. GFRG panels may generally be used in following ways:

- As lightweight load bearing walling in building (single or double storey construction) up to two storey constructions: the panel may be used with or without non-structural core filling such as insulation, sand polyurethane or lightweight concrete.
- As high capacity vertical and shear load bearing structural walling in multi-storey construction: the panel core shall be filled with reinforced concrete or panel is used with RCC beam column frame structure suitably designed to resist the combined effect of lateral and gravity loading for high rise buildings.
- As horizontal floor slabs / roof slabs with reinforced concrete micro beams and screed (T beam action). This system can also be used in inclined configuration, such as staircase waist slab and pitched roofing.

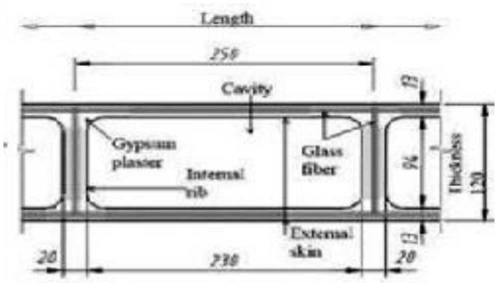

Figure1. Cross section of GFRG wall panel

2. Study on GFRG Panel

Yu-Fei Wu (2004) have conducting comprehensive experimental testing on GFRG panel to define the axial and shear behavior of glass fiber reinforced gypsum panel of standard size 2.85 m height. The width of panel specification was 1.02 m for axial load tests, 1.52 m and 2.02 m for shear load tests. Physical and mechanical properties of GFRG panel, as given by **Wu and Dare** (2004) are shown in Table 1. In his experimental studies on infill wall panel the compressive strength of unfilled wall panels was governed by the plaster strength and that of concrete filled panels was governed by out of plane buckling.

Table1. Mechanical Properties of GFRG Building Panel (Wu and Dare 2004)

S.No.	Mechanical property	Value
1	Weight	40 kg/m^2
2	Elastic modulus	3000-6000 Mpa.
3	Compressive strength	73.2 kg/cm^2
4	Tensile strength	35 kN/m
5	Flexural strength	21.25 kg/cm^2
6	Water absorption	<5%
7	Thermal conductivity	0.617

D. Menonin his research paper have carried out studies on the behavior of glass fiber reinforced gypsum wall panel in his studies they carrying axial load capacity of the wall panels using a minimum eccentricity causing out of plane bending. As per IS 456-2000, design of reinforced concrete structure take into account the actual eccentricity of the vertical force subjected to minimum value of 0.05 times the thickness of wall t. Finite element analysis of the GFRG wall panel, using plate shell elements to model both flange and webs, was carried out by using SAP 2000 NL software. In his research paper has studied the rapid affordable mass housing using Glass Fiber Reinforced Gypsum (GFRG) panels. In order to demonstrate this technology, a two storied GFRG demo building was built inside the IIT Madras campus. This building, constructed within a span of 30 days housing a total area of 1981 sq.ft, has 4 flats, two having carpet are of 269 sq.ft.

Table2. Axial Load Carrying Capacity of Unfilled GFRG Wall Panels (DevdasMenon)

Width of Panel (m)	**Numerical analysis Results (KN)**			**Experimental Result** (KN)**	
	e=0	**e=6mm (Minimum)**	**e=20mm**	**e=0**	**e=20mm**
1.02	173.7	168.7	158.1	132.4-166.7	119.6-166.7
1.52	245.3	252.4	230.1	-	-
2.02	328.7	319.6	300.0	-	-

e= Eccentricity
** Wu and Dare (2004)

3. Analytical Modeling

The frame structure was assumed to be fixed at the bottom. The column and beams of the frame structured are modeled with the help of providing diaphragm. Which means the beam at the same level act as rigid and the displaced structure of the frame is same at same level. The GFRG wall panel and masonry infill structure were modeled as one equivalent diagonal strut as frame section properties in sap2000 and hinges properties define as per ATC 40 code design as a brittle material which carries axial load only.

Three different modeling are considered as follows.

