Push over Analysis for G+30 Building Reinforced with GFRP Bars

Shaik Mahamood1[1] Thrimurthi Naik[2] K Madhu Sudan Reddy[3]
[1,2,3]Department of Civil Engineering
[1,2,3]Indira Institute of Technology & Sciences, Markapur

Abstract— The dissertation work is concerned with the comparison of the seismic evaluation of GFRP and Steel reinforced multistory Building with and without 'Shear wall, the method carried out in terms of equivalent static, response spectrum and pushover analysis according to IS 1893:2002(part1) code, G+03, G+10 and G+30 storey buildings are considered for the analysis. The comparison of equivalent static, response spectrum method and pushover analysis by using ETABS software is used to perform the modeling and analysis of G+ 03, G+10 and G+30 storey's buildings by considering the seismic zone IV as per IS 1893:2002(part I) 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 and response spectrum, pushover analysis i11 longitudinal direction & transverse direction discussed and comparisons of coda! values of the software analysis values. Results of these analyses arc 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 compare with Building with sheer wall.

Key words: Etabs, GFRP Bars, Lateral displacements, Storey Shear

I. Introduction

A. General

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. Living and non-living things on the earth crust can cause large scale loss of life, property and disrupts essential services such as water supply, sewerage systems, communication, power and transport etc. Due to vibration caused in earth crust as virtually shake up take place. In order to prevent risk of death or injury to people in or around those buildings the primary objective of earthquake resistant design as to be applied.

Earthquake forces are generated by the dynamic response of the building to earthquake induced ground motion. Thus the earthquake forces imposed 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 are treated as 'static' loads. In contrast, seismic loads are predominantly horizontal(lateral), reversible (the forces are back-and-forth), dynamic (the forces rapidly vary with time) and of very short duration. In order to make a building seismo-resistant, it should have good building configuration, lateral strength, lateral stiffness, ductility, stability and integrity. Seismic response of different buildings in Fig1.1.

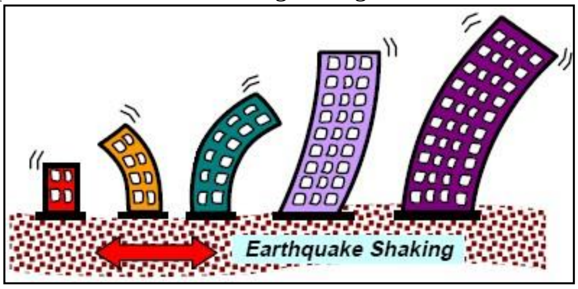

Fig. 1.1: Seismic response of different buildings

In recent years due to the development of design technology and material qualities in civil engineering, the structures (high rise buildings, long span bridges) have become more light and slender. This will cause the structure to develop the initial vibrations. Earthquakes are the Earth's natural means of releasing stress.

B. Building frequency and period

To begin with the magnitude of the building response that is, the accelerations which it undergoes depends primarily upon the0frequencies of the input ground motion and the building's natural frequency. In some circumstances, this dynamic amplification effect can increase the building acceleration to a value two times or more that of the ground acceleration at the base of the building. Generally, buildings with higher natural frequencies, and a short natural period, tend to suffer higher accelerations but smaller displacements. In the case of buildings with lower natural frequencies, and a long natural period, this is reversed the building will experience lower accelerations but larger displacements

C. Building stiffness

The taller a building, the longer its natural period tends to be. But the height of a building is also related to another building characteristics the0building flexibility. Taller buildings tend to be more flexible than short building.

D. Ductility

Ductility is the ability to undergo distortion or deformation (for example, bending) without resulting in complete breakage or failure. One of the primary tasks of an engineer designing a building to be earthquake resistant is to ensure that the building will possess enough ductility to withstand the size and types of earthquakes it is likely to experience during its lifetime.

II. Literature Review

D. H. Deitzet,al.,(2003) has tested a commercially produced 15mm GFRP rebar produced by Marshall Industries Composites, Inc. In their study they have taken 15mm GFRP rebar and cross sectional area is 177mm^2 per rebar, unbraced length varing from 50 to 380mm which are ribbed as same as steel rebars. In these paper they conducted compression test to obtain their ultimate strength and young's modulus, three failure modes are evaluated as crushing, buckling, and combined buckling and crushing. The test result on 15mm GFRP rebar has young's modulus in compression is equal to young's modulus in tension and 50% of ultimate tensile strength is equal to ultimate compression strength.

