

# Effect of Openings on Performance of GFRG Panel

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**ABSTRACT:** Glass fiber reinforced Gypsum (GFRG) panel is a new building panel product, where there is a tremendous need for cost-effective mass-scale affordable housing. GFRG panel otherwise called Rapidwall, is a vitality effective green building material with gigantic potential for use as load bearing and non load bearing wall panels. They are load bearing panels with cavities suitable for both external and internal walls. It can likewise be used as intermediate floor slab/roof slab in combination with RCC as a composite material. They are not only eco-friendly, but also resistant to termites, heat, rot, corrosion, water and fire. Concrete infill with vertical reinforcement rods enhances its vertical and lateral load capabilities. Light weighted Rapid wall has high compressive strength, shearing strength, flexural strength and ductility. Sometimes openings have to be provided in these floor slabs, but its effect on the response of GFRG panel is not fully explored. Furthermore there is a lack of sufficient information about the load carrying capacity of GFRG slab panel with opening. This thesis investigates the structural behaviour of GFRG slab panel with openings for different slab breadth ratios, different opening ratios and different loading distances. For this different models of panel with opening were modelled in finite element software ANSYS WORKBENCH 15.0. This project includes the Determination of range and distribution of Displacements and Ultimate load carrying capacity.

**KEYWORDS:** GFRG Panel, slab breadth ratios, opening ratios, loading distances.

## I. INTRODUCTION

Glass fibre reinforced gypsum, GFRG, better known as Rapid wall in the industry is a new building panel product, made of gypsum plaster, reinforced with glass fibres. GFRG is of particular relevance to India, where there is a need for cost-effective mass-scale affordable housing, and where gypsum is abundantly available as an industrial by-product waste. The product is eco-friendly or green, resistant to water and fire. GFRG panels are presently manufactured to a thickness of 124 mm, a length of 12m and a height of 3m. Although its main application is in the construction of walls, it can also be used in floor and roof slabs in combination with reinforced concrete. IIT Madras has been involved, since 2003, with the development of building systems especially with respect to use of GFRG panels as floor slabs and earthquake resistant design for use in India. The panel contains cavities that may be filled with concrete and reinforced with steel bars to improve additional strength and provide ductility. Experimental studies and research have shown that GFRG panels, suitably filled with reinforced concrete, possess great strength to act as load-bearing elements, and as shear walls, capable of resisting lateral loads due to earthquake and wind. It is possible to design such buildings up to ten storeys in low seismic zones and to lesser height in high seismic zones. However, such construction needs to be properly designed by a qualified structural engineer.

The threat of climate change caused by the increasing amount of greenhouse gases in the atmosphere is impelling the whole world into a disastrous crisis situation with universal concern. The requirement of this century is for green, energy efficient and eco-friendly products. The building industry counts for 40% of CO<sub>2</sub> emissions. Building construction causes CO<sub>2</sub> emissions as a result of embodied energy consumed in the production of energy intensive building materials and also the recurring energy consumption for cooling and heating of indoor environment. GFRG panel or Rapid wall is of specific relevance to India, where there is a tremendous need for cost-effective mass-scale

# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: [www.ijirset.com](http://www.ijirset.com)

Vol. 6, Issue 5, May 2017

affordable housing, and where gypsum is abundantly available as an industrial by-product waste. The product is not only eco-friendly or green, but also resistant to water and fire. This study aims at achieving the goal of development of alternative building material for better economic and structural benefits.

Paper is organized as follows. Section II describes the studies related to GFRG panel and its properties. Modelling and analysis of GFRG panel with varying opening sizes and loading distances are given in Section III. Section IV presents Analytical results showing Deformed shape and load deflection diagram. Finally, Section V presents conclusion.

## II. RELATED WORK

Conventional Building materials used in our construction industry consume intense energy and energy calculated or annual energy is more that is consumed by the buildings in order to meet the different needs associated with its typical use and shall reflect the heating energy needs and cooling needs. These buildings are not energy efficient. The demand of building materials like river sand, aggregate is growing and same time the cost is spiraling up. Construction is time consuming. Therefore there is a need for an alternative building Materials and fast construction methods for housing. Thus GFRG panel is most effective building material for this condition.