Model 1 – bare frame model, in which the strength and stiffness of GFRG wall panel and masonry infill were not considered; **Model 2 –** GFRG wall panel modeled as a single strut with using the widths of the strut calculated with ATC-40; **Model 3 –** masonry modeled as a single strut with using the widths of the strut calculated with ATC-40.

G+10 building with bare frame, Brick infill frame structure and Glass Fiber Reinforced (GFRG) panel infill frame structure were taken or the study. Three different building models with bay width of 5m in X-direction, 5m in Y-direction and story height equal to 3m were considered for this study. The structures are modeled by using computer software SAP 2000. The column section defined for the frame satisfies both the requirement for strength and stiffness. All the selected models were designed with M-25, M-30, M-35 grade of concrete are used and Fe-415 grade of reinforcing steel as per Indian standards

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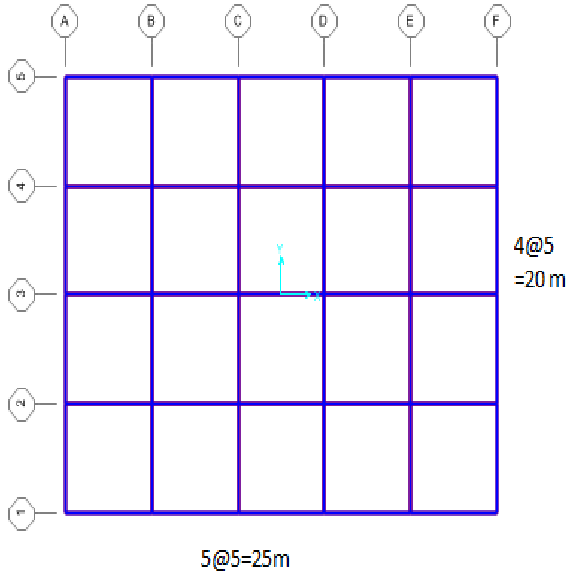

Figure2: plan of model1, model2, model3.

4. Methodology

A pushover analysis is a performance based study of a structure in which performance levels describes a limiting damage condition which may be considered satisfactory for a given building and a given ground motion. A seismic performance objective is defined by selecting a desired building performance level for a given level of earthquake ground motion. Lateral deformations at the performance point displacement are to be checked against the deformation limits of structure. Table3. Presents various performance levels maximum total drift is defined as the interstory drift at the performance point displacement. Maximum inelastic drift is defined as the portion of the maximum total drift beyond the effective yield point. For structure stability, the maximum total drift in story i at the performance point should not exceed the quantity $0.33V_i/P_i$, where V_i is the total calculated lateral shear force in story i and P_i is total gravity load.

Table3. Deformation Limits

5. Material Properties

The concrete material is used in a frame structure consisting beam and column in all three models having same dimensions and using different infill material in model 2 and modal 3. The steel reinforcing bars were considered as elastic perfectly plastic materials in both compression and tension. In modal 2 and modal 3 width of equivalent diagonal strut (w_{inf}) of infill material cab

	Performance Level			
Interstory drift limit	Immediate occupancy	Damage control	Life safety	Structural stability
Maximum total drift	0.01	0.01-0.02	0.02	$0.33V_i/P_i$
Maximum inelastic drift	0.005	0.005-0.015	No limit	No limit

be finding with the help of According to FEMA 273 in-plane masonry infill's elastic in-plane stiffness of a solid unreinforced masonry infill panel prior to cracking shall be represented with an equivalent diagonal compression strut of width, a given by equation 4.4. The equivalent strut shall have the same thickness and modulus of elasticity as the infill panel it represents.

$$a=0.175(\alpha_1 h_{col})^{-0.4} r_{inf}$$

Where

$$\alpha_1= (E_{me}t_{inf} \sin 2\beta/E_{fe}I_{col}h_{inf})^{0.25}$$

h_{col} = Column height between centerlines of beams, in.
h_{inf} = Height of infill panel, in.
E_{fe} = Expected modulus of elasticity of frame material, psi
E_{me}= Expected modulus of elasticity of infill material, psi
I_{col} = Moment of inertia of column, in^4.
L_{inf} = Length of infill panel, in.
r_{inf} = Diagonal length of infill panel, in.
t_{inf}= Thickness of infill panel and equivalent strut, in.
□□Angle whose tangent is the infill height-to length aspect ratio, radians
α_1=Coefficient used to determine equivalent width of infill strut.