Gajendra and D K Kulkarni (2015), has model the beam-column joint with steel and GFRP bars. In their study they have taken for various building heights of G+3, G+5 and G+7 using ETABS 9 for seismic load using pushover analysis. The seismic behaviour of multi-story building using GFRP bars in beam-column joint using pushover analysis was done in these paper. The results for beam-column joint has made advantage that is load carrying capacity of GFRP reinforced building has large deformation which satisfactorily dissipate seismic energy and GFRP bars are performing very well as compare to steel for high storey building.

III. Objective and Scope of Work

A. Introduction

Extensive work has been executed on beam,column, cubes of 150mm×150mm×150mm, beam-column joint which reveal through literature review but there is very few information is available on GFRP reinforced multistorey building behaviour under earthquake loads. GFRP reinforced multistorey buildings have its own behaviour limitation.

B. Objective of the Study

The GFRP reinforcing bars are standing out as a realistic and cost-effective alternative reinforcement to conventional steel bars for concrete structures under severe environmental conditions. The main objectives of this study are Structural Response evaluation of 3D GFRP reinforced concrete multistorey building with and without shear wall. Now days, many rebars are coming up instead of steel rebars,

1) To model the GFRP reinforced multistorey Building with and without shear wall using Etabs software.
2) Lateral displacement, storey drift and base shear of GFRP reinforced multistorey Building to determine the seismic response.
3) Control the seismic response of the GFRP reinforce d multistorey Building using shear wall.

C. Material

Detailed summary of the existing various properties of GFRP. This presents the existing knowledge on the properties of GFRP using useful graphs and tables, and discusses their advantages and disadvantages in a systematic manner.

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.

IV. Seismic Analysis of Structures

A. General

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 seismic0induced 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 structuresby 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 in this chapter.

B. Seismic Design Philosophy

The design philosophy adopted in the seismic code is to ensure that structures possess at least a minimum strength to

1) Resist minor earthquakes which may occur frequently without damage.
2) Resist moderate earthquake without significant structural damage and minor non-structural damage.
3) Resist major earthquake without collapse.

Design Basis Earthquake(DBE) is defined as the maximum earthquake that reasonably can be expected to experience at the site once during lifetime of the structure. The earthquake corresponding to the ultimate safety requirements is often called as maximum considered earthquake(MCE).Generally, DB E is half of MCE.

C. Design Lateral Force

The procedure recommended for the determination of lateral force in IS: 1893-2002(Part 1) performing are based on the approximation that effects of yielding can be accounted for by linear analysis of the building using design spectrum. This analysis is carried out by either equivalent lateral force procedure or dynamic analysis procedure given in the clause 7.8 of IS: 1893-2002 (Part 1). The main difference between the two procedures lies in the magnitude and distribution of lateral forces over the height of the building. In the dynamic analysis procedure, the lateral forces are based on properties of the natural vibration modes of the building which are determined by distribution of mass and stiffness over the height. In the equivalent lateral force procedure the magnitude of forces is based on an estimation of the fundamental period and on the distribution of forces as given by a simple empirical formula that is appropriate only for regular buildings. The following sections will discuss in detail the above mentioned procedures of seismic analysis.

1) 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, along the considered direction of lateral force.

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

$V_B = A_h \times W$

Where,

$$A_h = \frac{ZI\,Sa}{2Rg}$$

Is 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 1thfloor measured from base and n is the number of stories in the building.

V. METHODOLOGY

A. General

The building has been analysed by a 3D space frame0model. Which consisting of assemblage of slab, beam, and column elements. The buildings will be designed for gravity loads and evaluated for seismic forces.

B. Detailed Data of The Buildings

Structure	Special RC moment resisting frame (SMRF)
No. of storey	G+03,G+10 and G+30
Storey height	3.5m For G+03, G+10 and G+30. Ground floor height of parking purpose is 5M for G+30
Type of building use	Commercial
Seismic zone	IV
Soil type	Medium soil

Table 1: Detailed data Of the Buildings

Grade of concrete For G+03 For G+10 For G+30	M20 M25 M30
Density of reinforced concrete	25 kN/m3
Modulus of Elasticity of concrete, E For G+03 For G+10 For G+30	5000√(fck) 22360679 KN/m 25000000 KN/m 27386127.8 KN/m
Poisson's ratio of Concrete	0.175

Table 2: Material Properties

C. Modelling of the Multistorey Building

The majority of buildings in which floor diaphragms are0sufficiently rigid in their planes, the dynamic analysis can be carried out by using reduced 3D model. This is based on the following assumptions:

1) The floors are rigid in their planes having 3D to horizontal translations and a single rotation about a vertical axis.
2) The mass of building and mass moment of inertia are lumped at the floor levels at the corresponding degrees of freedom.
3) The inertia forces or movements due to vertical or rotational components of joint motions are negligible, therefore ignored.

