International Journal of Technical Innovation in Modern Engineering & Science (IJTIMES)
Impact Factor: 5.22 (SJIF-2017), e-ISSN: 2455-2585
Volume 5, Issue 04, April-2019

COMPARATIVE ANALYSIS OF STRUCTURES MADE BY GFRP REBARS AND GEOPOLYMER CONCRETE AGAINST CONVENTIONAL REINFORCED CONCRETE SYSTEM

Panchal akash[1], Chetan machhi [2]

[1]*Civil Engineering Department, Sardar Patel College of Engineering (GTU)*
[2]*Civil Engineering Department, Sardar Patel College of Engineering (GTU)*

Abstract— The main purpose of this paper is to comparative study of strength of multi-storey, multibay frame buildings for lateral load for all materials combinations comes out of GFRP rebars, steel rebars, Geopolymer concrete, and conventional cement based concrete (such as GFRP-CONCRETE FRAME, GFRP-GEOPOLYMER FRAME, STEEL-CONCRETE FRAME, and STEEL-GEOPOLYMER FRAME of G+8, G+10, and G+12 STORIES) using nonlinear pushover analysis. Pushover analysis will carried out using ETABS 2016 software and using M3 and V2 hinges for beams and P-M-M hinges for columns. This paper shows the comparisons of displacement vs base shear at performance point and also shows comparison of maximum storey displacement vs base shear curve.

Keywords—glass fibre reinforced polymer (GFRP), geopolymer concrete, concrete structures, ETABS, Pushover analysis,

I. INTRODUCTION

Fibre reinforced polymer (FRP) bar is considerably acceptable as internal reinforcement for concrete structures because of its non-corrosive, lightweight, nonmagnetic, and high tensile strength properties while geopolymer concrete, normally manufactured using industrial waste materials like fly ash and blast furnace slags, has been successfully used in the construction of pavement, retaining walls, and bridges. Till now numerous research works on FRP-reinforced concrete and steel-reinforced geopolymer concrete are available. However, the use of FRP bar as internal reinforcement to geopolymer concrete had not been studied extensively and this has been the key motivation of this undertaking. The main purpose of this research is to comparative study of strength of multi-storey, multibay frame for lateral load for all materials combinations comes out of GFRP rebars, steel rebars, Geopolymer concrete, and conventional cement based concrete using nonlinear pushover analysis. Pushover analysis will carried out using ETABS 2016 software and using M3 and V2 hinges for beams and P-M-M hinges for columns.

Reinforced concrete is one of the most widely used composite material of civil infrastructure such as road, bridge, multistorey building, retaining wall and underground structures. But still it has many disadvantages including corrosion of internal reinforcing steel bar, sustainability issue of cement such as emission of carbon dioxide during production of cement and the maintenance, repair, and rehabilitation of damaged and deteriorating RC structure are very costly. Which became motivation for engineer and researchers to look for alternative for traditional steel reinforced concrete. Corrosion is the main contributing factor for deterioration of concrete. 1 tonne of cement production emits 1 tonne of carbon dioxide which is very harmful for environment. About 8% of yearly worldwide carbon dioxide emission is contributed by cement industry. With the stated drawback of conventional RC system, engineers and researchers were driven to modify the existing system and to develop new more effective solution. Among the current solution that are being employed are to replace steel bars with glass fibre reinforced polymer (GFRP) bars or to replace ordinary concrete with geopolymer concrete.

Combination of steel with conventional cement base concrete and steel with geopolymer concrete are feasible and practically acceptable currently, but combination of GFRP rebars with conventional cement base concrete are feasible and practically acceptable for flexural members and slab only. It is not acceptable practically for compression members currently but many researches are carried out for it. And its design specifications are given in CSA and ACI codes. And combination of geopolymer and GFRP rebars are not practically acceptable currently but it is in developing mode. So this paper shows only structural behaviour for pushover analysis of all four combination frame buildings based on materials physical and mechanical properties.

II. LITERATURE REVIEW

A. PROPERTIES GEOPOLYMER CONCRETE

(Hardjito and Rangan, 2005) GEOPOLYMER CONCRETE MIXTURE is given in this table in which two standard proportions of concrete is given which is used to get the properties of GEOPOLYMER CONCRETE.

Table 1
GEOPOLYMER CONCRETE MIXTURE

Materials		Mass (kg/m3)	
		Mixture 1	Mixture2
	20 mm	277	277
Coarse aggregates:	14 mm	370	370
	7 mm	647	647
Fine sand		554	554
Fly ash (low-calcium ASTM Class F)		408	408
proportions Sodium silicate solution (A53)		103	103
Sodium hydroxide solution		41 (8 Molar)	41 (14 Molar)
Super plasticiser		6	6
Extra water		None	22.5

(S. E. Wallah and B. V. Rangan 2006) Compressive strength of GEOPOLYMER CONCRETE MIXTURE 1 is given in the below chart in ambient temperature at different periods of time of the year. The compressive strength at the end of 28 days (4 weeks) will be considered in our project.