Unless a more rigorous analysis is done, the expected flexural and shear strengths of column members adjacent to an infill panel shall exceed forces resulting from one of the following conditions:

1. The application of the horizontal component of the expected infill strut force applied at a distance, l_{ceff}, from the top or bottom of the infill panel equal to:

   $$L_{ceff}= a/ \cos\beta$$

   Where

   $$\tan h_{inf}/ L_{inf}$$

2. The shear force resulting from development of expected column flexural strengths at the top and bottom of a column with a reduced height equal to l_{ceff}.

From above criteria the equivalent width of the GFRG (Glass Fiber Reinforced Gypsum) panel and brick infill is modeled in **model-2** and **model-3** shown in figure. Having the properties of material calculated from IS-code

Table4. Details of the modeling.

Modal number	1	2	3
Beam dimensions b*h(mm)	450*450	450*450	450*450
Column dimensions b*h(mm)	600*600	600*600	600*600
Concrete strength of concrete (N/mm²)	25	25	25
Equivalent diagonal width (mm)	-	758.8	671.8
Live load (KN/m²)	3	3	3
Dead load of wall (KN/m)	8.85	8.85	1.449
Elastic modulus of infill material (N/mm²)	3850	3850	6000
Elastic modulus of concrete (N/mm²)	25000	25000	25000

b=width
h=depth

6. Analysis Method (pushover analysis)

The pushover analysis of a structure is a static non-linear analysis under permanent vertical loads and gradually increasing lateral loads. The equivalent static lateral loads approximately represent earthquake induced forces. A plot of the total base shear versus top displacement in a structure is obtained by this analysis that would indicate any premature failure or weakness. The analysis is carried out up to failure, thus it enables determination of collapse load and ductility capacity. On A building frame and plastic rotation is monitored, and a lateral inelastic force versus displacement response for the complete structure is analytically computed. This type of analysis enables weakness in the structure to be identified. The decision to retrofit can be taken in such studies. The seismic design can be viewed as a two-step process. The first, and usually most important one, is the conception of an effective structural system that needs to be configured with due regard to all important seismic performance objectives, ranging from serviceability considerations. The rules of thumb for the strength and stiffness targets, based on fundamental knowledge of ground motion and elastic and inelastic dynamic response characteristics, should suffice to configure and rough-size an effective structural system. Elaborate mathematical/physical models can only be built once a structural system has been created. Such models are needed to evaluate seismic performance of an existing system and to modify component behavior characteristics (strength, stiffness, deformation capacity) to better suit the specified performance criteria. The second step consists of the design process that involves demand/capacity evaluation at all important capacity parameters, as well as the prediction of demands imposed by ground motions. Suitable capacity parameters and their acceptable values, as well as suitable methods for demand prediction will depend on the performance level to be evaluated. The implementation of this solution requires the availability of as set of ground motion records (each with three components) that account for the uncertainties and differences in severity, frequency characteristics, and duration due rapture characteristics distances of the various faults that may cause motions at the site. It requires further the capability to model adequately the cyclic load-deformation characteristics of all important elements of the three dimensional soil foundation structure system, and the availability of efficient tools to implement the solution process within the time and financial constraints on an engineering problem.

