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Analysis and Design of Multistorey R.C. Frame Using FRP Reinforcement

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ABSTRACT

The use of fibre reinforced polymers (FRP) as construction materials is gaining acceptance in the construction industry. The primary reason for this increase is the superior performance of FRP reinforcement in corrosive environments, its long term durability, high tensile strength-to-weight ratio, electromagnetic neutrality and resistance to chemical attacks. The use of FRP bars as concrete reinforcement is relatively new, with very few applications in practice, although externally applied FRP sheets, strips and bars for rehabilitation and seismic retrofit purposes is not uncommon. There is lack of research in performance and design of new FRP reinforced concrete structures; particularly for seismically active regions. The use of FRP bars as reinforcement is a new concept with limited experimental and analytical information. The main purpose of this research is to study seismic behavior of multi-storey, multibay structure by using GFRP reinforcement using nonlinear pushover analysis. Pushover analysis was carried out using ETABS 9.7.4 software and using M3 and V2 hinges for beams and P-M-M hinges for columns.

Keywords: Seismic Analysis, FRP Reinforcement, Nonlinear Pushover Analysis, ETABS.

1. INTRODUCTION

Fibre Reinforced polymer is a group of advanced composite materials. FRP are not an invention but the result of steady evolution. This evolution was initiated by a variety of industries for engineering applications. Today FRP are indispensable materials for aircraft, automobiles and for many types of sports gear. “FRP” is an acronym for fibre reinforced polymers, which some also call fibre reinforced plastics. The term composite material is a generic term used to describe a combination of two or more materials that yields a product that is more efficient from its constituents. One constituent is called the reinforcing or fibre phase (one that provides strength); the other in which the fibres are embedded is called the matrix phase. The matrix, such as a cured resin-like epoxy, polyester, vinyl ester, or other matrix acts as a binder and holds the fibres in the intended position, giving the composite material its structural integrity by providing shear transfer capability. The structural concrete industry is the beneficiary of this evolution. The development of reinforcement technology is becoming more advanced as engineers are not just using steel reinforcement in concrete in their design. In recent years, Fibre Reinforced Polymer (FRP) has been proposed as one of the main material in reinforced concrete.

In past lot of research work is reported on the seismic analysis of structure by using GFRP reinforcement. Radhika J. Popat, Rajul K. Gajjar (2013) investigated seismic performance of beam-column joints using GFRP bars in multi-storey building using ETAB software. This study deals with evaluation of concrete beam-column joints reinforced with GFRP bars in a multibay, multi-storey building, under seismic load using pushover analysis. Performance of joints in a five, eight and ten Storey building with reinforcing bar ratio as a varying parameter and having centre of mass equal to centre of stiffness has been studied. Pushover analysis was carried out using ETABS using M3 and V2 hinges for beams and P-M-M hinges for columns. The results reveals that building reinforced with GFRP bars, fails at higher displacement than Steel because of low modulus of elasticity. Shabana T S & Dr. K.A Abubaker (2015) have presented finite element analysis of beam column joint with GFRP under dynamic loading. In this study first model and analyse G+4 office building using ETABS. Beam column joints were manually designed on the basis of both IS456:2000 and IS13920:1993 by using structural data available from ETABS. Four exterior reinforced concrete beam column joint specimens were modelled using ANSYS package. The first specimen had reinforcement as per code IS 456:2000. The second specimen had reinforcement as per code IS 13920:1993. The third specimen had reinforcement as per code IS 456:2000 and was wrapped with GFRP sheets. The fourth specimen had reinforcement as per code IS 13920:1993 and was wrapped with GFRP sheets. During the analysis both the ends of column were hinged. Static load was applied at the free end of the cantilever beam up to a controlled load. The efficiency of confining the reinforced beam column joints with GFRP sheet wrapped at the beam column joint under dynamic loading and the results are presented. The

