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Stiffening the soft storey using carbon fiber strands with varying angle in a low rise G+4 R.C frame Building

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Abstract— In present scenario of increasing urbanization, open ground storey is a typical feature in commercial and residential building. Such buildings are resulting in their poor performance as observed during past earthquake. These provision reduce the stiffness of lateral load resisting system and progressive collapse become unavoidable in serve earthquake for such building. The seismic performance of building can be improved by using shear wall and bracing. Advantage of carbon fiber strand over shear wall and bracing is getting plenty of free space and increase stiffness of ground storey. In the present study, Alternative method to stiffen the R.C frame building with an open ground storey using carbon fiber strand is analysed. It protect the building against quakes by tying the first floor to ground. The study includes the performance of building using different angle of tying strands with a specific configuration plan having G+4storey and various results are compared with shear wall. The performance of building has been evaluated based on linear static and dynamic analysis using Etabs software.

Keywords— Stiffening, Soft Storey, Carbon fiber strands, Equivalent Diagonal Struts, Static Analysis, Response Spectrum Analysis

I. INTRODUCTION

Many urban multistorey buildings in India today have open ground storey as an unavoidable feature. This is primarily being adopted to accommodate parking or reception lobbies in the ground storeys. It has been noted that several structures were damaged or entirely collapsed during the past earthquake in India due to presence of soft storey. For instance, the city of Ahmedabad alone has about 25,000 five storey building and about 1500 eleven storey buildings majority of them have open ground storey. Further a large number of similarly designed and constructed building exist in the various towns and cities situated in moderate to severe seismic zones (namely III, IV and V) of the country. The collapse of more than hundred R.C frame buildings with open ground storey at Ahmedabad (approx. 225km away from epicentre) during the 2001 Bhuj earthquake has emphasized that such building are extremely vulnerable under earthquake shaking.

II. OBJECTIVES OF STUDY

The structure should have adequate lateral strength, lateral stiffness and sufficient ductility to meet the requirements of safety and minimum damage to structural elements during earthquake. Among the various structural system, shear wall and bracing system is mostly preferred by the designers. Alternative method to remove soft storey effect by using carbon fiber strands also perform better during earthquake. Therefore this study has been undertaken to remove soft storey effect by balancing the stiffness of open ground storey with upper storey in multi storey building using carbon fiber strand without affecting parking area which reduce the displacement, improve the lateral strength and aesthetic view of building.

III. BUILDING MODELS STUDIED

The plan layout of R.C frame building with open ground storey, chosen for this study is shown in fig. 1 and side elevation for different arrangement is shown in fig. 2. The building is symmetrical in plan having five bays in x-direction and four bays in y-direction. The plan dimension for G+4 residential building is 23m x 20m with 19.5m height of the building.

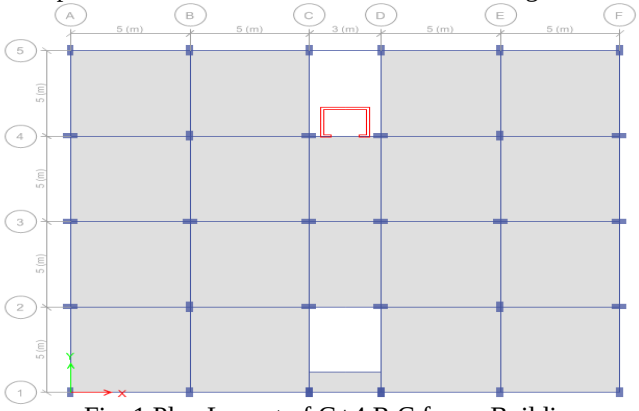
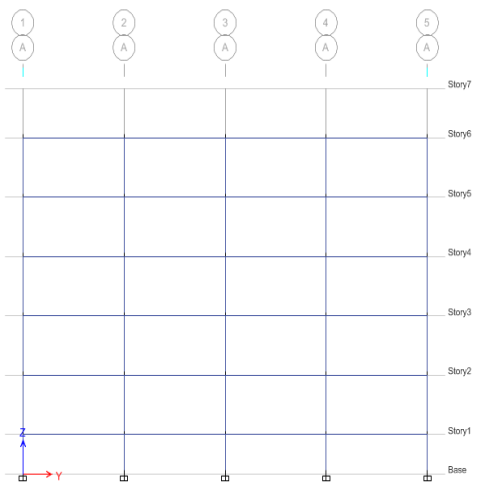
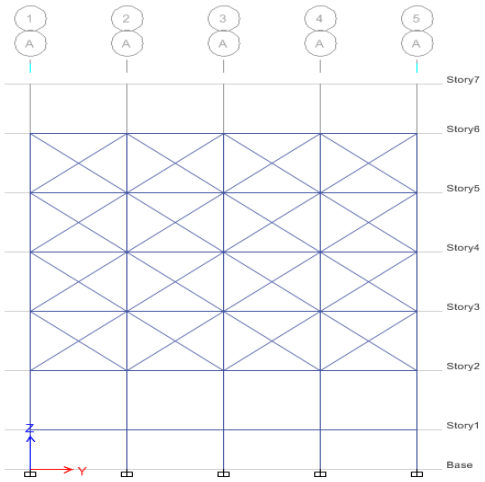