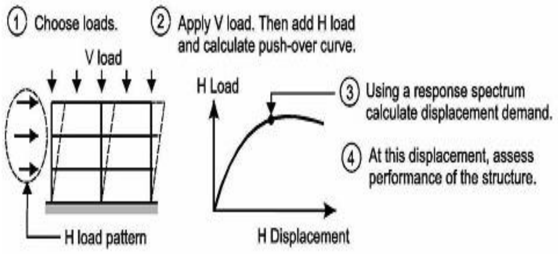

Figure3: Pushover Analysis

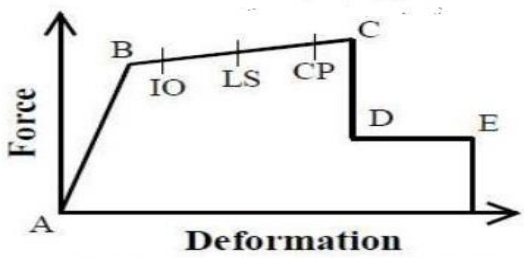

Figure4: Force-Deformation for pushover hinge

Structural performance levels and Ranges

Structural performance levels and Ranges are assigned a title and, for case of reference, a number. The number is called structural performance number and is abbreviated SP-n (where n is the designated number).
Structural performance levels-

- Immediate occupancy
- Life safety
- Structural stability (damage control)

7. Result and Discussions

From the output of SAP2000, different results obtained are prepared by graphs and is compared to find effective infill against lateral load. The effect of GFRG wall panel as a infill to give pushover results by two different method ATC-40 and FEMA-440. With more data against story displacement and story shear is studied.

7.1 Pushover Result

Table5. Target Shear and displacement from pushover curve.

Modal	Target Shear (KN)	Target Displacement (m)
Modal 1	7316.415	0.159
Modal 2	10255.695	0.143
Modal 3	13594.027	0.098

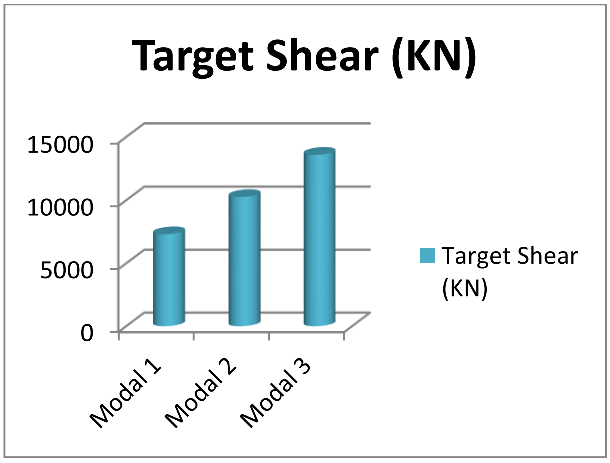

Figure5: Target shear from ATC-40

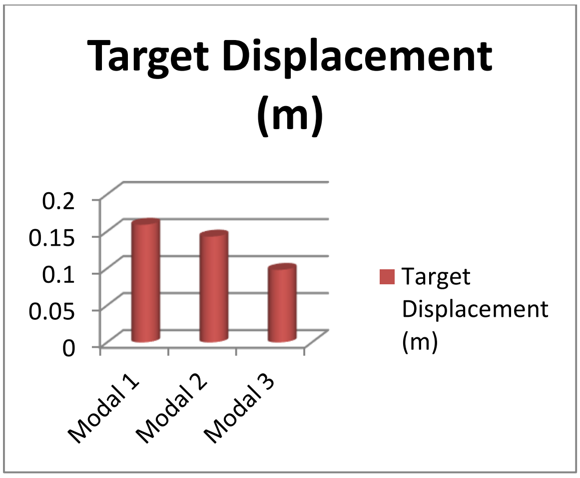

Figure6: Target displacement from ATC-40

Table6: Story displacement in X-direction

Story number	Story displacement in X direction (mm)		
	Model 1	Model 2	Model 3
Story 1	1.8	1.6	1.3
Story 2	5	4.6	3.8
Story 3	8.7	7.9	6.3
Story 4	12.4	11.2	8.8
Story 5	16	14.4	11.2
Story 6	19.5	17.4	13.5
Story 7	22.6	20.2	15.6
Story 8	25.3	22.6	17.4
Story 9	27.5	24.6	19
Story 10	29.1	26	20.1
Story 11	30.1	26.8	20.7