percentage of increase in efficiency of wrapped over unwrapped is found to be 37% for beam column joint designed as per IS 456:2000 and 20% for designed as per IS 13920:1993 and also Aly M Said & Moncef L Nehadi (2004), B. Binici and G. Ozcebe (2006), Biswarup Saikia & Phanindra Kumar (2007), S. Cimilli Erkmen & M. Saatcioglu (2008),Ramadass S & Job Thomas (2010) are some of the important researchers. In above research overall behavior of structure was not considered by the authors. Further investigation is required to evaluate the overall seismic behavior of GFRP reinforced concrete frame.
The need for present study is to check the suitability of fibre rebar's as a main reinforcement in concrete structures and accordingly to study the performance of frame. The aim of the present study is to investigate the seismic behavior of multistoried RC framed buildings with steel as a reinforcement and glass fibre polymer rebar as reinforcement. For this purpose buildings having generic plan with P+7, P+9 and P+11 storied height, situated in very severe seismic zone and in soil type-II (medium soil) is considered. Non-linear seismic analysis is carried out on different types of framed building models to study the various seismic parameters.

2. MATERIAL PROPERTIES

The mechanical properties of reinforcing bars used are listed in Table 1.

Table 1 Mechanical Properties of Steel and GFRP

Properties	Densities g/cm3	Yield Stress Mpa	Tensile Strength Mpa	Elastic Modulus Mpa	Yield Strain %	Rupture Strain %
Steel	7.90	276-517	483-690	210	0.14-0.25	6.0-12.0
GFRP	1.25-2.1	N/A	483-1600	35-76	N/A	1.2-3.1

3. METHODOLOGY

3.1. Building and Loading

I. Low and high rise reinforced concrete frame buildings.
II. Application of gravity as well as earthquake loads.

3.2. Modelling and Analysis Method

I. Space frame modelling for analysis using ETABS.
II. Analysis by Non-Linear Pushover Analysis Method.

3.3. Non-Linear Pushover Analysis

Pushover analysis which is an iterative procedure is looked upon as an alternative for the conventional analysis procedures. Pushover analysis of multi-story RCC framed buildings subjected to increasing lateral forces is carried out until the preset performance level (target displacement) is reached. The promise of performance-based seismic engineering (PBSE) is to produce structures with predictable seismic performance. The recent advent of performance based design has brought the non-linear static pushover analysis procedure to the forefront. Pushover analysis is a static non-linear procedure in which the magnitude of the structural loading along the lateral direction of the structure is incrementally increased in accordance with a certain pre-defined pattern. It is generally assumed that the behavior of the structure is controlled by its fundamental mode and the predefined pattern is expressed either in terms of story shear or in terms of fundamental mode shape. With the increase in magnitude of lateral loading, the progressive non-linear behavior of various structural elements is captured, and weak links and failure modes of the structure are identified. In addition, pushover analysis is also used to ascertain the capability of a structure to withstand a certain level of input motion defined in terms of a response spectrum.

3.3.1 Pushover Methodology

ATC 40, FEMA 273, FEMA 356 and FEMA 440 have described the pushover analysis procedure, modeling of different components and acceptable limits. Two methods, namely Capacity Spectrum method and Displacement Coefficient method are introduced in FEMA 440. The pushover analysis procedure considers only first mode shape of the equivalent single degree of freedom system. This is the limitation of this method. Still it is very efficient analysis procedure because it gives insight of the nonlinear behavior of the structure. A key requirement of any meaningful performance based analysis is the ability to assess seismic demands and capacities with a reasonable degree of certainty.

4. PROBLEM FORMULATION

P+7, P+9 and P+11 storey reinforced concrete frame with steel and GFRP bars is analyzed according to Indian code of practice IS 456-2000 and IS 1893-2002. The plan of frame as shown in Figure 1. The study is performed on bare, soft storey and full masonry infill type frames along with steel and GFRP reinforcement.

