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COMPARATIVE STUDY ON GFRP AND STEEL BAR REINFORCEMENT IN MULTISTOREY BUILDING UNDER SEISMIC LOAD BY PUSHOVER ANALYSIS

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Abstract - *The seismic evaluation of GFRP and RCC structure, the method carried out in terms of equivalent static according to the IS codes. Multi storey Structure is to be considered for the analysis. The comparison of equivalent static method by using ETABS software is used to perform the modeling and analysis of multi storey structure by considering the suitable seismic zone as per IS code. For analysis various IS codes are to be considered. For different seismic load combinations as per IS code is considered. In this study structure model analysis carried out namely equivalent static in longitudinal direction & transverse direction discussed and comparisons of IS code values of the software analysis values. Results of these analyses are discussed in terms of the storey displacement, drift and base shear. From the result they concluded that storey displacement, drift and base shear will be more common in buildings.*

***Key Words*: Beam-Column Joint, Stroey Displacement, GFRP bars, Steel bars, ETAB, Pushover analysis**

1.INTRODUCTION

An earthquake is the agent which causes shaking of the earth this exists due to the sudden release of energy at the lithosphere of earth crust which forms seismic waves. Due to
earthquake larger damages has been occurred to the structure by which, this causes the loss of human life in larger extent. To minimize the failures, resistant to earthquake, the resistant structures can be developed.

1.1 Background of Beam Column joint Design :

In past thirty years ,all over the world enormous research work of beam column joint and joint connections place of many structure in reinforced concrete frame and load resisting joint are under many types of seismic loads and experiments were conducted on structural labs.
Depending on those test executed and results indicated, the design recommendations that are developed towards resisting to earthquake loads

- ❖ Identification of result obtained under various load condition.
- ❖ Lesser strength in reinforced beam column place to resist earthquake load and its lateral

forces.

- ❖ For all the considered structure a complete detail procedure of design specifications needed.
- ❖ The design as per proposed specification and recommendation is very difficult and uneconomical.

1.2 Using GFRP Bar as replacement of steel reinforcement:

Now a days a Glass fibre reinforced polymer bar (GFRP bar) are used as replacement for steel reinforcement bar in reinforced concrete structures. These bars were light weight, corrosion free, having higher tensile strength and higher strength to weight ratios. Due to corrosion property of the steel generally they cannot be used in bridge structure so there is an alternate material is required which can be replacement of steel with cost and strength related properties such as GFRP can be used because of its higher strength of RC structures. By recent research in many RC structures like bridges, rigid pavements, large infrastructures and other civil engineering structures. There more research is required on the design code with GFRP bars in construction. The factors are to be studied which related to GFRP material are:- type of fiber , Volume, orientation, Type of resin used , curing, Void content, temperature, Quality control at the time of manufacturing.

1.3 GFRP bar behaviour:

- ❖ The GFRP bar is having higher strength towards fiber placed direction due to its anisotropic property.
- ❖ GFRP increases shear strength and beam column joint performance.
- ❖ GFRP will not show the yielding due to its elastic property before failure.
- ❖ Design influences to lack in ductility.
- ❖ By the use of GFRP in Structure ,it will be under more deformability.

1.3 GFRP bars advantages:

1. Due to corrosion resistance property GFRP bar is more durable.
2. Tensile strength of GFRP bar is greater then steel.
3. Weight of the GFRP bar is lighter then steel.
4. It is not effected by magnetic field and radio frequency.
5. It is non conductivity in electricity and thermal effect.

1.4 GFRP bars Disadvantages:

1. Welding process cannot be used in the connection with GFRP material.
2. The GFRP bar's property are depending upon manufacturer, type of fiber, resin and other materials used.
3. Linear elastic to failure is under stress strain behaviour.
4. With respect to time strength will decrease.