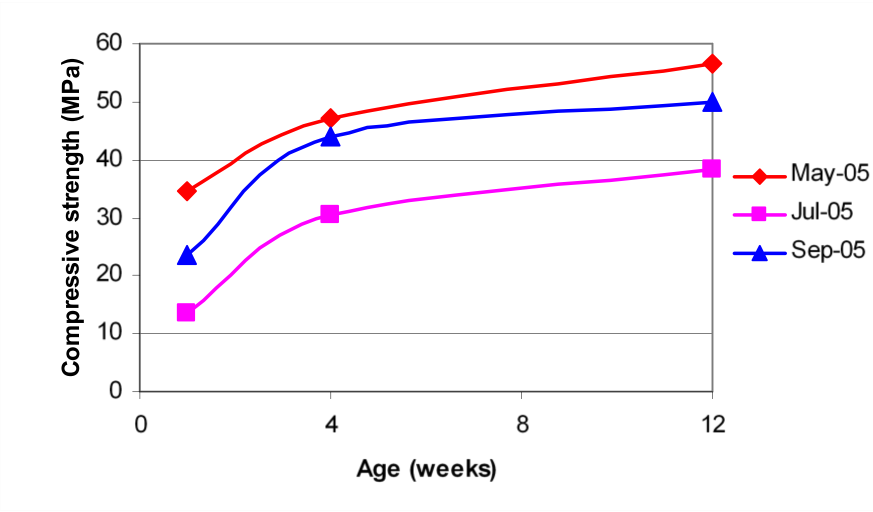

Fig. 1 Compressive strength of geopolymer concrete

(Harjitto and Rangan 2005) STRESS-STRAIN Curve formula is given and compared with experimental results for GEOPOLYMER CONCRETE MIXTURE1. Collins et al (1993) have proposed that the stress-strain relation of OPC concrete in compression can be predicted using the following expression: EQUATION 1

$$\sigma_c = f_{cm}\frac{\varepsilon_c}{\varepsilon_{cm}}\frac{n}{n-1+(\varepsilon_c/\varepsilon_{cm})^{nk}}$$ ……………………………………….Equation 1

Where
fcm = peak stress εcm = strain at peak stress
n = 0.8 + (fcm/17)
k = 0.67 + (fcm/62) when εc/εcm>1
= 1.0 when εc/εcm≤1
The strains at the peak stress are in the range of 0.0024 to 0.0026. These values are similar to those reported for geopolymer concrete. The stress strain curve obtain from equation 1 and experimental result are similar.

(Harjitto and Rangan 2005) American Concrete Institute (ACI) Committee 363 (1992) has recommended the following expression to calculate the modulus of elasticity.

$E_c = 3320 \sqrt{f_{cm}} + 6900$ (MPa) …………………………………………………………………..Equation 2

(Harjitto and Rangan 2005) Density
The average density of fly-ash based geopolymer concrete is 2350 kg/m^3

(Harjitto and Rangan 2005) Poission ratio
The Poisson's ratio of geopolymer concrete falls between 0.12 and 0.16

(M, Talha, junaid 2017) Co-efficient of thermal expansion
Co-efficient of thermal expansion of fly ash based geopolymer concrete is falls between $10.3*10^{-6}$ to $10.9*10^{-6}$

B. *PROPERTIES GFRP REBARS*

(V-Rod® Australia) Physical and mechanical properties of GFRP bars manufactured by V-Rod® Australia

Table 2
Physical and mechanical properties of GFRP bars manufactured by V-Rod® Australia

Property	Unit	#3	#4	#5	#6
Bar diameter	Mm	9.5	12.7	15.9	19.0
Unit weight	kg/m	0.243	0.380	0.558	0.811
Cross-sectional area	mm^2	71.3	126.7	197.9	285.0
Tensile strength	MPa	1372	1312	1184	1105
Tensile modulus	GPa	65.1 $\pm$ 2.5	65.6 $\pm$ 2.5	62.6 $\pm$ 2.5	63.7 $\pm$ 2.5
Tensile strain	%	2.11	2.00	1.95	1.99
Poisson's ratio	-	0.25	0.26	0.25	0.25
Flexural strength	MPa	1734	1377	1239	1196
Flexural modulus	GPa	65.5	64.9	63.5	60.2
Flexural strain	%	2.65	2.12	1.95	1.99
Transverse shear capacity	kN	41	67	94	127
Nominal bond strength	MPa	14			
Glass content by volume	%	65			
Glass content by weight	%	83			
Longitudinal thermal expansion	x10^{-6}/C	6.2			
Transverse thermal expansion	x10^{-6}/C	23.8			
Glass type	-	E			
Resin type	-	Vinyl ester			

(Vasilii Plevkov, Igor Baldin, Konstantin Kudyakov, and Andrei Nevskii 2017) The stress-strain diagram of GFRP and CFRP rebar under static tension and compression.

Table 3
The stress-strain curve of GFRP and CFRP rebar under static tension and compression

Material type	**Test type**	**Tensile strength, MPa**	**Relative strain limits**	**Elastic modulus, MPa**
GFRP	Tension	1284	0.0212	60560
	Compression	788	0.0192	41040
CFRP	Tension	1903	0.0132	144160
	Compression	1008	0.0096	105000

III. METHODOLOGY AND MODEL DESCRIPTION

A. *METHODOLOGY*

Step 1: Studied related research paper and collected data required for further research

Step 2: Defining material properties of GEOPOLYMER CONCRETE and GFRP REBARS required by Etabs as we get it from research papers.