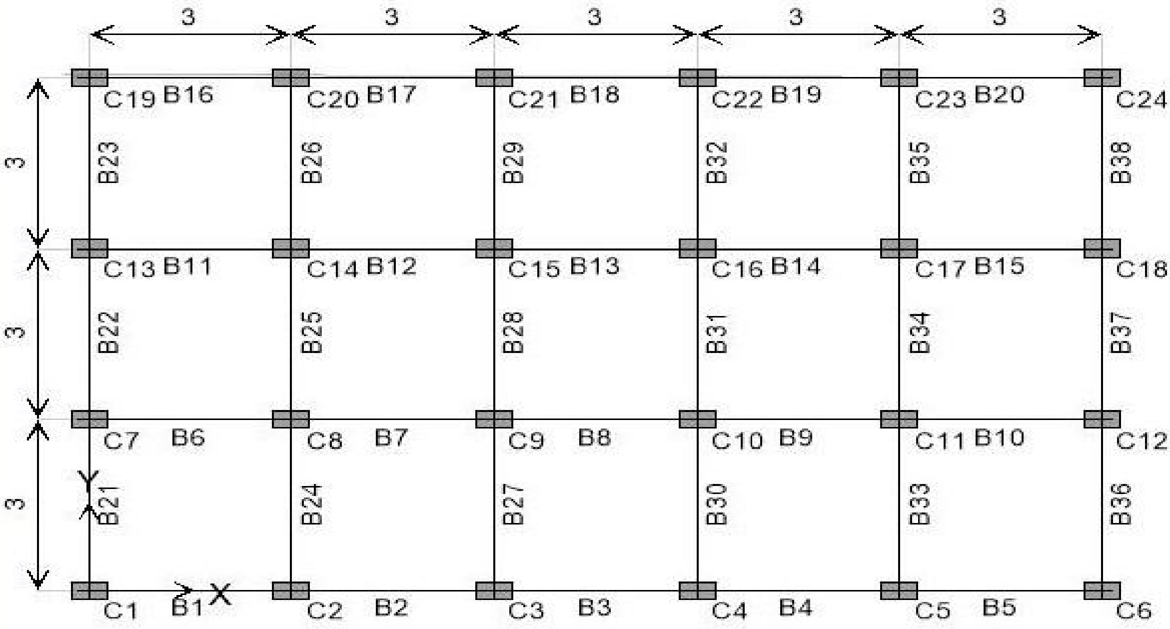

Figure 1. Plan of Frame

Various design seismic parameters of selected frame is listed in Table 2 are as follow:

Table 2 Design Seismic Parameters

A) Geometric Parameters		**B) Earthquake Parameters**	
Plan Dimensions	: 15m X 9m	Zone	: V
Storey Height	: 3.2m	Type of Soil	: Medium
No. of Storey	: 8, 10, 12	Importance Factor	: 1
Spacing in X and Y Direction	: 3m	Reduction Factor	: 5
Thickness of Slab	: 120mm		
Grade of Concrete	: M25		
Live Load	: 4 KN/m2		
Floor Finish	: 1 KN/m2		

5. RESULTS AND DISCUSSIONS

In ETABS rigid diaphragm is provided to each storey levels for same value of displacement shown by all joints of particular storeys. The graphs of storey level v/s maximum displacement is shown in Figure 2, 3 and 4. It is observed that building reinforced with glass fibre reinforced polymer bars reinforced frames fails at higher displacement than steel frame due to low modulus of elasticity of Glass Fibre Reinforced Polymer bars. If the modulus of elasticity is low for material the strain is more for same stress as compared to material having high modulus of elasticity (i.e. steel) and the large deformation shown by GFRP bars, allows the GFRP reinforced frames to dissipate seismic energy.

The inter storey drift demand at each storey is shown in Figure 5, 6 and 7. The drift demands for glass fibre reinforced polymer reinforced concrete building frame were comparable to those obtained for steel reinforced concrete building implying that similar performance level can be attained during moderate to strong earthquake.

The performance point for bare, soft storey and full infill models is shown on Table 3. From Table 3 it is observed that frames with GFRP attracts more base shear as well as displaced more than steel reinforced frames.