2. LITERATURE REVIEW

Pramodkumar H V, et al.
"Comparative seismic evaluation of GFRP reinforced and steel reinforced concrete buildings using ETABS".
They carried out equivalent static analysis of G+3 storey building by considering earthquake zone-4 as per IS: 1893-2002(Part-1). They concluded that GFRP reinforced building shows more lateral displacements compared to steel reinforced building which is due to the variation in modulus of elasticity. The storey drifts for GFRP reinforced building shows more value than the steel reinforced building and its variation is about 5 to 18% which is within the permissible limits and hence the provision of GFRP reinforcement for buildings are viable

Anna Rebecca, et al.
"Seismic analysis and cost estimation of GFRP and RCC auditorium building using ETABS".
In this linear static and response spectrum analysis of a RCC structure is compared with GFRP panel. The auditorium is G+1 storey building in earthquake zone-3 with soil type-3, density of GFRP-17.25KN/m3, response reduction factor-3. They concluded that maximum storey drift, displacement, base shear and storey stiffness of GFRP is better than RCC and from structural and economic viewpoint, GFRP structure is better than RCC structure.

Amitshaha Rafai, et al.
"Analysis and design of multistory RC frame using FRP reinforcement".
The FRP used in this study is of Glass i.e. GFRP. P+7, P+9, P+11 storeys RC frame with steel and GFRP bars are analyzed. The study is performed on bare, soft storey and full masonry infill type frames along with steel and GFRP reinforcement. Pushover analysis is carried out using M3 and V2 hinges for beams and P-M-M hinges for columns in ETABS. It is observed that frames reinforced with GFRP bars fail at higher displacement than steel frame due to low modulus of elasticity of GFRP bars. The drift demands for GFRP concrete building frame are comparable to those obtained for steel reinforced concrete building implying that similar performance level can be attained during moderate to strong earthquake and the base shear of bare frame is lower than base shear of infill frames in both types of reinforcement. This is due to the presence of infill masonry which increases the mass and stiffness of infill frames.

Gajendra, et al.
"Seismic evaluation of beam column joints using GFRP bars in multistory building using ETABS".
Pushover analysis for G+3, G+5 and G+7 storey buildings were carried out for M3 and V2 type of hinges for beams and P-M-M hinges for columns. The earthquake zone considered is zone-5, importance factor is 1, type of soil is medium soil with response reduction factor-5 and seismic zone factor-0.16. They concluded that load carrying capacity of GFRP is more than steel and at greater height of storey, GFRP bars perform better than steel bars. Large deformations were showed by GFRP bars which allows the GFRP reinforced building to satisfactorily dissipate the seismic energy and since GFRP bars with smaller thickness possess higher strength, the congestion of reinforcement in beam-column joint is less.

3. METHODOLOGY

3.1 Building and loading

I. Low and high raise RC frame building

II. Combination of gravity load and earth-quake load

3.2 Modelling and Analysis Method

I. 3D modeling for analysis using ETABS

II. The building is analysed by and Pushover analysis

4. DISCRIPTION OF THE BUILDING

Data to be considered for analysis:

- Live load (As per IS 875 part I) - 3KN/m2
- Floor finish (FF) load - 1KN/m2
- Concrete grade - 20 N/mm2
- Steel grade - 500 N/mm2
- Properties of GFRP bars - As per manufacturer
- Clear cover (CC) for beam and column - 30mm
- Concrete density - 25 KN/m3
- Brick wall density - 20KN/m3

Earthquake Details (IS 1893-2002):

- Importance Factor, I – 1
- Zone – V
- Type of soil - Type II, Medium
- Seismic Zone Factor, Z - 0.16
- Bearing pressure - 180 KN/m3
- Response Factor, R – 5
- Response Spectrum - As per code IS 1893-2002

Details of Reinforcement:

