# A Comparative Seismic Evaluation of GFRP Reinforced and Steel Reinforced Concrete Buildings using ETABS

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**Abstract -** *The seismic evaluation of GFRP and Steel reinforced concrete building, the method carried out in terms of equivalent static according to IS 1893:2002(part1) codes. G+03 storey buildings are considered for the analysis. The comparison of equivalent static method by using ETABS software is used to perform the modeling and analysis of G+03 storey buildings by considering the seismic zone IV as per IS 1893:2002(part 1) code. For analysis various IS codes have been referred. For 0.9, 1.2 and 1.5 seismic load combinations as per IS 1893:2002 (part 1) code is referred. In this study building model analysis carried out namely equivalent static in longitudinal direction & transverse direction discussed and comparisons of codal values of the software analysis values. Results of these analyses are discussed in terms of the storey displacement, storey drift and base shear. From this result it is concluded that storey displacement, storey drift and base shear will be more in regular buildings.*

***Key Words***: *GFRP Bars, Equivalent static, storey displacement, storey drift, base shear.*

## 1. INTRODUCTION

In natural hazards earthquakes is considered as one of most destructive. It occurs when sudden transient motion of the ground which in turn release enormous energy in few seconds. The impact of the event is most traumatic because it affects large area, occurs all of a sudden and unpredictable. Earthquake forces are generated by the dynamic response of the building to earthquake induced ground motion. Thus the earthquake forces are directly influenced by the dynamic inelastic characteristics of the structure itself. The importance of dynamic effects in structural response depends on the rate of change of external forces and the dynamic properties of structures. Dynamic responses are stresses, strains, displacement, acceleration etc. The design of buildings for seismic loads is special, when compares to the design for gravity loads (dead loads and live loads). Gravity loads are relatively constant, in terms of their magnitude and are treated as 'static' loads.

Fibers and matrix are the materials used in manufacture of Fiber Reinforced Polymers as strength and stiffness is provided by fibers whereas matrix ties the fibers together, abrasion and corrosion are protected from them. Glass, Carbon and Aramid are three types of fibers used to manufacture typical Fiber Reinforced Polymer reinforcing bars in which glass fiber is considered as most popular due to their lower costs. Depending on glass fiber bars properties and chemical composition E-Glass, S-2 Glass, AR-Glass, A-Glass, C-Glass, D-glass, R-Glass and ECR-Glass are the types of glass fibers. Due to its high strength and electrical resistivity E-Glass is mostly used for reinforcement, but it is the low cost that makes GFRP the most popular FRP reinforcement in civil engineering applications.

## 2. SEISMIC ANALYSIS

Exact seismic analysis of the structure is highly complex and to tackle this complexity, number of researches has been done with an aim to counter the complex dynamic effect of seismic induced forces in structures. This re-examination and continuous effort has resulted in several revisions of Indian Standard: 1893 (1962, 1966, 1970, 1975, 1984 and 2002) code of practice on ―Criteria for earthquake resistant design of structures by the Bureau of Indian Standards (BIS), New Delhi. Many of the analysis techniques are being used in design and incorporated in codes of practices of many countries. However, since in the present study our main focus is on the IS a codal provision, the method of analysis described in IS 1893 (Part 1): 2002 are presented.

## 2.2 Equivalent Lateral Force Method

The total design lateral force or design base shear along any principal direction is given in terms of design horizontal seismic coefficient and seismic weight of the structure. Design horizontal seismic coefficient depends on the zone factor of the site, importance of the structure, response reduction factor of the lateral load resisting elements and the fundamental period of the structure. The procedure generally used for the equivalent static analysis is explained below:

(i) Determination of fundamental natural period (Ta) of the buildings

$T_a = 0.075h^{0.75}$ Moment resisting RC frame building without brick infill wall

$T_a = 0.085h^{0.75}$ Moment resisting steel frame building without brick infill walls

Where, h -is the height of building in m,

d - Is the base of building at plinth level in m,

(ii) Determination of base shear (VB) of the building

$V_B = A_h \times W$

Where, $A_{h=} (Z\ I\ S_a / 2RG)$

the design horizontal seismic coefficient, which depends on the seismic zone factor (Z), importance factor (I), response reduction factor (R) and the average response acceleration coefficients (Sa/g). Sa/g in turn depends on the nature of foundation soil (rock, medium or soft soil sites), natural period and the damping of the structure.