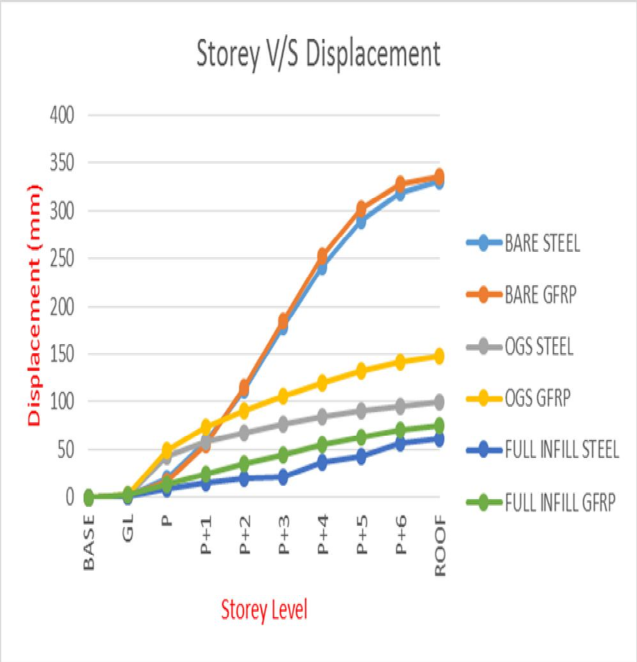

Figure 2. Max. Displacement at each storey for P+7 model

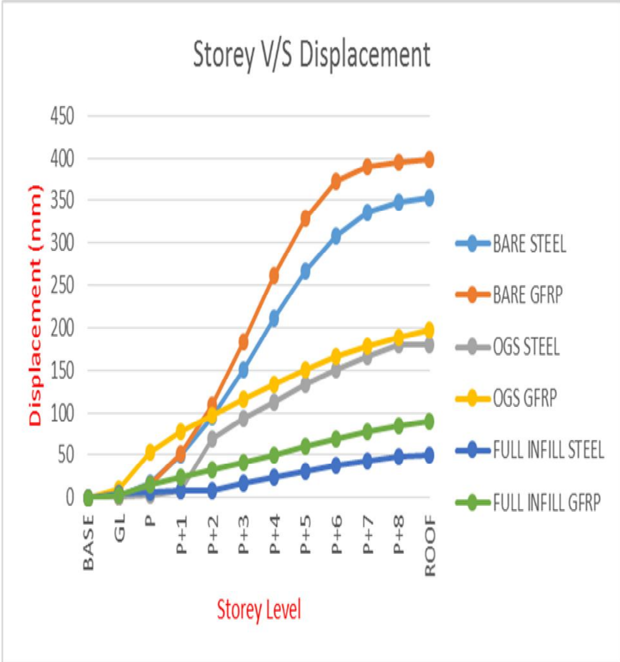

Figure 3. Max. Displacement at each storey for P+9 model

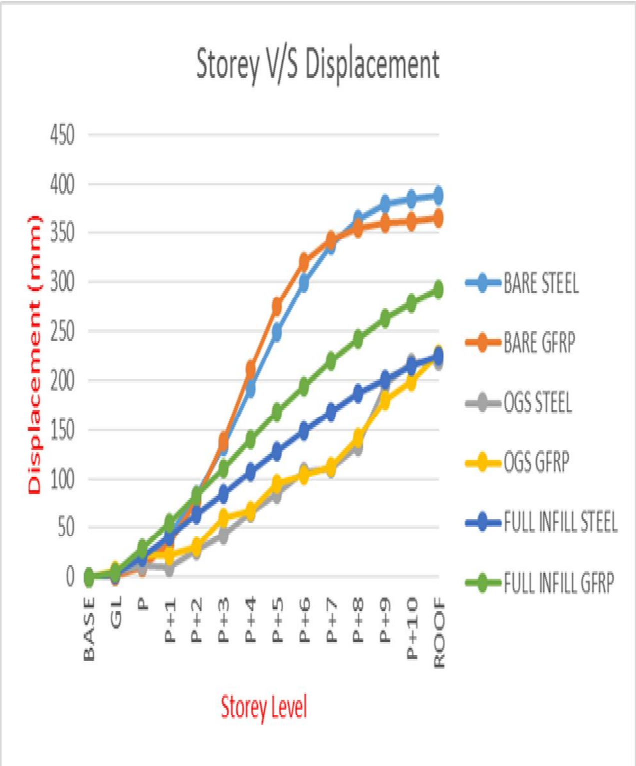