Table 4
DEFINING MATERIAL (GEOPOLYMER CONCRETE) IN ETABS

MATERIAL PROPERTIES	MAGNITUDE
COMPRESSIVE STRENGTH	30 KN
MODULUS OF ELASTICITY	25084 (MPA)
POISON RATIO	0.12
DENSITY	2350 KG
CO-EFFICIENT OF THEMAL EXPANSION	10.9×10^{-6}

STESS-STRAIN CURVE

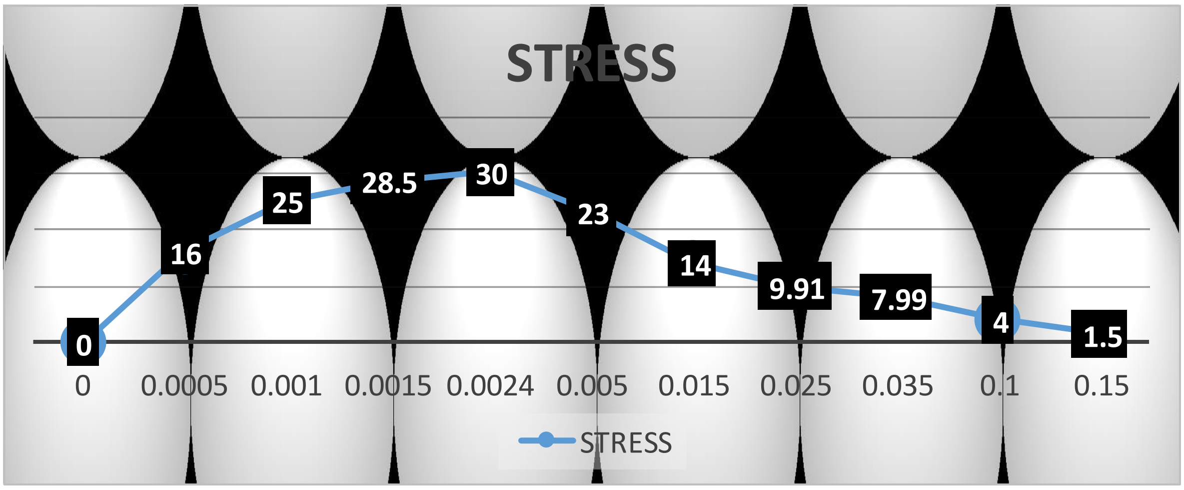

Fig. 2 Stress-strain curve of geopolymer concrete for etabs

Table 5
DEFINING MATERIAL (GFRP REBARS) IN ETABS

MATERIAL PROPERTIES	MAGNITUDE
AVERAGE DENSITY	2100 KG/M^3
MODULUS OF ELASTICITY	65.1 + 2.5 GPA
COEFFICIENT OF THERMAL ELPANSION	6.2x10^6 /C
YIELD STRENGTH	1105 MPA
TENSILE STRENGTH	1105 MPA
EXPECTED YIELD STRENGTH	1105 MPA
EXPECTED TENSILE STRENGTH	1105 MPA

STESS-STRAIN CURVE

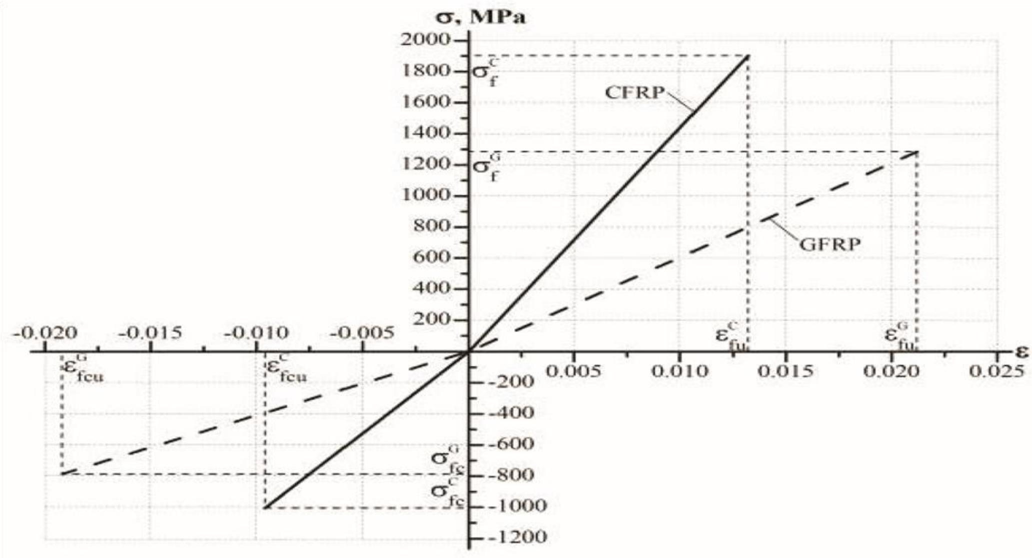

Fig. 3 Stress-strain curve of GFRP-REBARS for ETABS

Step 3: Define section properties required for ETABS.