(iii) Distribution of design base shear

The design base shear $V_B$ thus obtained shall be distributed along the height of the building as per the following expression:

$$Q_i = V_B * \frac{W_i\, h_i^{\,2}}{\sum_{i=1}^{n} W_i h_i^{\,2}}$$

Where, $Q_i$ is the design lateral force, $W_i$ is the seismic weight, $h_i$ is the height of the 1th floor measured from base and n is the number of stories in the building.

## 3. METHODOLOG

The building has been analysed by a 3D space frame model. Which consisting of assemblage of slab, beam, and column elements. The buildings will be designed for gravity loads and evaluated for seismic forces.

### 3.1 DETAILED DATA OF THE BUILDINGS

**Table -1:** Detailed data of the Buildings

| | |
|---|---|
| Structure | Special RC moment resisting frame (SMRF) |
| No. of storey | G+03 |
| Storey height | 3.5m For G+03 |
| Type of building use | Commercial |
| Seismic zone | IV |
| Soil type | Medium soil |

**Table -2:** Material Properties

| | |
|---|---|
| Grade of concrete | M20 |
| Density of reinforced concrete | 25 kN/m3 |
| Modulus of Elasticity of concrete, E For G+03 | $5000\sqrt{(f_{ck})}$ 22360679 KN/m |
| Poisson's ratio of Concrete | 0.175 |

**Table -3:** Member Properties

| | |
|---|---|
| Slab Thickness | 0.150 m |
| Beam Size | 0.23 X 0.45 m |
| Column Size | 0.30 X 0.30 m |

**Table -4:** Type of Loads & their intensities

| | |
|---|---|
| Floor finish | 1.75 kN/m² |
| Live load on floors | 3 kN/m² |
| Live load on roof | 2 kN/m² |

**Table -5:** Seismic properties

| | |
|---|---|
| Zone factor (Z ) | 0.36 |
| Importance factor ( I ) | 1 |
| Response reduction factor ( R ) | 5 |
| Soil type | II |
| Damping ratio | 0.05 |

### 3.2 LOAD COMBINATIONS

The following load combinations are considered for the analysis and design as per IS: 1893-2002.

**Table-5:** Load combinations as per IS: 18932002 and IS: 875(Part3)-1987

| Load combination | Load Factors | |
|---|---|---|
| Equivalent static analysis | X-Direction | 0.9(DL+EQX)<br>1.5(DL+EQX)<br>1.2 (DL+ LL+EQX) |
| | Y-Direction | 0.9(DL+EQY)<br>1.5(DL+EQY)<br>1.2 (DL+ LL+EQY) |