Figure 4. Max. Displacement at each storey for P+11 model

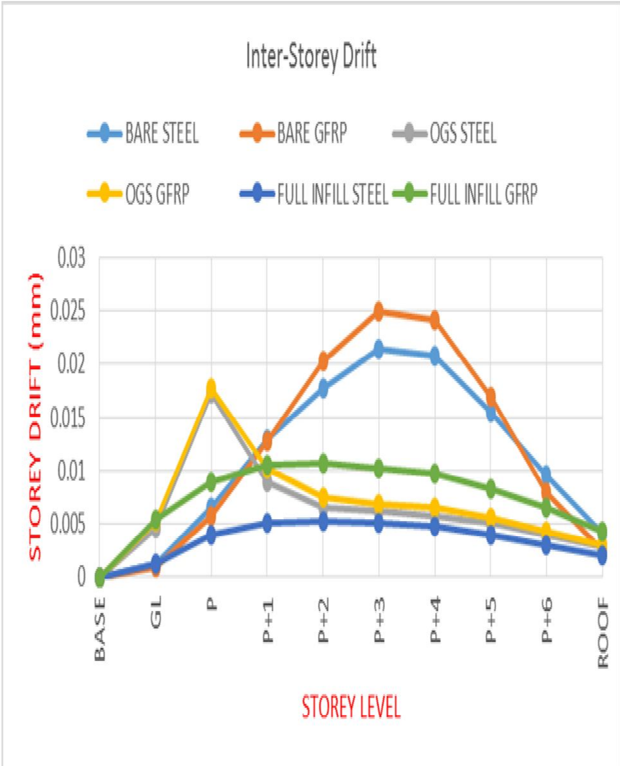

Figure 5. Storey Drift at each storey for P+7 model

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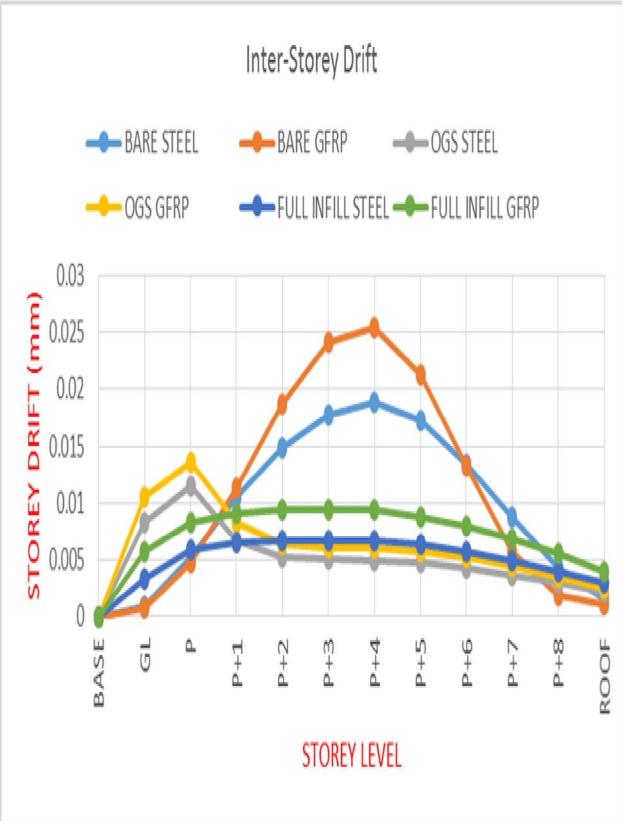