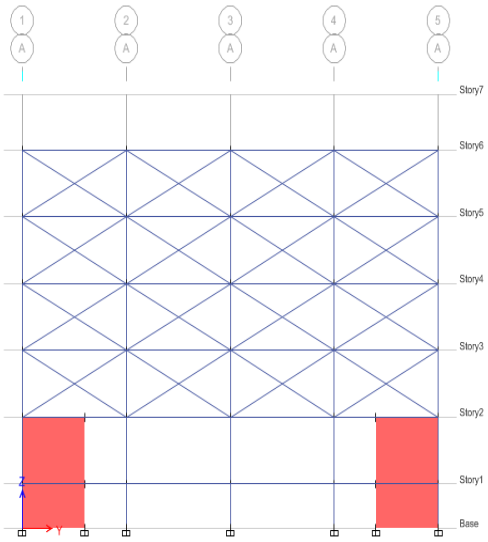
Fig. 1 Plan Layout of G+4 R.C frame Building



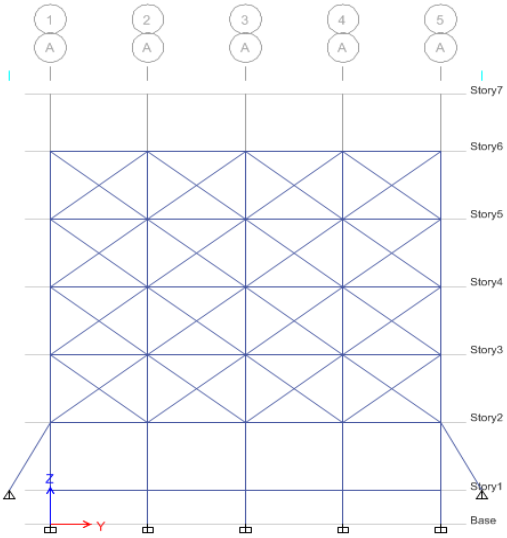
(a) Elevation of bare frame



(b) Elevation of bare frame with infill walls



(c) Elevation of bare frame with infill walls and shear walls



(d) Elevation of bare frame with infill walls and carbon fiber strands tied at an angle of 30° 35° and 40°

Fig. 2 Elevation of different building models arrangement

Six different models of building are studied (fig 2). These are:

Model – I Building modelled as bare frame. However masses of the walls included in the model.

Model – II Building has no walls in the ground storey and external walls and internal walls (using equivalent diagonal struts) in the upper stories

Model – III Building has no walls in the ground storey and external walls and internal walls (using equivalent diagonal struts) in the upper stories and shear walls from foundation to first storey

Model – IV Building has no walls in the ground storey and external walls and internal walls (using equivalent diagonal struts) in the upper stories and for ground storey using carbon fiber strands tied at an angle of 30°. Here the number of strand used are 11 each per column

Model – V Building has no walls in the ground storey and external walls and internal walls (using equivalent diagonal struts) in the upper stories and for ground storey using carbon fiber strands tied at an angle of 35°. Here the number of strand used are 09 each per column

Model – VI Building has no walls in the ground storey and external walls and internal walls (using equivalent diagonal struts) in the upper stories and for ground storey using carbon fiber strands tied at an angle of 40°. Here the number of strand used are 06 each per column