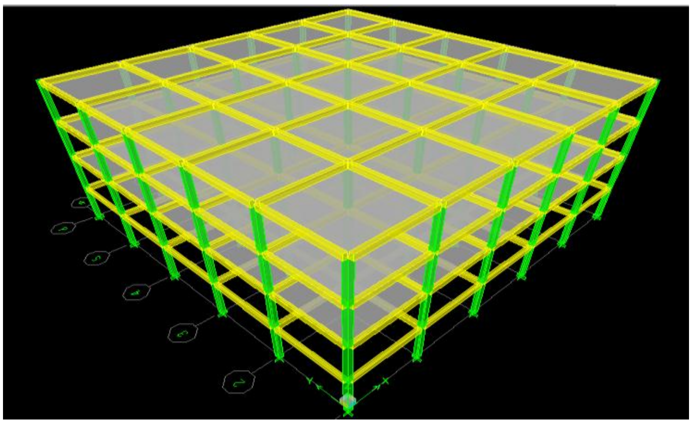

**Fig -1**: G+03 3D Plan

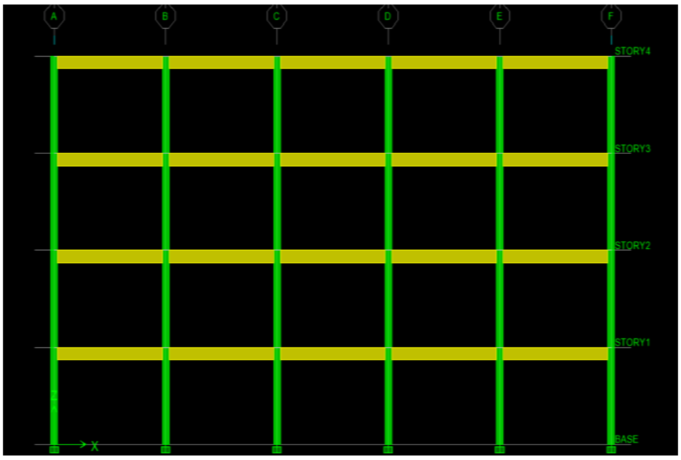


**Fig -2**: G+03 Elevations

## 4. SEISMIC ANALYSIS RESULTS

### 4.1 STOREY SHEAR

**Validation**:

I. Determination of fundamental natural period (Ta) of the buildings

$T_a = 0.075h^{0.75} = 0.075 \times 14^{0.75} = 0.543$ Sec

II. Determination of base shear (VB) of the building

$V_B = A_h \times W$

Where,

$$A_h = \frac{ZI\ Sa}{2Rg} = \frac{0.36 \times 1 \times 2.50}{2 \times 5} = 0.09$$

$V_B = A_h \times W = 0.09 \times 8793.75 = 773.43$KN

**Table-6:** Storey shear in X and Y-Direction

| Storey | Storey shear for G+03 storey in KN | | |
|---|---|---|---|
| | In X and Y-Direction | | |
| | GFRP reinforced | STEEL reinforced | Manual calculation as per Code |
| | EQX & EQY | EQX & EQY | EQX & EQY |
| 3F | 448.14 | 448.14 | 451.218 |
| 2F | 755.12 | 755.12 | 689.904 |
| 1F | 848.56 | 848.56 | 768.318 |
| GF | 855.96 | 855.96 | 773.435 |

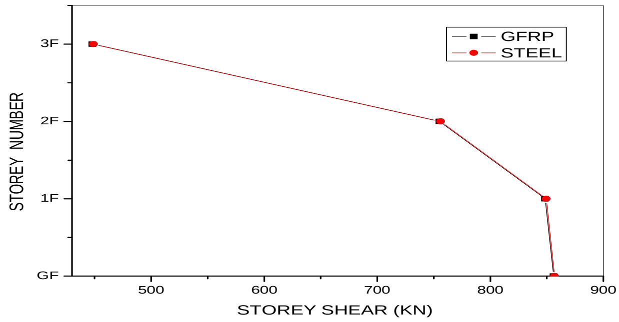


**Chart -1**: Storey Shear profile for G+ 03 storeys building in X and Y-Direction

### 4.2 LATERAL DISPLACEMENT

**Table-7:** lateral displacements in X and Y-Direction with 0.9(DL+EQX) & 0.9(DL+EQY) load combination

| Storey | lateral displacements for G+03 storey in mm | | |
|---|---|---|---|
| | In X and Y-Direction | | |
| | 0.9(DL+EQX) & 0.9(DL+EQY) | | |
| | GFRP reinforced | STEEL reinforced | % of increase w.r.t steel reinforced |
| 3F | 18.16 | 16.00 | 11.91 |
| 2F | 14.31 | 13.00 | 9.16 |
| 1F | 7.88 | 7.81 | 0.88 |
| GF | 0.88 | 0.82 | 6.81 |
| BASE | 0 | 0 | 0 |