Step 4: Modelling of all 12 possible combination of bare frame models from material such as 1)STEEL, 2)CEMENT BASED CONCRETE, 3)GEOPOLYMER CONCRETE, and 4)GFRP REBARS for G+8, G+10, AND G+12 STORIES.

All possible 12 combination are-:

1. **GFRP-CONCRETE FRAME G+8**
2. **GFRP-GEOPOLYMER FRAME G+8**
3. **STEEL-CONCRETE FRAME G+8**
4. **STEEL-GEOPOLYMER FRAME G+8**
5. **GFRP-CONCRETE FRAME G+10**
6. **GFRP-GEOPOLYMER FRAME G+10**
7. **STEEL-CONCRETE FRAME G+10**
8. **STEEL-GEOPOLYMER FRAME G+10**
9. **GFRP-CONCRETE FRAME G+12**
10. **GFRP-GEOPOLYMER FRAME G+12**
11. **STEEL-CONCRETE FRAME G+12**
12. **STEEL-GEOPOLYMER FRAME G+12**

Step 6: NON LINEAR PUSH OVER ANALYSIS is carried out of all the models and check for the results

B. *MODELING DISCRIPTION*

Table 6
MODEL DATA

DATA FOR G+8,G+10,G+12 STORIES FRAME	
NO OF BAYS IN X DIRECTION	3
NO OF BAYS IN Y DIRECTION	5
LENGTH OF EACH BAY IN X DIRECTION	3 METRE
LENGTH OF EACH BAY IN Y DIRECTION	3 METRE
NO OF STORIES	8, 10, 12
STOREY HEIGHT	3.2 METRE
column size	Beam size
700*700 mm	450*250 mm