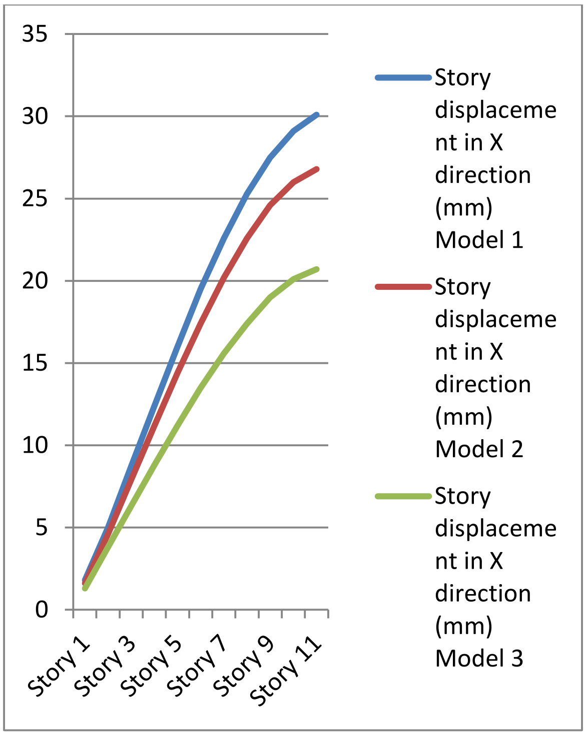

Figure7: story displacement in X-direction

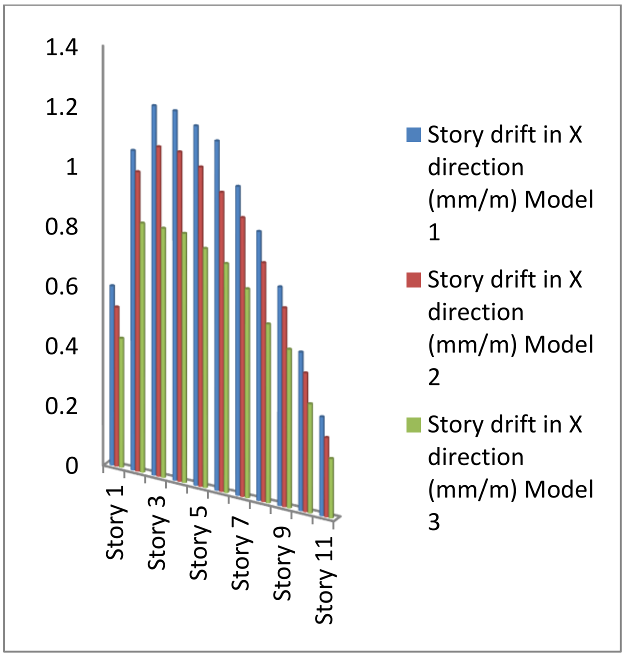

Figure8: Story drift in X-direction

Table7: Story drift in X-direction due to earthquake

Story number	Story drift in X direction (mm/m)		
	Model 1	Model 2	Model 3
Story 1	0.6	0.533	0.433
Story 2	1.067	1	0.833
Story 3	1.233	1.1	0.833
Story 4	1.233	1.1	0.833
Story 5	1.2	1.067	0.8
Story 6	1.167	1	0.767
Story 7	1.033	0.933	0.7
Story 8	0.9	0.8	0.6
Story 9	0.733	0.667	0.533
Story 10	0.533	0.467	0.367
Story 11	0.333	0.267	0.2

8. Conclusions

The following conclusions are made on the basis of analysis:

- In earthquake condition both GFRG wall panel having a story displacement is 61.63% as compare to Bare Frame and Brick infill frame.
- Story shears increases from bare frame to Brick infill and GFRG wall panel structure.
- Performance level total storey drift of GFRG wall Panel infill is fall in Damage control where Brick infill and Bare frame in life safety condition.
- Inelastic drift limit is only occurring in GFRG wall panel infill in damage control condition.
- Due to 16.37% weight of Brick wall structure having same dimension GFRG wall panel also reduce the overall structural weight of the building.

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