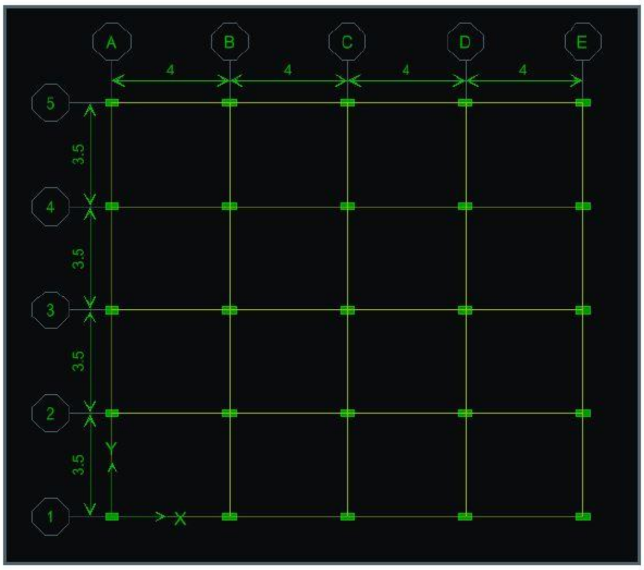
For the considered work two types of reinforcement are using such as steel and GFRP bar as reinforcement, and comparing the results of strength, storey drift and joint displacement etc.., and also the behaviour of GFRP bars in multi-storey building were studied.

The Geometrical Details of the structure:

- Number of stories considered - 4, 6 and 8
- Each height of storey - 3.2m
- Number of bays considered in x-direction – 4
- Number of bays considered in y-direction – 4
- Width of bays considered in x-direction - 4.0 m
- Width of bays considered in y-direction - 3.5 m
- Slab thickness considered - 150 mm

5. MODELLING AND ANALYSIS OF HIGH RAISE BUILDING BY ETABS

A regular multi storey structure is considered for modeling and analysis. The typical plan is shown in above fig. and we considered the soil below ground is hard for the analysis. The brief procedure of creating or modeling high raise structure and making nonlinear analysis explained below by taking the above different details like geometrical details, plan of the structure, various types of loads of forces, properties of reinforcement details etc .... The different forces or load are taken as per IS codes IS 875 part I, part II and design is done as per IS 456-2000 and for earthquake IS 1893-2002 code is used for analysis.



6. RESLTS AND CONCLUSIONS

6.1 Performance points

In the below table it is clearly shown the comparative result of several models having different stories with GFRP and STEEL bars. In table 6.1 it is shown the performance point and base shear for all different models. It is observed that the building model with GFRP bar is having less displacement than the steel bar with more base force.

	G+3		G+5		G+7	
CASES	PERFORMANCE POINT		PERFORMANCE POINT		PERFORMANCE POINT	
	BASE FORCE	DISPLACEMENT	BASE FORCE	DISPLACEMENT	BASE FORCE	DISPLACEMENT
	KN	mm	KN	mm	KN	mm
STEEL	721	172	978	208	1284	269
GFRP	777	141	1098	188	1368	223