TABLE I
DESCRIPTION OF THE MODEL

Sr No	Items	Description
1.	No of storey	G + 4
2.	Floor height	3m
3.	Plinth height	2m
4.	Stilt height	3m
5.	Shear wall thickness	115mm
6.	Infill external wall thickness	230mm
7.	Infill internal wall thickness	115mm
8.	Live Load on typical floor	2 kN/m^2
	Live Load on terrace	1.5 kN/m^2
9.	Floor finish	1.5 kN/m^2
	Water proofing	2 kN/m^2
10.	Dimension of lift	1.8m x 1.5m
11.	Size of column	300mm x 600mm
12	Size of beam	300mm x 450mm
13.	Size of Door (opening)	1m x 2.1m
14.	Size of Window (opening)	1m x 1m
15.	Slab thickness	115mm
16.	Grade of concrete	M20
17.	Grade of steel	Fe 415
18.	Elastic Modulus of concrete	22360.67 Mpa
19.	Elastic Modulus of masonry	5500 Mpa
20.	Poisson Ratio of concrete	0.20
21.	Poisson Ratio of masonry	0.15
22.	Specific weight of concrete	25 kN/m^3
23.	Specific weight of masonry	20 kN/m^3
24.	Type of soil	Medium
25.	Zone	III
26.	Response Spectrum	IS 1893 - 2002
27	Carbon fiber strand	Description (As per Tokyo Rope Ltd Japan)
	Diameter	40mm
	Tensile Strength	2690 Mpa
	Elastic Modulus	155 GPa
	Poisson ratio	0.23
	Specific Gravity	1.5 g/cm^3
	Coefficient of linear expansion	0.6 x 10^{-6} / °C
28	Width of Equivalent Diagonal struts	(thickness x depth)
	External walls (X direction)	230mm x 534.19mm
	External walls (Y direction)	230mm x 465.04mm
	Internal walls (X direction)	115mm x 406.83mm
	Internal walls (Y direction)	115mm x 354.16mm

IV. ANALYSIS OF THE BUILDING

Seismic analysis is a major tool in earthquake engineering which is used to understand the response of building due to seismic excitation in a simpler manner. It is a part of structural analysis and a part of structural design where earthquake is prevalent. Main feature of seismic method of analysis based on Indian standard 1893 (Part-1) code "Criteria for Earthquake Resistant Design of Structures".

A. Static Analysis

Seismic analysis of most of the structure are still carried on the basis of lateral force assumed to be equivalent to actual dynamic loading. The base shear which is the total horizontal force on the structure is calculated on the base of structure mass and fundamental period of vibration and corresponding mode shape. The base shear is distributed along the height of structure in terms of lateral forces according to IS 1893 (Part-1) code.

B. Response Spectrum Analysis

The approach permits the multiple modes of response of a building to be taken into account. This is required in many building codes for all except for very simple or very complex program. The structural response can be defined as a

combination of many modes. Computer analysis can be used to determine these modes for a structure. For each mode, a response is obtained from the design spectrum, corresponding to the modal frequency and modal mass and then they are combined to estimate the total response of the structure. In this the magnitude of forces in all direction is calculated and then effects on the building is observed.

V. RESULTS AND DISCUSSIONS

The displacement from the static analysis method are consistently increased by about 20% than those from dynamic analysis method.

Storey Stiffness

The storey stiffness of ground and first floor are shown in Table II.

TABLE II
STOREY STIFFNESS OF GROUND AND FIRST STOREY FOR DIFFERENT MODELS

1	Storey Stiffness (kN/mm) @ Ground & First Floor				
Sr.No	Building Model	Y Direction		X Direction	
		Ground	First	Ground	First
1	Bare Frame including mass of infill	460.98	373.41	493.26	426.94
2	Open ground storey + infill in upper stories	742.41	1501.89	753.57	1290.77
3	Open ground storey + infill + Shear wall	2542.28	2521.53	2436.62	2388.4
4	Open ground storey + infill + Carbon strands at 30^0 @ GF	2707.78	2700.47	2602.61	2660.86
5	Open ground storey + infill + Carbon strands at 35^0 @ GF	2743.001	2708.29	2631.65	2655.22
6	Open ground storey + infill + Carbon strands at 40^0 @ GF	2588.03	2581.11	2505.77	2584.76

The stiffness irregularity in building models with bare frame is about 18% of that of first storey. And for Open ground storey with infill walls in upper stories is about 50% of that of first storey. The use of shear wall in Model-III and carbon fiber strands at different angles for Model IV V & VI in ground storey reduces the stiffness irregularity.