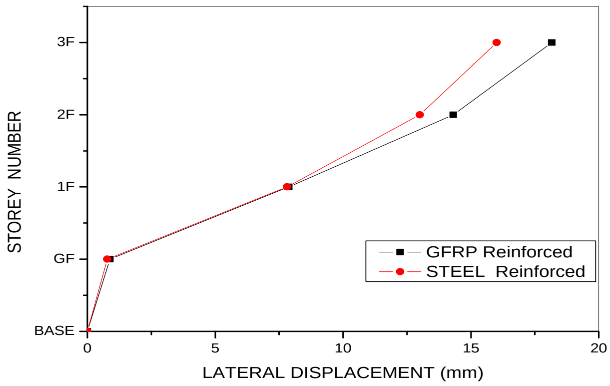


**Chart -2**: Lateral Displacements profile for G+03 for 0.9(DL+EQ) loading

**Table-8:** lateral displacements in X and Y-Direction with 1.5(DL+EQX) & 1.5(DL+EQY) load combination

| Storey | lateral displacements for G+03 storey in mm | | |
|---|---|---|---|
| | In X and Y-Direction | | |
| | 1.5(DL+EQX) & 1.5(DL+EQY) | | |
| | GFRP reinforced | STEEL reinforced | % of increase w.r.t steel reinforced |
| 3F | 30.27 | 26.67 | 11.89 |
| 2F | 23.85 | 21.67 | 9.14 |
| 1F | 13.13 | 13.01 | 0.89 |
| GF | 1.3 | 1.23 | 5.38 |
| BASE | 0 | 0 | 0 |

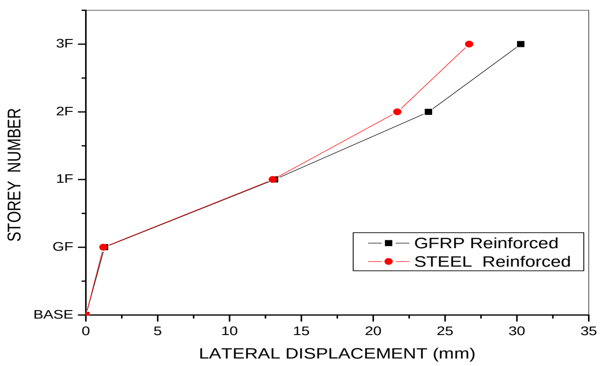


**Chart -3**: Lateral Displacements profile for G+03 for 1.5 (DL+EQ) loading

**Table-9:** lateral displacements in X and Y-Direction with 1.2(DL+LL+EQX) &1.2(DL+LL+EQY) load combination

| Storey | lateral displacements for G+03 storey in mm | | |
|---|---|---|---|
| | In X and Y-Direction | | |
| | 1.2(DL+LL+EQX) &1.2(DL+LL+EQY) | | |
| | GFRP reinforced | STEEL reinforced | % of increase w.r.t steel reinforced |
| 3F | 24.21 | 21.34 | 11.88 |
| 2F | 19.08 | 17.34 | 9.10 |
| 1F | 10.50 | 10.41 | 0.82 |
| GF | 1.46 | 1.36 | 6.84 |
| BASE | 0 | 0 | 0 |