6.2 Base Shear

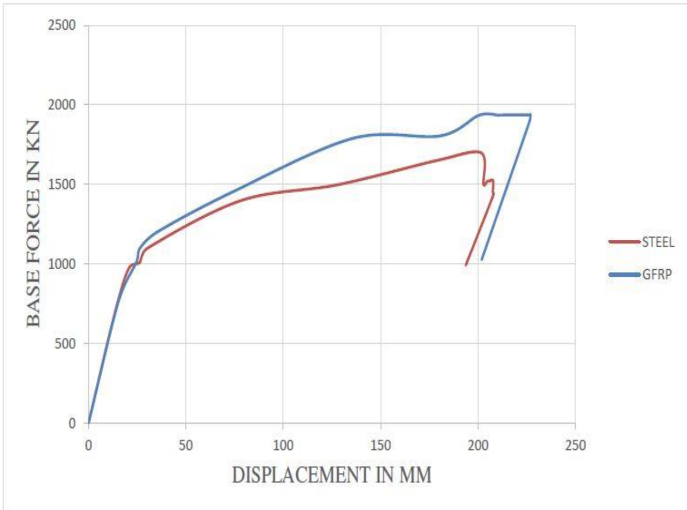


Fig 6.1 Base force v/s displacements for G+3 models

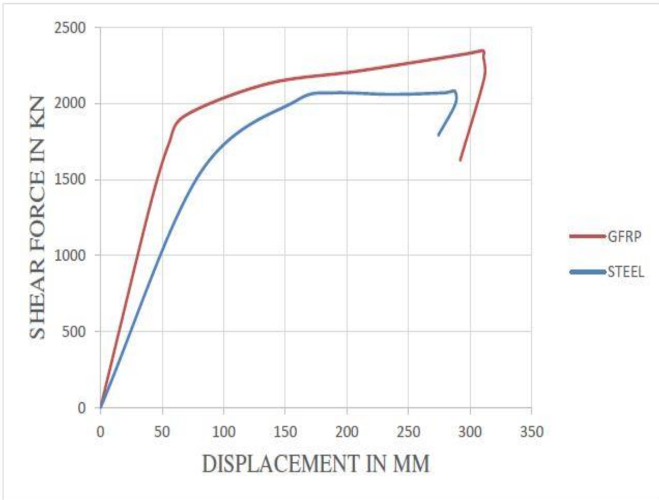


Fig 6.2 Base force v/s displacements for G+5 models

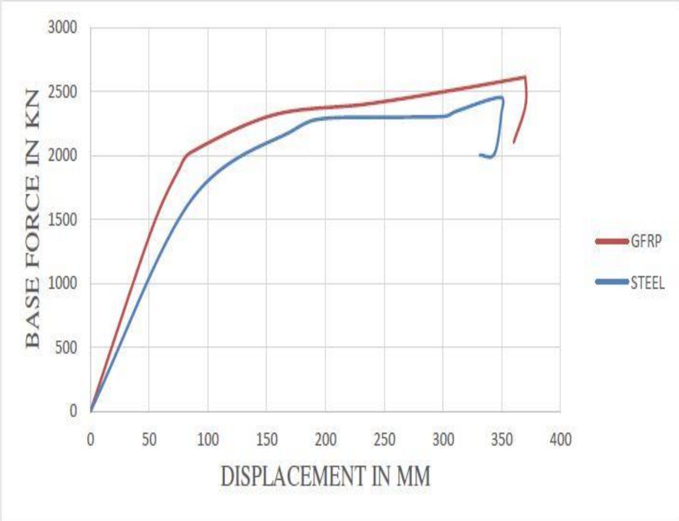


Fig 6.3 Base force v/s displacements for G+7 models

From above figures 6.1, 6.2 and 6.3 shows the base force v/s displacement for all types of models. From above figures and tables it were clearly seen that load thing carrying capacity is more when the GFRP model were compared with the STEEL model, the thing is after reaching the failure point (yield point) the STEEL model were deflect due the remaining strength, whereas in GFRP model after reaching the failure point (yield point) it fails suddenly because the GFRP bars shows the stress- strain characteristic is linear elastic up to the failure after that its fails suddenly, it will not undergo deflection. As we increase the number of stories the GFRP bar performing very well when it is compared with STEEL model as we can see in graph clearly, and also GFRP model is deflect more with increase in flexibility of overall structure well when it is compared with STEEL model.