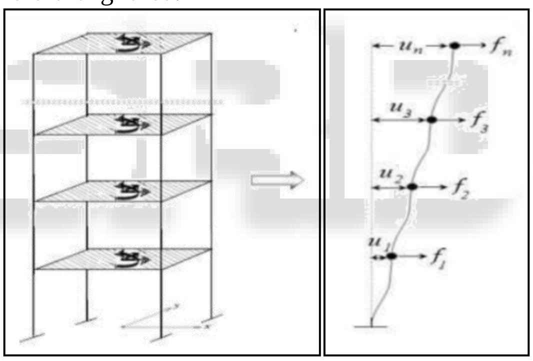

Fig. 5.1: Building Model with 3D Fs

The simplified model with above assumptions is shown in Fig. 5.1. The dynamic degrees of freedom are drastically reduced by static condensation and yet it produces quite accurate results.

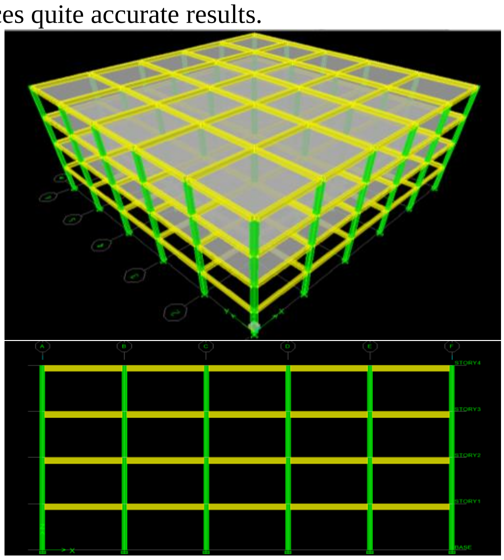

Fig. 1 G+03 3D Plan and Elevation

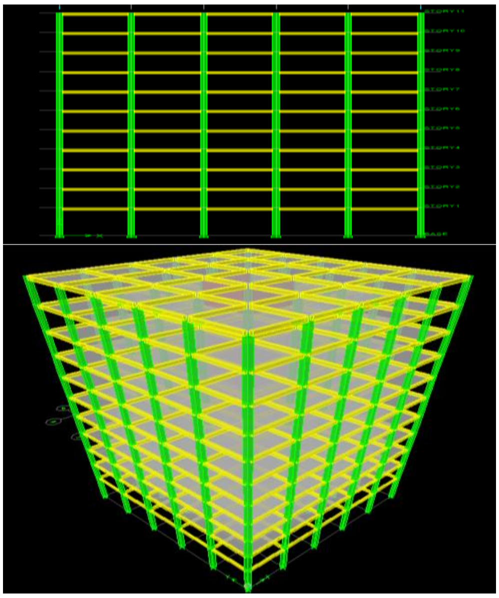

Fig. 2: G+10 3D Plan and Elevation

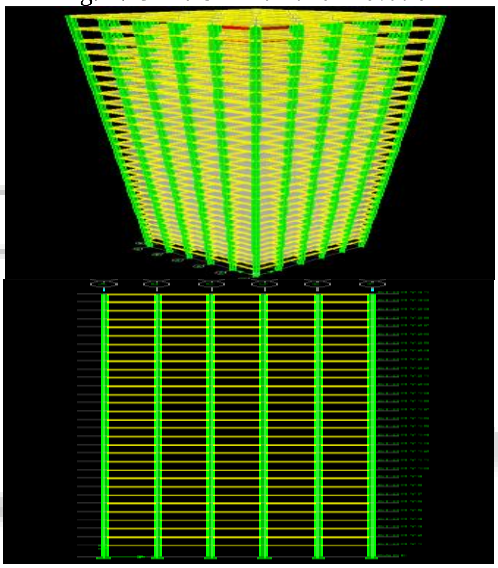

Fig. 3: G+30 3D Plan and Elevation

VI. RESULTS AND DISCUSSIONS

A. Introduction

In the equivalent static method design horizontal acceleration value obtained from the natural period, which was mentioned in the code and the basic assumption in the equivalent static method is that only first In this chapter an effort has made to study the behaviour of GFRP reinforced concrete bare frame buildings in comparison with steel reinforced buildings with and without shear wall. Here in the present study, the behaviour of each model sare captured and the results are tabulated in the form of Storey shear, lateral displacements and inter storey drifts.st mode of vibration of building For analysis purpose there type of buildings are taken, each building was made with provision of GFRP and Steel refaced bars and in each case the parameters are compared with the steel reinforcement. The taken buildings are

G+3 with ground floor height as 3.5m for parking purpose
G+10 with ground floor height as 5.0m for parking purpose
G+30 with ground floor height as 5.0mfor parking purpose.