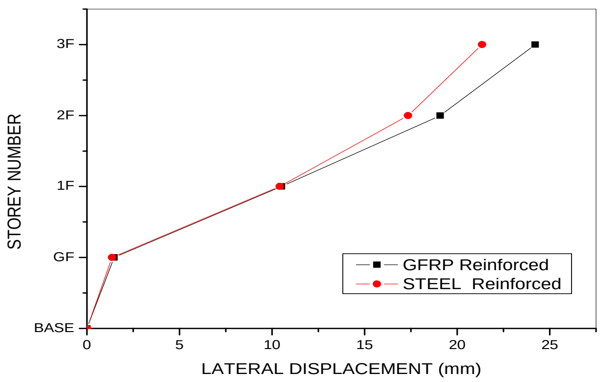


**Chart -4**: Lateral Displacements profile for G+03 for 1.2 (DL+LL+EQ) loading

## 4.3 STOREY DRIFTS

**Table-10:**Storey Drifts in X and Y-Direction with 0.9(DL+EQX) & 0.9(DL+EQY) load combination

| Storey | Storey Drift for G+03 storey in m | | |
|---|---|---|---|
| | In X and Y-Direction | | |
| | 0.9(DL+EQX) & 0.9(DL+EQY) | | |
| | GFRP reinforced | STEEL reinforced | % of increase w.r.t steel reinforced |
| 3F | 0.0011 | 0.0009 | 14.89 |

| | | | |
|---|---|---|---|
| 2F | 0.0018 | 0.0015 | 14.48 |
| 1F | 0.0020 | 0.0019 | 7.33 |
| GF | 0.0016 | 0.0015 | 4.455 |
| BASE | 0 | 0 | 0 |

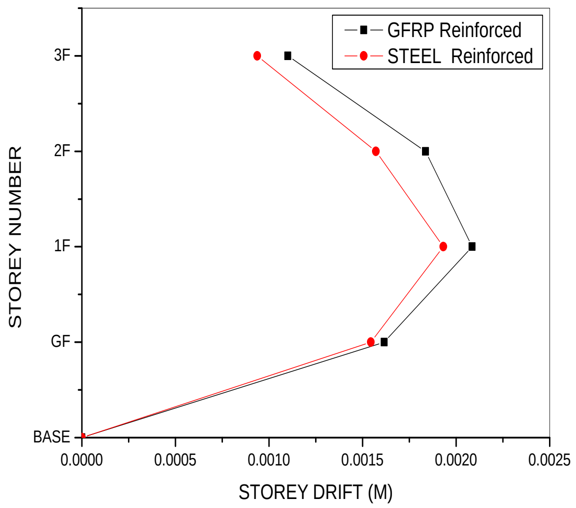


**Chart -5**: Storey Drift profile for G+03 with 0.9(DL+EQ) loading.

**Table-11:** Storey Drifts in X and Y-Direction with 1.2(DL+LL+EQX) &1.2(DL+LL+EQY) load combination

| Storey | Storey Drift for G+03 storey in m | | |
|---|---|---|---|
| | In X and Y-Direction | | |
| | 1.2(DL+LL+EQX) &1.2(DL+LL+EQY) | | |
| | GFRP reinforced | STEEL reinforced | % of increase w.r.t steel reinforced |
| 3F | 0.0014 | 0.0012 | 14.85 |
| 2F | 0.0024 | 0.00209 | 14.53 |
| 1F | 0.0027 | 0.002 | 7.37 |
| GF | 0.0021 | 0.0020 | 4.76 |
| BASE | 0 | 0 | 0 |