6.3 STOREY DISPLACEMENT

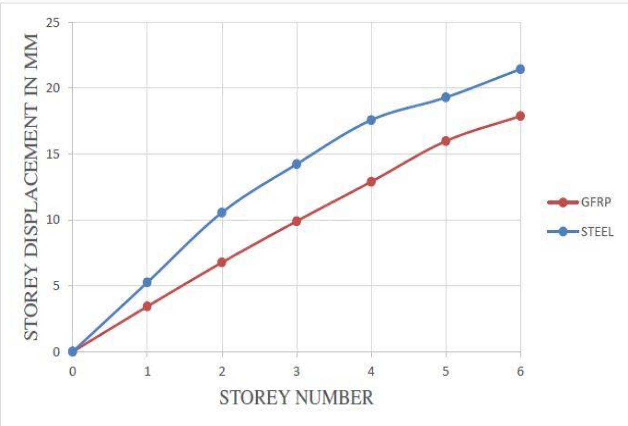


Fig 6.4 Storey number v/s Storey displacement in mm for G+5 models

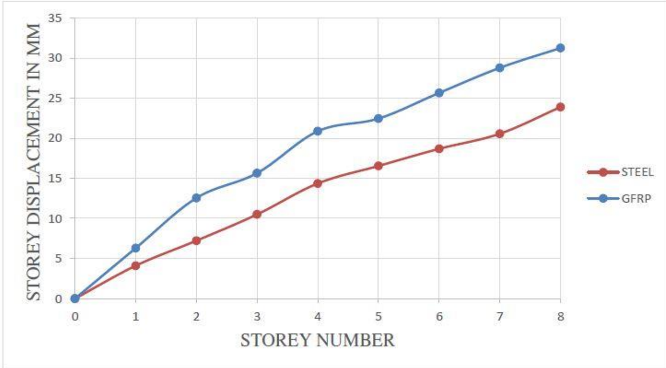


Fig 6.6 Storey number v/s Storey displacement in mm for G+7 models

In the model for the analysis of multi storey building the rigid diaphragm is assigned for each storey, so all the joints which are present in the same storey they have the amount of displacements. From above figures 6.4 to 6.6 shows the comparative results of all models of different reinforcement. From the above table and figures it is observed that the GFRP model is having more displacement than that of STEEL model, because the GFRP bars having less modulus of elasticity (Young's modulus) which makes the building more flexible.