Panels that have higher reinforcement exhibit shear-dominant behaviour, while those having lesser reinforcement exhibits flexure-dominant behaviour. The GFRG wall panels showed continued increase in energy dissipation despite substantial reduction in the lateral load capacity in the post-peak region, indicating gradual failure. GFRG panels can be used with confidence as it has the potential for adequate strength, stiffness, ductility and energy dissipating capacity, if suitably designed. Because of higher ductility ratio, this can be used as an efficient structural system. (Devdas Menon and A Meher Prasad, 2013). Rapidwall Panel provides a new method of building construction in fast track, fully utilising the benefits of prefabricated, light weight large panels with modular cavities and time tested, conventional cast-in-situ constructional use of concrete and steel reinforcement. By this process, man power, cost and time of construction is reduced. The use of scarce natural resources like river sand, water and agricultural land is significantly reduced. Rapidwall panels have reduced embodied energy and require less energy for thermo-regulation of interiors (FACT RCF Building products Ltd). GFRG, in its short life, without extensive product development and comprehensive structural design guidelines, has been used as the principal wall construction material in more than 3,000 dwellings across Australia. As GFRG walls find more and more applications and interests in the building industry in Australia as well as in other countries, comprehensive structural design guidelines for GFRG walls and their building system have become necessary. Comprehensive experimental testing and theoretical studies started in 2002 as an international research and development program to develop structural design guidelines for GFRG walls (Yu-Fei Wu and Mike P. Dare, 2004)

## III. MODELLING AND ANALYSIS OF GFRG PANEL WITH OPENINGS

Modelling of the GFRG panel was done using ANSYS WORKBENCH 15.0 which was capable of undertaking material and geometric nonlinearities. GFRG panel is modelled using SOLID 185, the reinforcements were modelled using LINK 180 property and concrete was modelled using solid 65. GFRG panel with 50mm screed concrete is chosen for finite element modelling. Microbeam consists of reinforcement having size 12mm diameter and screed concrete having wire mesh of size 10 gauge.

Modelling was completed satisfying the actual parameters like engineering property and geometry. Openings are introduced to facilitate building services. Openings of different shapes are commonly used. Openings cause a significant reduction area of the specimen. This reduction in the area causes an overall reduction in the load carrying capacity of the member and thereby effects the ultimate load carrying capacity of the member which includes cross sectional area of the member, size of the openings and the location of the openings.

Element types used in ansys software are, SOLID 65

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Vol. 6, Issue 5, May 2017

SOLID 65 is used for the three-dimensional modelling of solids with or without reinforcing bars. The solid is capable of cracking in tension and crushing in compression. In concrete applications, the solid capability of the element may be used to model the concrete while the rebar capability is available for modelling reinforcement behaviour. Other cases for which the element is also applicable would be reinforced composites (such as fiberglass) and geological materials (such as rock). The element is defined by eight nodes having three degrees of freedom at each node: translations in the nodal x,y and z directions.

**LINK 180**

LINK 180 is a 3-D spar that is useful in a variety of engineering applications. The application can be used to model trusses, sagging cables, links, springs and so on. The element is a uniaxial tension-compression element with three degrees of freedom at each node: translations in the nodal x,y,z directions. Tension-only and compression-only options are supported. Plasticity, creep, rotation, large deflection and large strain capabilities are included.

**SOLID 185**

SOLID 185 is used for the three dimensional modelling of solid structures. The element is defined by eight nodes having three degrees of freedom at each node: translations in the nodal x,y and z directions. The element has plasticity, stress stiffening, large deflection and large strain capabilities.