IV. RESULTS AND DISCUSSION

A. *G+8 STORIES FRAME*

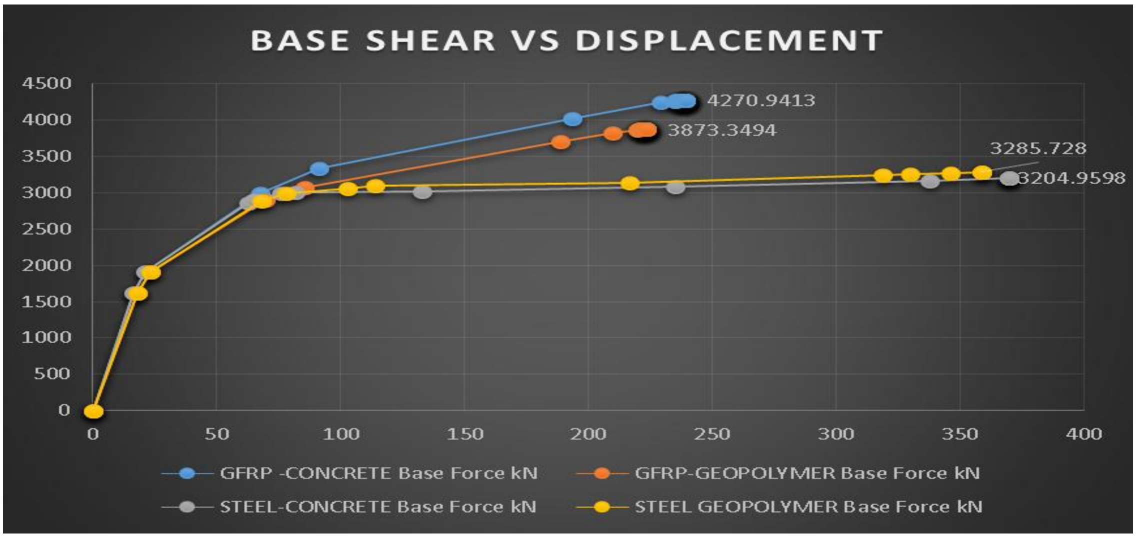

Fig. 4 G+8 STORIES FRAME MAXIMUM DISPLACEMENT VS BASE SHEAR

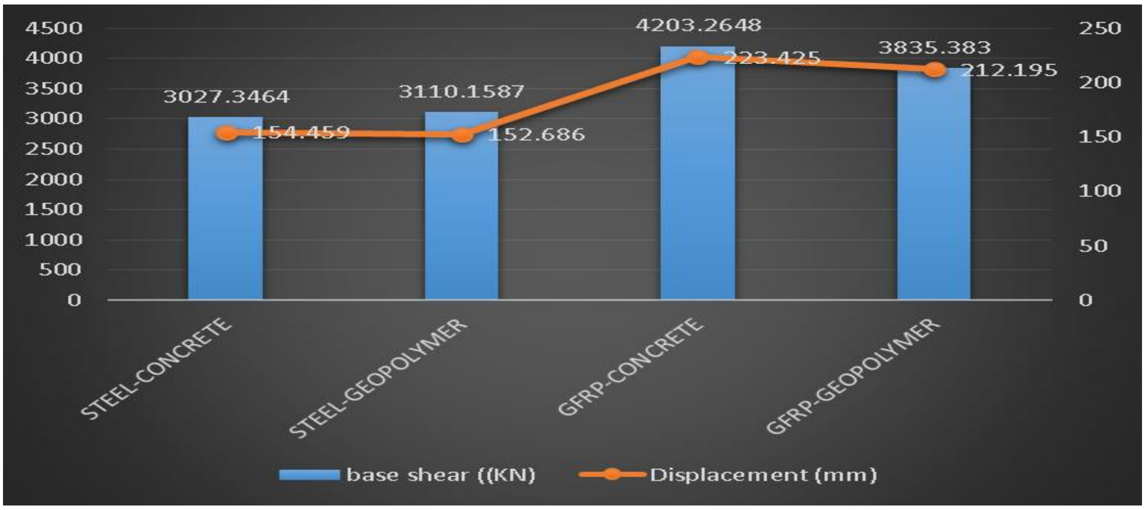

Fig. 5 G+8 STORIES FRAME BASE SHEAR VS DISPLACEMENT AT PERFORMANCE POINT

B. *G+10 STORIES FRAME*

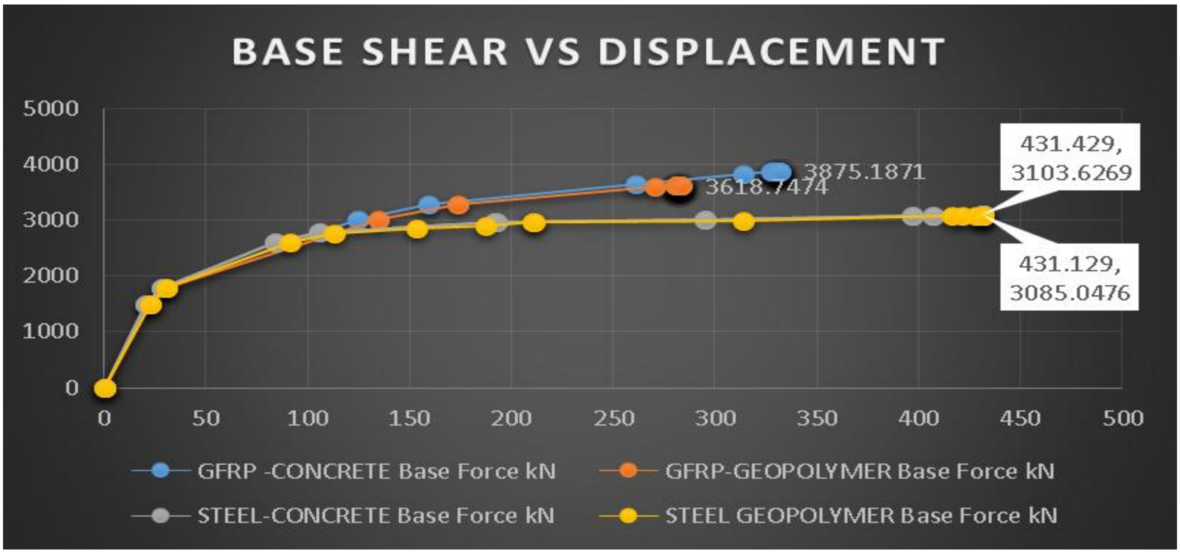

Fig. 6 G+10 STORIES FRAME MAXIMUM DISPLACEMENT VS BASE SHEAR

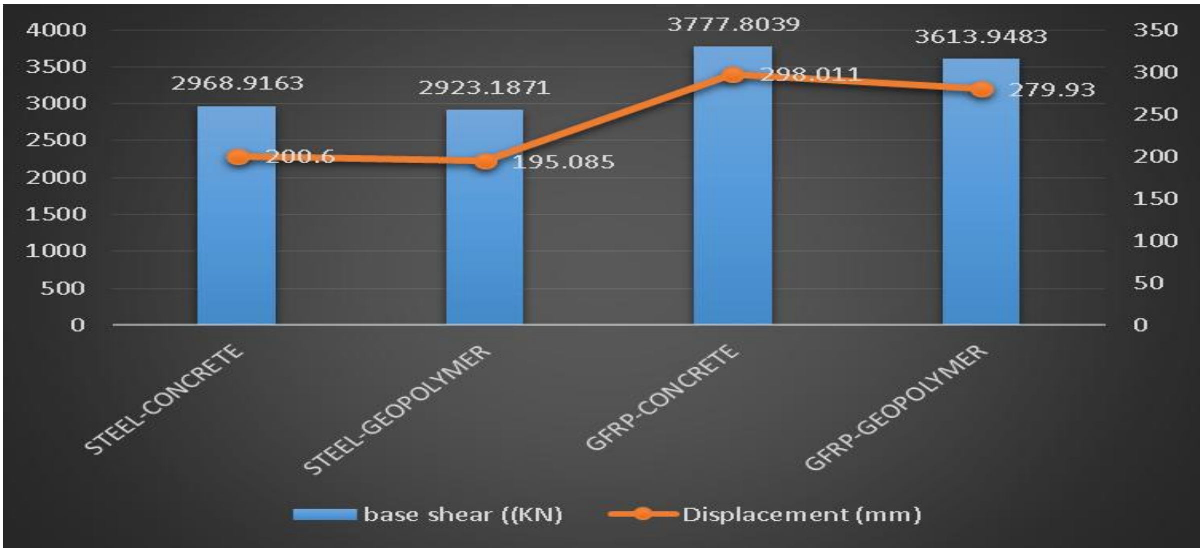

Fig. 7 G+10 STORIES FRAME BASE SHEAR VS DISPLACEMENT AT PERFORMANCE POINT

C. G+12 STORIES FRAME

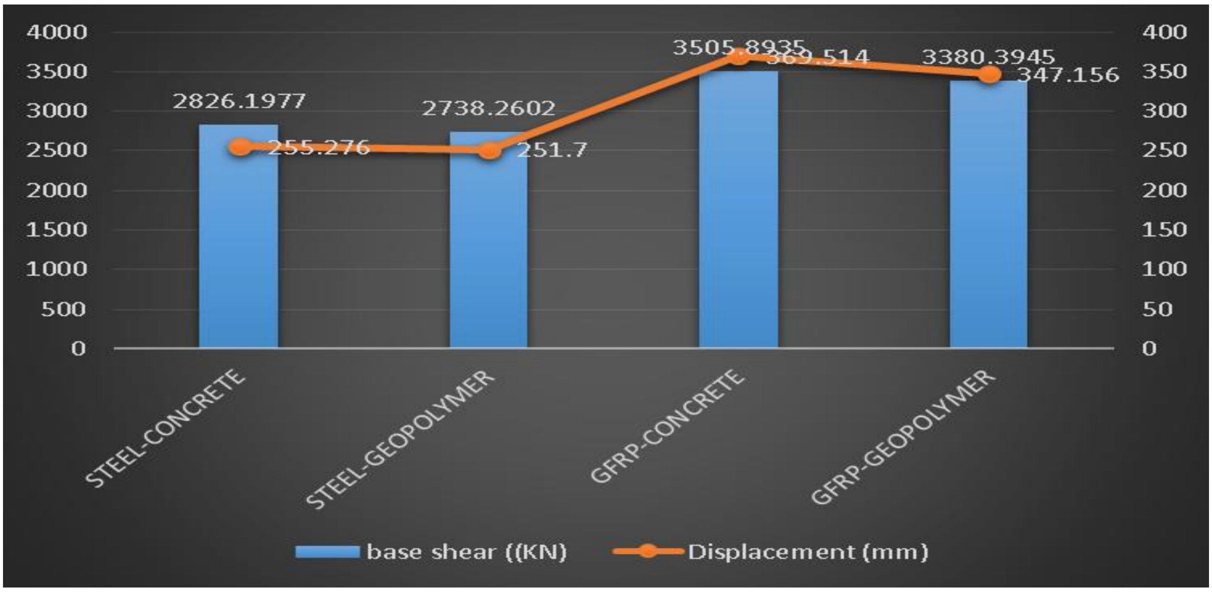

Fig. 8 G+12 STORIES FRAME BASE SHEAR VS DISPLACEMENT AT PERFORMANCE POINT

D. STEEL-CONCRETE

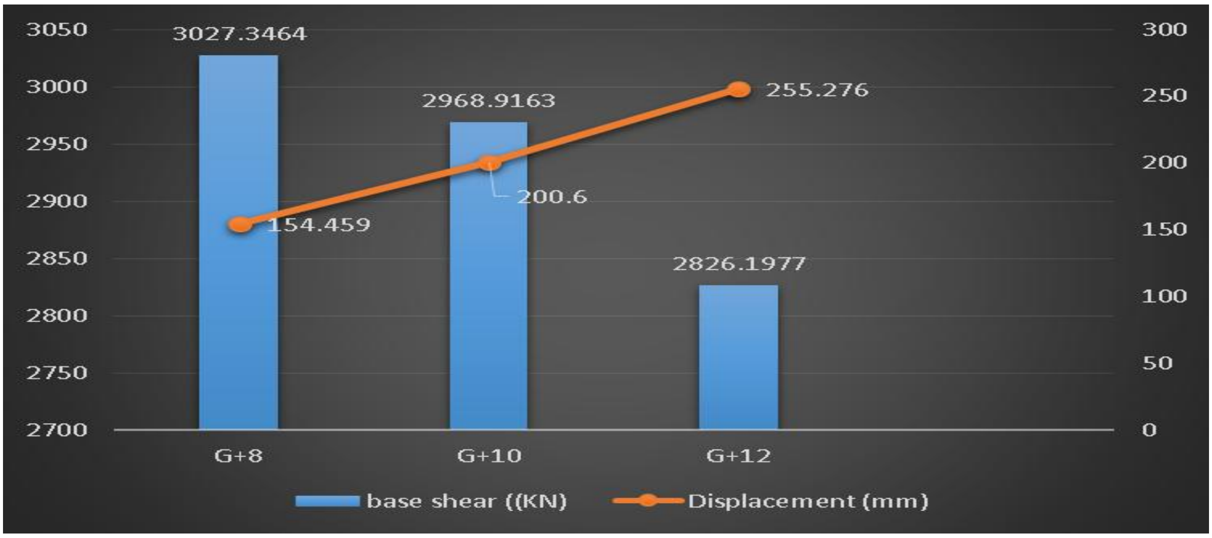

Fig. 8 STEEL-CONCRETE DISPLACEMENT VS BASE SHEAR AT PERFORMANCE POINT

E. ***STEEL-GEOPOLYMER***

Fig. 9 STEEL-GEOPOLYMER DISPLACEMENT VS BASE SHEAR AT PERFORMANCE POINT

F. ***GFRP-CONCRETE***