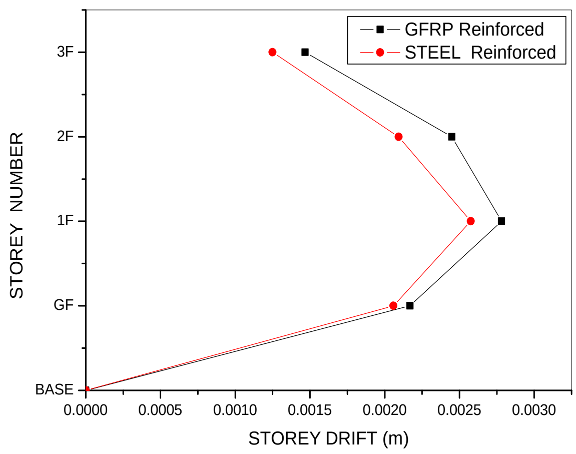


**Chart -6**: Storey Drift profile for G+03 with 1.2(DL+EQ) loading.

**Table-12:**Storey Drifts in X and Y-Direction with 1.5(DL+EQX) & 1.5(DL+EQY) load combination

| Storey | Storey Drift for G+03 storey in m | | |
|---|---|---|---|
| | In X and Y-Direction | | |
| | 1.5(DL+EQX) & 1.5(DL+EQY) | | |
| | GFRP reinforced | STEEL reinforced | % of increase w.r.t steel reinforced |
| 3F | 0.0018 | 0.0015 | 14.87 |
| 2F | 0.0030 | 0.0026 | 14.5 |
| 1F | 0.0034 | 0.0032 | 7.2 |
| GF | 0.0028 | 0.0027 | 3.14 |
| BASE | 0 | 0 | 0 |

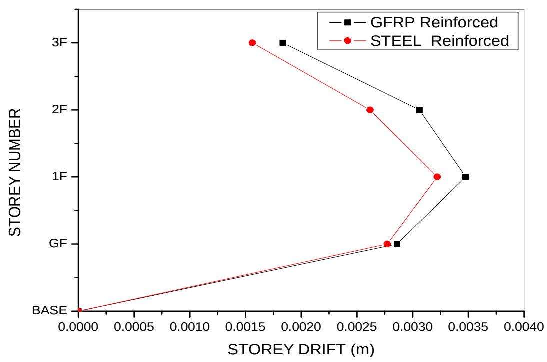

**Chart -7**: Storey Drift profile for G+03 with 1.5(DL+EQ) loading.

## 5. CONCLUSIONS

The Seismic behavior of GFRP reinforced and steel reinforced Building in medium soil at zone IV using analytical techniques. Storey shear, lateral displacement, storey drift was studied for building G+03 by static method with building having symmetrical in plan. The conclusions that are concluded from present work done is as follows

1. From the results is noticed that there is a marginal difference between the manual and software calculations. This variation may be due to considering the some digital values after point while calculating the base shear. Though there is a mass variation between the steel and GFRP bars, during the feeding of material properties for the software the density of concrete taken as 25kN/m$^3$, due to this the base shear values for GFRP and Steel reinforced buildings shown same value.
2. The GFRP reinforced building shown more lateral displacements when compared with steel reinforced building; this may be due to the variation in the modulus of elasticity between the materials of GFRP and Steel. The GFRP bar show lesser modulus of elasticity than the steel at initial state of loading. From figures is also noticed that, beyond the first floor level the % of increase variation for three loading conditions is all most same. The variation between the GFRP and steel is not more than 13.5%. The provision of GFRP bars for G+03 building in respect to the lateral displacement is accepted.
3. The storey drifts for GFRP reinforced building shown more values than the building reinforced with steel and its variation is about 5 to 18%. The maximum drift is noticed at first floor and lower drift is noticed at third floor. Among the GFRP and Steel reinforcements, the GFRP building showed more drifts, this may due to greater stiffness of the GFRP material.
4. According to IS 1893(Part 1):2002 clause 7.11.1 Storey drifts limitations are explained that, the Storey drifts in any storey due to the minimum specified design lateral force, with partial load factor of 1.0 shall not exceed 0.004 times the storey height. In the present case the total building height is 11.5m, with this the maximum drift can be permitted as 0.0468m or 46.8mm. For GFRP reinforced building of 0.9(DL+EQ), 1.5(DL+EQ)and 1.2(DL+LL+EQ) loadings the maximum drifts are 2.085mm, 3.47mm and 2.78mm respectively. These inferences no ware the buildings were shown crossing the permissible limits. In this aspect also the provision of GFRP reinforcement for buildings are viable.

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