Material properties used in the analysis are,

Table 1 Material properties for concrete

Youngs Modulus	27386 MPa
Poisson's ratio	0.2
Bulk modulus	1.5214E+04MPa
Shear modulus	1.1411E+04MPa

Table 2 Material properties for steel

Youngs Modulus	2.06E+05MPa
Poisson's ratio	0.3
Bulk modulus	1.7167E+05MPa
Shear modulus	7.9231E+05MPa
Yield strength	415 MPa
Tangent modulus	20.00 MPa

Table 3 Material properties for GFRG

Youngs Modulus	7500 MPa
Poisson's ratio	0.24
Bulk modulus	4.8077E+03MPa
Shear modulus	3.0242E+03MPa

Analysis was done by altering the geometry by applying different slab and opening breadth ratios, opening ratios and varying loading distances from the centre of opening. Loading is applied with the help of 25 mm thick bearing plates. Quarter portion of the GFRG panel is considered for the analysis.

Opening size was determined by using slab panel breadth ratio and opening size ratio.

$$\begin{aligned} \text{Taking } b/B &= 0.125 \\ & \quad b - \text{Breadth of opening} \\ & \quad B - \text{Breadth of slab panel} \\ \text{Therefore } B &= 2000 \text{ mm} \\ b &= 250 \text{ mm} \end{aligned}$$

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Taking	$l/b$	$=$	$1$	
Therefore	$l$	$=$	$250$ mm	
Opening size,	$l \times b$	$=$	$250$ mm x $250$ mm	
The slab panel is named as S1				
Taking	$b/B$	$=$	$0.25$	
			$b$ – Breadth of opening	
			$B$ – Breadth of slab panel	
	$B$	$=$	$2000$ mm	
Therefore	$b$	$=$	$500$ mm	
Taking	$l/b$	$=$	$1$	
Therefore	$l$	$=$	$500$ mm	
Opening size,	$l \times b$	$=$	$500$ mm x $500$ mm	

The slab panel is named as S2

The loading on the bearing plate varies at a distance 500,650 and 800 mm from the centre of the opening

## IV. ANALYTICAL RESULTS

From the analysis, Ultimate load carrying capacity and Deformation are obtained. Figures shows the results of Analysis of GFRG Panel with openings by ANSYS WORKBENCH15.0 Figs 1 (a) shows Deformed shape of S1500 (b) Deformed shape of S1650 (c) Deformed shape of S1800

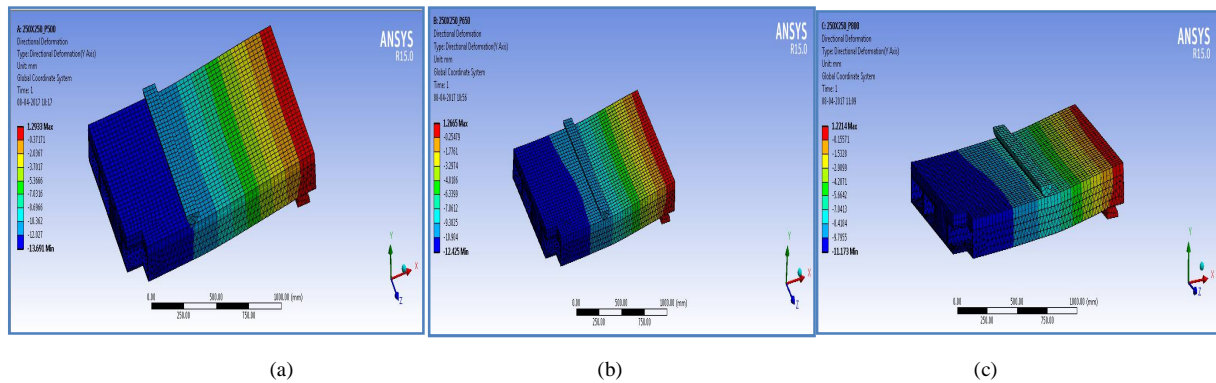


Fig. 1. Results (a) Deformed shape of S1500 (b) Deformed shape of S1650 (c) Deformed shape of S1800

Figs 2 (a) shows Deformed shape of S2500 (b) Deformed shape of S2650 (c) Deformed shape of S2800