Figure 6. Storey Drift at each storey for P+9 model

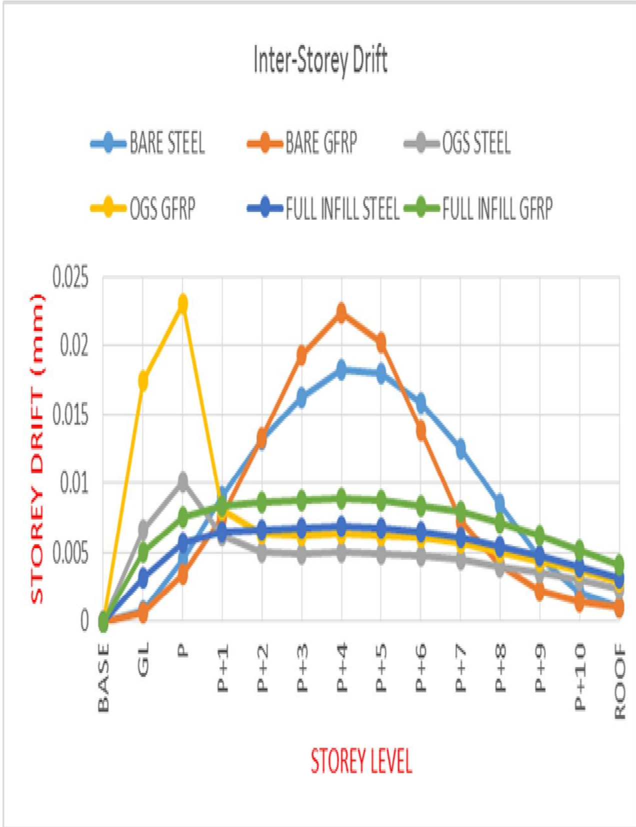

Figure 7. Storey Drift at each storey for P+11 model

Table 3 Performance Point of Frame

Type of Frame	Height of Frame	REINFORCEMENT TYPE			
		STEEL		GFRP	
		Base Shear (KN)	Displacement (mm)	Base Shear (KN)	Displacement (mm)
Bare	P+7	2088.984	120.986	2213.468	132.208
	P+9	1947.119	153.837	2093.301	163.115
	P+11	1861.193	183.517	2021.689	184.589
Soft Storey	P+7	6937.977	91.172	7248.017	91.831
	P+9	6879.624	113.849	7148.371	115.659
	P+11	6652.387	140.526	6972.715	143.119
Full Infill	P+7	7787.27	84.375	7985.003	86.185
	P+9	7250.081	110.943	7630.699	111.241
	P+11	6873.886	138.304	7268.921	147.546

6. CONCLUSION

- Load carrying capacity of GFRP reinforces frames is higher than steel reinforced frames.
- The base shear of bare frame is lower than that of base shear of infill frames in both type of reinforcement. This is due to presence of infill masonry increases mass and stiffness of infill frames.
- Due to anisotropic behavior of GFRP bars lateral stiffness of frames increases and hence it attracts more base shear force as compared to steel reinforced frames.
- As we go for higher storey level it is observed that GFRP reinforced frames are performing very well hence GFRP bars can be effectively used for high rise buildings.

- For different frame types Glass Fibre Reinforced Polymer reinforcement has yielded not only greater flexural strength to the beams but also good shear capacity and bending moments.
- In bare frame analysis, absence of strength and stiffness effect of masonry infill leads to underestimation of base shear and this will cause's collapse of structure during earthquake shaking. As glass fibre reinforced polymer frames gives higher base shear as compared to steel reinforced frame the analyzing the structure at this base shear will be minimize the effect of collapse failure during severe earthquake.
- The performance point of frames with Glass Fibre Reinforced Polymer bars is higher than that of frames with steel bars for bare as well as infill type frames.

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