6.4 STOREY DRIFT

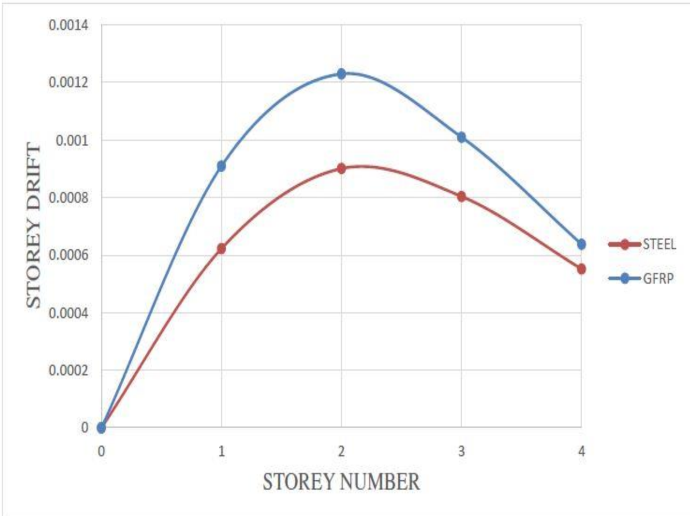


Fig 6.7 Storey number v/s Storey drift for G+3 models

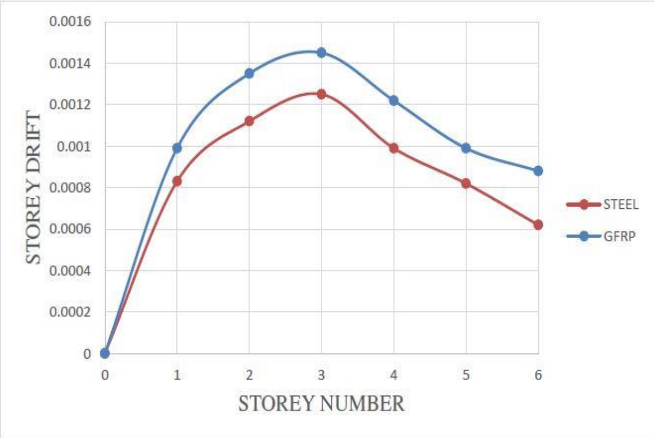


Fig 6.8 Storey number v/s Storey drift for G+5 models

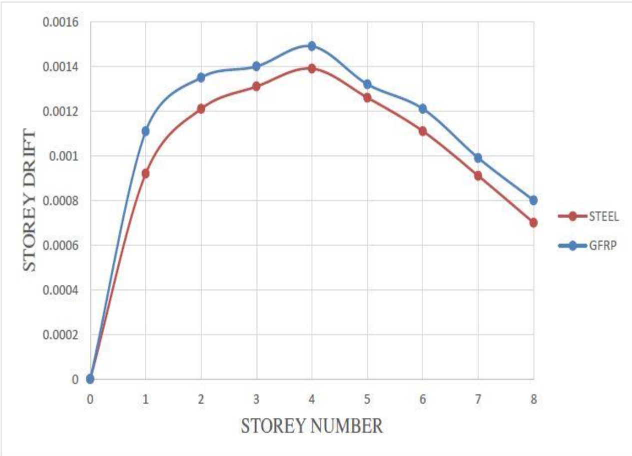


Fig 6.9 Storey number v/s Storey drift for G+7 models

The increase in lateral displacement in two consecutive stories is known as the storey drift or the total displacement of lateral that occurs or present in a single storey of a high raise building. In ETAB we provided the rigid diaphragm for the analysis on each storey of all the joints which are present in that storey, so all joints shows the same magnitude of drift. fig 6.7 to 6.9 shows the comparison of drift for all models. From that is clearly observed that the joints in GFRP model is having higher drift than the STEEL model because the young modulus of elasticity is less which makes them flexible.

6.5 HINGE RESULTS

From Table 6.20 to 6.22 it were observed that the GFRP model fails at very high displacement when compare to STEEL model so it can be said that low modulus elasticity of GFRP led to reducing overall stiffness of structure.

Table 6.20 Hinge results for GFRP and STEEL model for G+3 model

Description	G+3 model	
	Displacement in mm	
	STEEL	GFRP
First hinge formation B to IO	17	13
IO to LS	65	57
LS to CP	99	119
Failure point C to D	198	201
Residual strength D to E	226	248

Table 6.21 Hinge results for GFRP and STEEL model for G+5 model

Description	G+5 model	
	Displacement in mm	
	STEEL	GFRP
First hinge formation B to IO	35	28
IO to LS	71	61
LS to CP	125	168
Failure point C to D	198	211
Residual strength D to E	274	248

Table 6.22 Hinge results for GFRP and STEEL model for G+7 model

Description	G+7 model	
	Displacement in mm	
	STEEL	GFRP
First hinge formation B to IO	45	31
IO to LS	97	61
LS to CP	136	148
Failure point C to D	268	305
Residual strength D to E	301	362

7 CONCLUSIONS

- As we increase the height of storey it is observed that the GFRP bars showing a very good results when it was compare to STEEL, so the GFRP bars can be used efficiently for high raise buildings.

- More deformations were seen in the GFRP bars model as it is compare with the STEEL bars model.

- As per observation of the performance point was concerned, it is observed that as increase reinforcement of GFRP bar, the displacement of various structure is decreasing as increase in force and performance of building represents a well within the permissible limits as per the IS 1893 (part-1) 2002

- The load carrying capacity of the GFRP models were more than that of STEEL bars model.

- The failure point after reaching the STEEL bars are deflect more due to the presence of remaining strength, where as in GFRP bars the failure is taking place very fast because the elastic properties are linear up to failure.

- ❖ The GFRP bars are having less thickness with more strength when it is compare with STEEL bars.

FUTURE SCOPE

- ❖ To study the Analysis of slab with GFRP bars.
- ❖ To study the Parametric study in deep beams with GFRP bars.
- ❖ To evaluate Performance by using GFRP bar's in various civil engineering structures can be studied.

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