In the above buildings the story height has been considered as 3.5m. For G+3 and G+10 buildings equivalent static analysis was carried and G+10 building was analysed with provision of shear wall in order to reduce the lateral displacements.

For G+30 building was analysed with response spectrum and non-linear push over analysis. Here also the building was analysed with shear wall provision and the effects are compared.

B. G+03storey

STATIC ANALYSIS RESULTS
STOREY SHEAR

From the equivalent static method, the base shear (V_B) obtained as per clause 7.8.2 of IS: 1893 (Part 1):2002. The base shear is a function of mass, height, and the natural period of the building structure. In the equivalent static method design horizontal acceleration value obtained from the natural period, which was0mentioned0in the0code and the0basic assumption0in the0equivalent static method is0that only first0mode of vibration0of building governs the dynamics and the effect of higher modes are not significant therefore, higher modes are not considered in this method. The sample calculation for base shear (VB) as per IS 1893 (Part 1): 2002 is furnishing below and for remaining stories the base shear was calculated, the same values are presented in table 6.2a and figure 6.1. In the same table the base shears, which were obtained from the ETabs software, are also furnished. 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.

1) Sample Calculation

Determination of fundamental natural period (Ta) of the buildings

$T_a = 0.075h^{0.75} = 0.075\times14^{0.75} = 0.543$ Sec

Determination of base shear (VB) of the building

$V_B = A_h \times W$

Where,

$$A_h = \frac{ZI\,Sa}{2Rg} = \frac{0.36\times1\times2.50}{2\times5} = 0.09$$

$V_B = A_h \times W = 0.09\times8793.75 = 773.43$KN

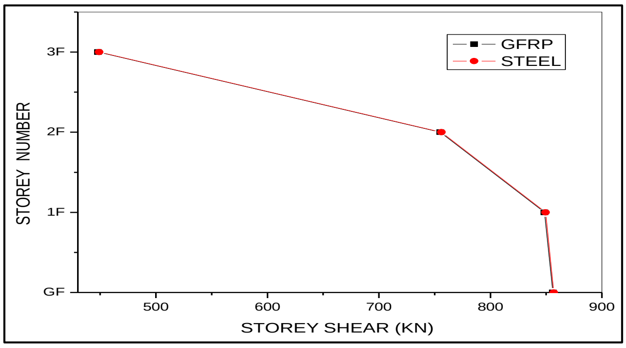

Fig. 4: Storey Shear profile for G+ 03 storey's building in X and Y-Direction

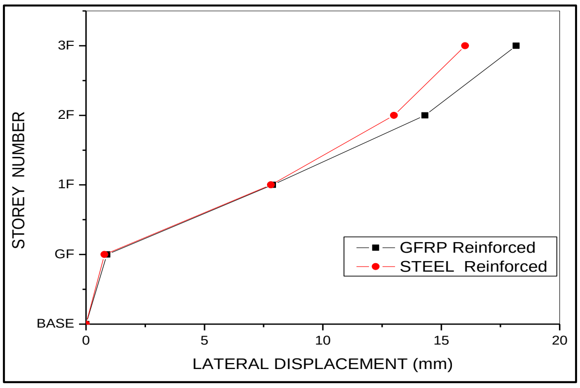

Fig. 5: Lateral Displacementsprofile for G+03for 0.9(DL+EQ) loading

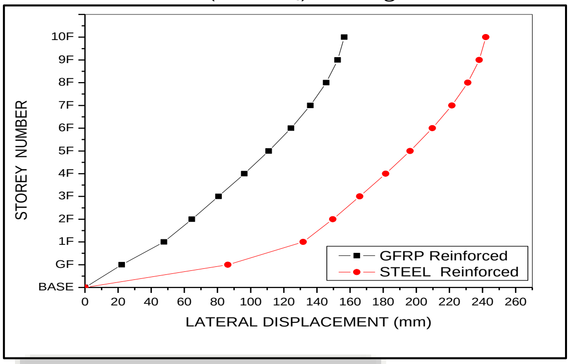

Fig. 6: Lateral Displacements profile for G+ 10 storeys building in X and Y-Direction