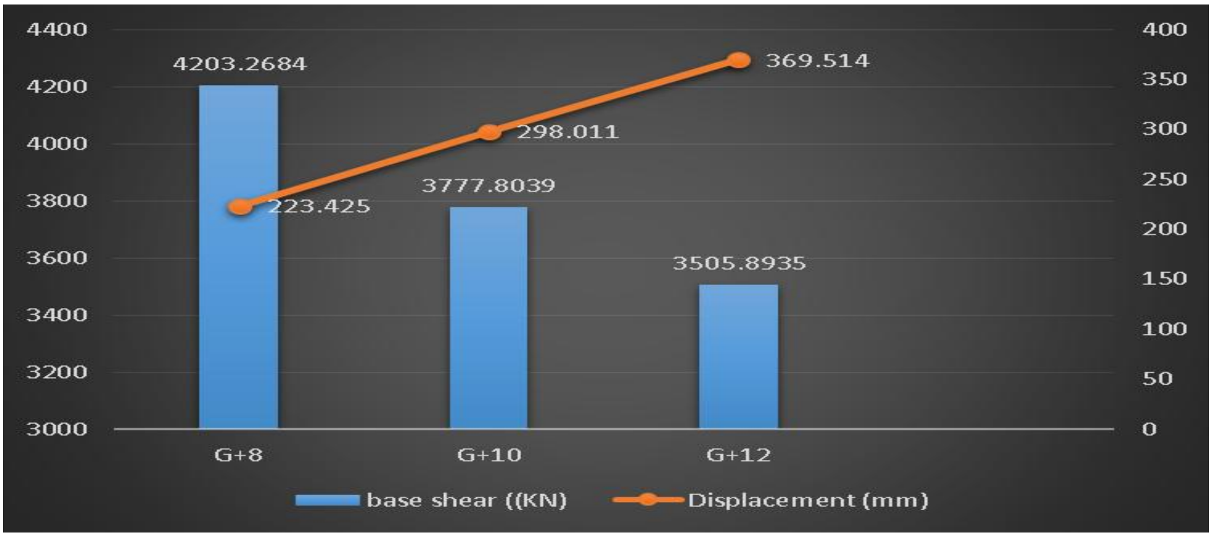

Fig. 10 GFRP-CONCRETE DISPLACEMENT VS BASE SHEAR AT PERFORMANCE POINT

G. ***GFRP-GEOPOLYMER***

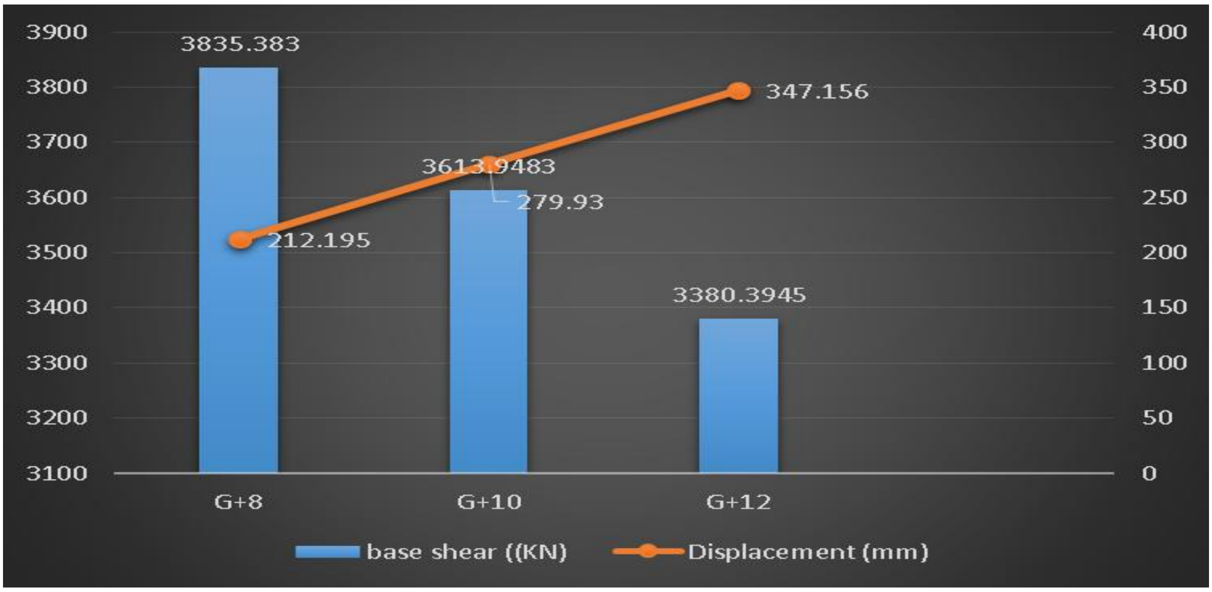

Fig. 11 GFRP-GEOPOLYMER DISPLACEMENT VS BASE SHEAR AT PERFORMANCE POINT

H. SUMMARY

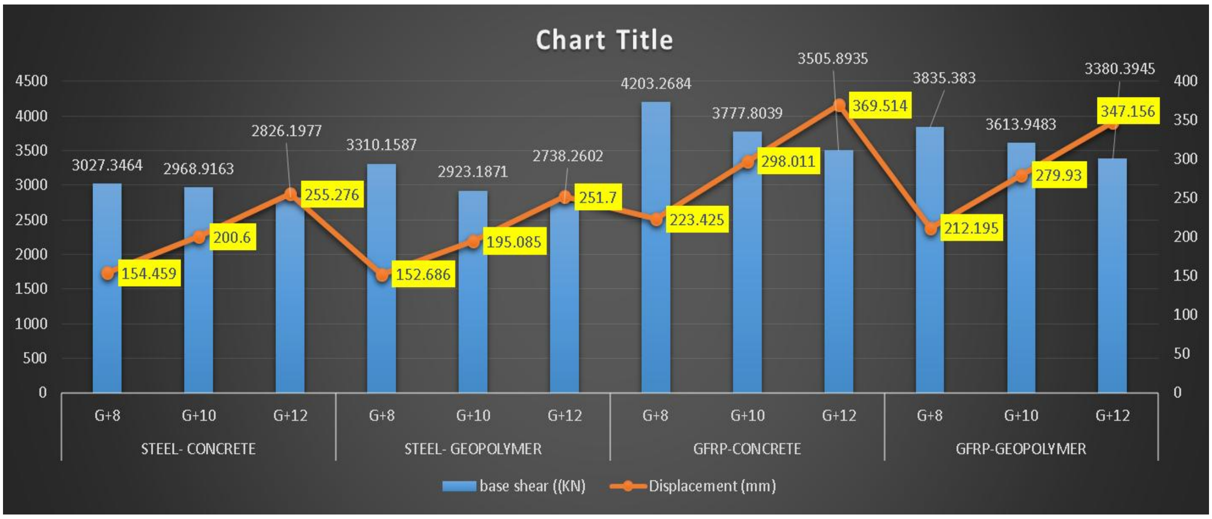

Fig. 12 SUMMARY OF DISPLACEMENT VS BASE SHEAR AT PERFORMANCE POINT

Table 7
Summary of displacement vs. base shear at performance point

		base shear ((KN)	Displacement (mm)
STEEL-CONCRETE	G+8	3027.3464	154.459
	G+10	2968.9163	200.6
	G+12	2826.1977	255.276
STEEL-GEOPOLYMER	G+8	3310.1587	152.686
	G+10	2923.1871	195.085
	G+12	2738.2602	251.7
GFRP-CONCRETE	G+8	4203.2684	223.425
	G+10	3777.8039	298.011
	G+12	3505.8935	369.514
GFRP-GEOPOLYMER	G+8	3835.383	212.195
	G+10	3613.9483	279.93
	G+12	3380.3945	347.156

V. CONCLUSIONS

1. Frame consist of steel rebars has more maximum displacement compare to frame consist of gfrp rebars due high ductility of steel and as gfrp rebars are brittle