Natural Periods

As per IS – 1893 2002 and Etabs natural periods of building models are shown in Table III. It seen that software results do not tally with empirical formula as per code. The bare frame and Open ground storey with infill walls in upper stories has over estimation of natural period compared to other models.

TABLE III
NATURAL PERIOD OF DIFFERENT MODELS

2	Fundamental Natural Period (sec)				
Sr.No	Building Model	Transverse		Longitudinal	
		Code	Software	Code	Software
1	Bare Frame including mass of infill	0.695	0.851	0.695	0.832
2	Open ground storey + infill in upper stories	0.392	0.458	0.365	0.55
3	Open ground storey + infill + Shear wall	0.392	0.314	0.365	0.34
4	Open ground storey + infill + Carbon strands at 30^0 @ GF	0.392	0.303	0.365	0.33
5	Open ground storey + infill + Carbon strands at 35^0 @ GF	0.392	0.302	0.365	0.329
6	Open ground storey + infill + Carbon strands at 40^0 @ GF	0.392	0.309	0.365	0.336

Maximum Storey Displacements

The lateral displacement of various models for two different analysis performed in this study are shown in Table IV.
The ground storey lateral displacement in building models for bare frame and Open ground storey with infill walls in upper stories is very severe. By the use of shear wall in Model –III and carbon fiber strands in Model –IV V and VI, displacement drastically reduce is about 25%

TABLE IV
MAXIMUM STOREY DISPLACEMENT OF DIFFERENT MODELS

3	Maximum Storey Displacement (mm) @ Ground Floor				
Sr.No	Building Model	Static Analysis @ Ground Floor		Dynamic Analysis @ Ground Floor	
		Y Direction	X Direction	Y Direction	X Direction
1	Bare Frame including mass of infill	2.304	2.508	1.603	2.475
2	Open ground storey + infill in upper stories	1.99	2.439	1.371	2.66
3	Open ground storey + infill + Shear wall	0.53	0.618	0.415	0.53
4	Open ground storey + infill + Carbon strands at 30^0 @ GF	0.487	0.633	0.415	0.578
5	Open ground storey + infill + Carbon strands at 35^0 @ GF	0.478	0.622	0.405	0.571
6	Open ground storey + infill + Carbon strands at 40^0 @ GF	0.51	0.659	0.441	0.6

Maximum Storey Drift

The storey drift of various models for two different analysis performed in this study are shown in fig 3.

The ground storey drift in building models for bare frame and Open ground storey with infill walls in upper stories is very severe. By the use of shear wall in Model –III and carbon fiber strands in Model –IV V and VI, drift is drastically reduced is about 22%