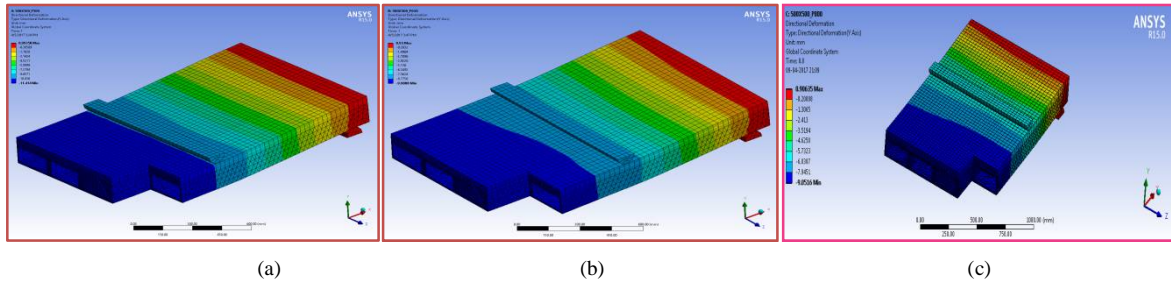


Fig. 2. Results (a) Deformed shape of S2500 (b) Deformed shape of S2650 (c) Deformed shape of S2800

Figs 3 (a) Load deflection graph of slab with opening size 250x250mm (b) Load deflection graph of slab with opening size 500x500mm

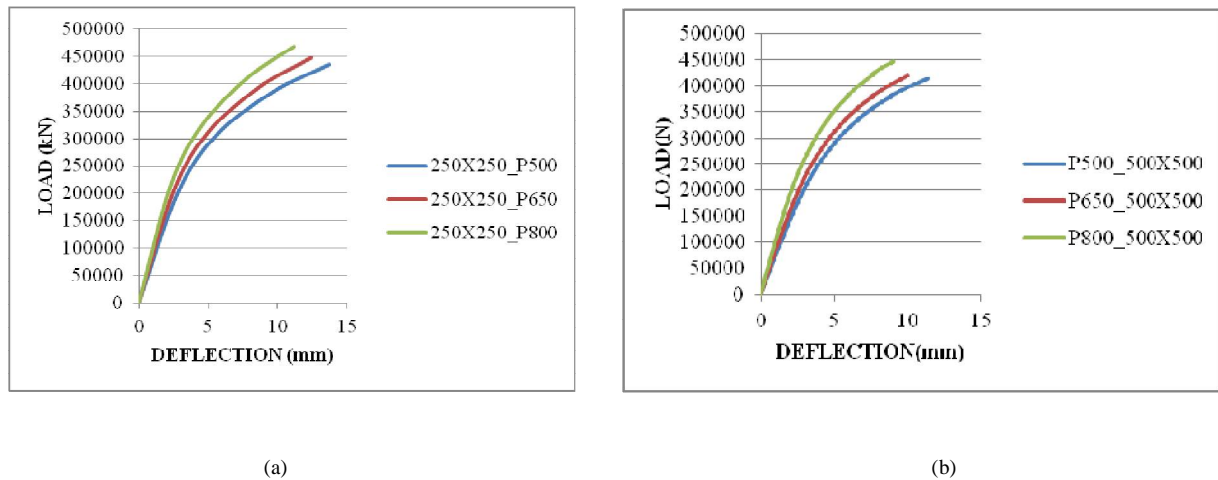


Fig. 3. Load deflection graph (a) Opening size 250 x 250mm (b) Opening size 500 x 500mm

Considerable increase in Ultimate load carrying capacity is observed when analysed the slab panel with opening 250 x 250 mm and 500 x 500 mm with varying loading distances. The loading distance make considerable increase in the ultimate load carrying capacity of the section.

### V. CONCLUSION

It is concluded that as opening size increases, the ultimate load carrying capacity decreases. At the same time, as b/B Ratio increases, the ultimate load carrying capacity also decreases. There is 5 % decrease in the ultimate load carrying capacity when b/B ratio increases. As loading distance increases by 150mm, Ultimate carrying capacity increases about 2-6%. Area of openings having 1.04% to 4% of slab area, the reduction in load carrying capacity is about 7.5% to 8.15%.

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Website: [www.ijirset.com](http://www.ijirset.com)

Vol. 6, Issue 5, May 2017

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