2. Frame consist of cement base concrete has more maximum displacement compare to frame consist geopolymer concrete due high modulus of elasticity of cement base concrete compare to geopolymer concrete but
3. Load carrying capacity of GFRP reinforced frames is higher than steel reinforced frames.
4. 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.
5. For different frame types Glass Fiber Reinforced Polymer reinforcement has yielded not only greater flexural strength to the beams but also good shear capacity.
6. Frame structure with GFRP-REBARS and GEOPOLYMER CONCRETE has acceptable performance. It can be preferred for ecofriendly and economy point of view if it became feasible in future.

REFERENCES

[1] (S. E. Wallah and B. V. Rangan 2006) low-calcium fly ash-based geopolymer concrete: long-term properties.
[2] (D. Harjito and B.V. Rangan 2005) Development and properties of low-calcium fly-ash based geopolymer concrete
[3] V-Rod® Australia (2012) Physical and mechanical properties of GFRP bars manufactured by V-Rod® Australia
[4] (Vasilii Plevkov, Igor Baldin, Konstantin Kudyakov, and Andrei Nevskii 2017) Mechanical properties of composite rebar under static and short-term dynamic loading
[5] (Lloyd and Rangan 2010) Geopolymer concrete with flyash

[6] (M, Talha, junaid 2017) Deformational behavior of fly ash-based geopolymer concrete at temperature of it up to 150 degree celcius

[7] (Ginghis Maranan1; Allan Manalo2; Karu Karunasena3; and Brahim Benmokrane et al 2014) Bond stress–slip behavior of GFRP bars in geopolymer concrete

[8] (Ginghis Maranan1; Allan Manalo2; Karu Karunasena3; and Brahim Benmokrane et al 2015) Evaluation of the flexural strength and serviceability of geopolymer concrete beams reinforced with glass-fibre-reinforced polymer (GFRP) bars.