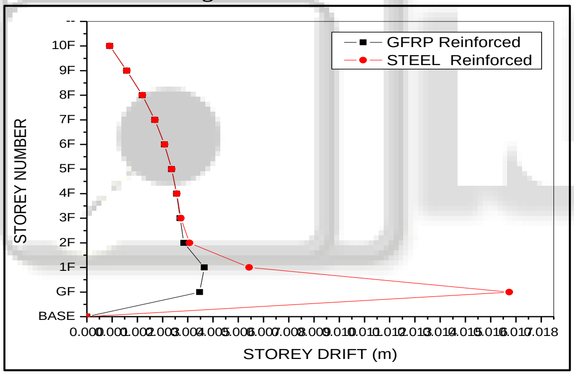

Fig. 7: Storey drifts profile for G+ 10 storey's building in X and Y-Direction

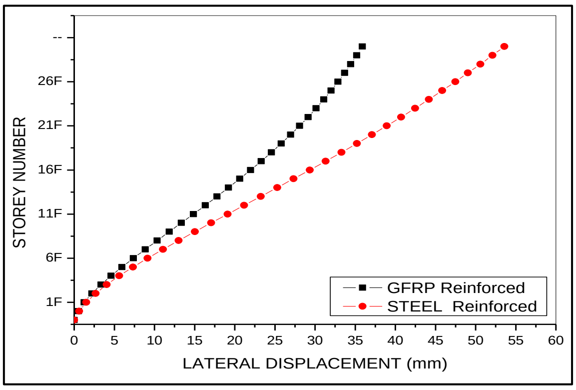

Fig. 8: lateral displacements profile for G+ 30 storey's building in X and Y-Direction

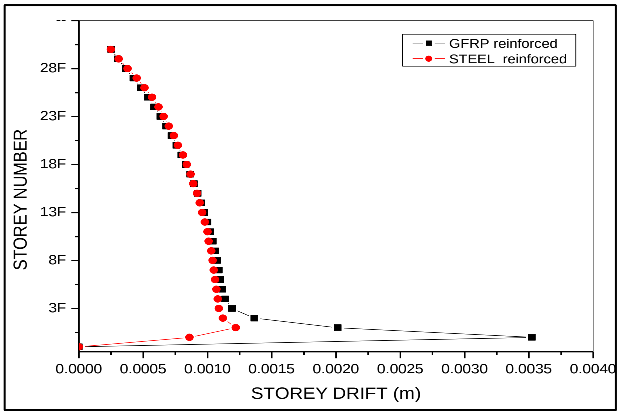

Fig. 9: Storey drifts profile for G+ 30 storey's building in X and Y-Direction

VII. CONCLUSIONS

The Present work done is concentrated on the Seismic behaviour of GFRP reinforced multistory Building in medium soil at zone IV using analytical techniques. Storey shear, lateral displacement, storey drift was studied for building G+03, 0+10 using static analysis and G+30 using dynamic analysis for building with and without shear wall. The Seismic behaviour is undertaken by static method for G-+-03, G+ I 0, response spectrum method and Pushover analysis for 0+30 storey building having symmetrical in plan. The conclusions that are concluded from present work done is as follows

1) Load carrying capacity of the GFRP reinforced building is higher than steel reinforced building which is major advantage of GFRP bars.
2) As we raise the height of storey it is observed that GFRP bars are performing very well as compare to STEEL, hence GFRP bars can be used effectively for high storey buildings.
3) As far as performance point is concerned, it is found the displacement of building is decreasing at higher loads and which is within permissible limit as given in IS 1893 (pan-I) 2002 due to increase in GFRP reinforcement ratio.
4) Storey shear obtain due to seismic force for the building with shear wall are more than the storey shear obtained without shear wall.
5) The base shears due to seismic forces for the building with shear wall are more than the base shear obtained for without shear wall.
6) Building reinforced with GFRP bars, fails al higher displacement than Steel, so we can say that low young's modulus(E) of GFRP reinforcement lead to reduce the overall stiffness of structure which is advantage on the overall structural behaviour. If the young's modulus of elasticity is low for a material, the strain is more for same stress as compared to a material having high modulus of elasticity.

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