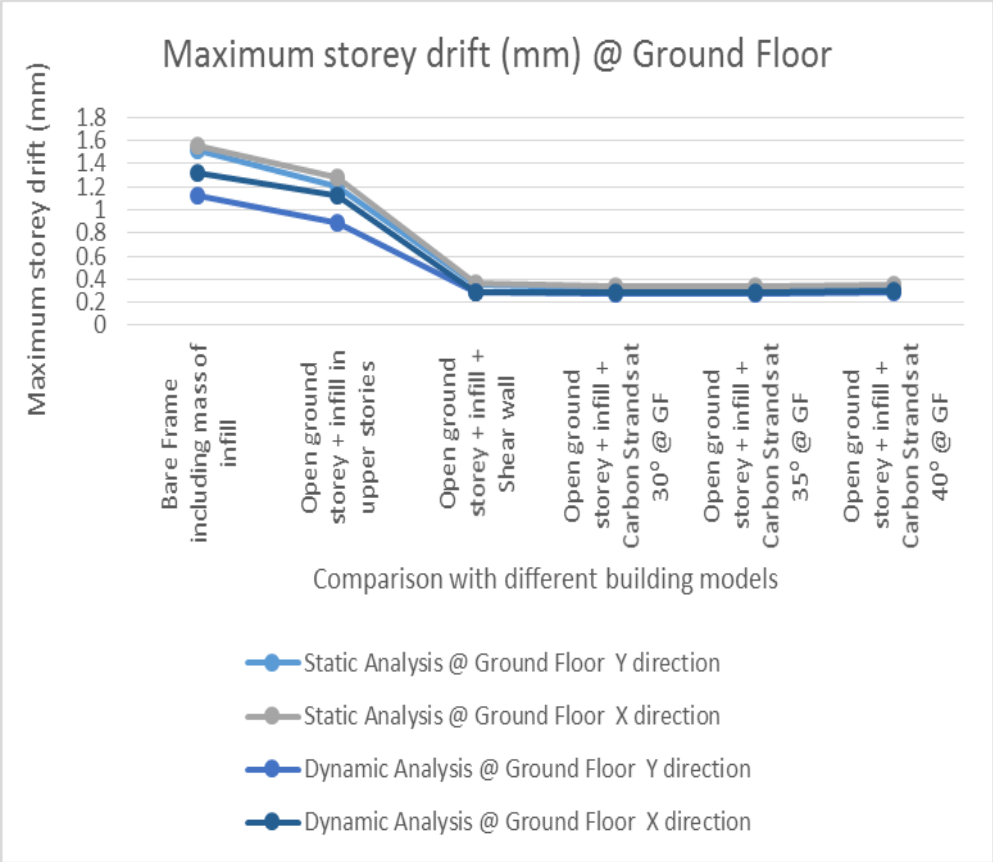


Fig 3 Maximum storey drift

Base Shear

The base shear of various models for two different direction performed in this study are shown in fig 4. Base Shear value of bare frame is 23% lower than bare frame with infills. Here except bare frame all other models values are same is about 890kN.

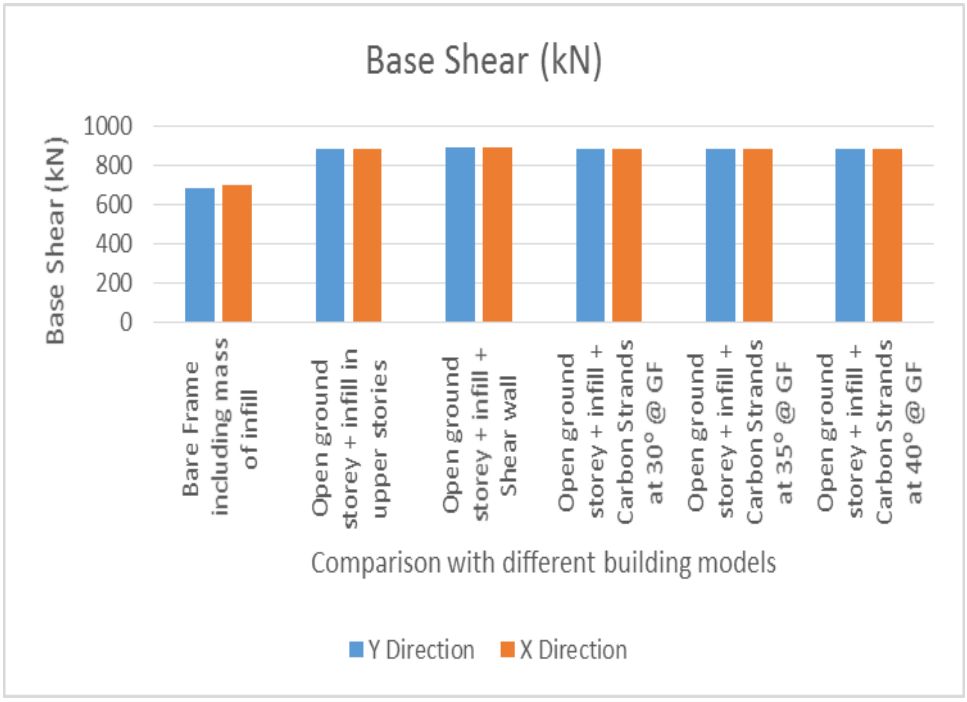


Fig 4 Base shear

Maximum Moment

Maximum moment for corner columns in ground storey are shown in fig. 5.The bending moments are severely higher in bare frame and Open ground storey with infill walls in upper stories which is 26% than in other models. The use of shear walls and carbon fiber strands reduce the moments in columns.

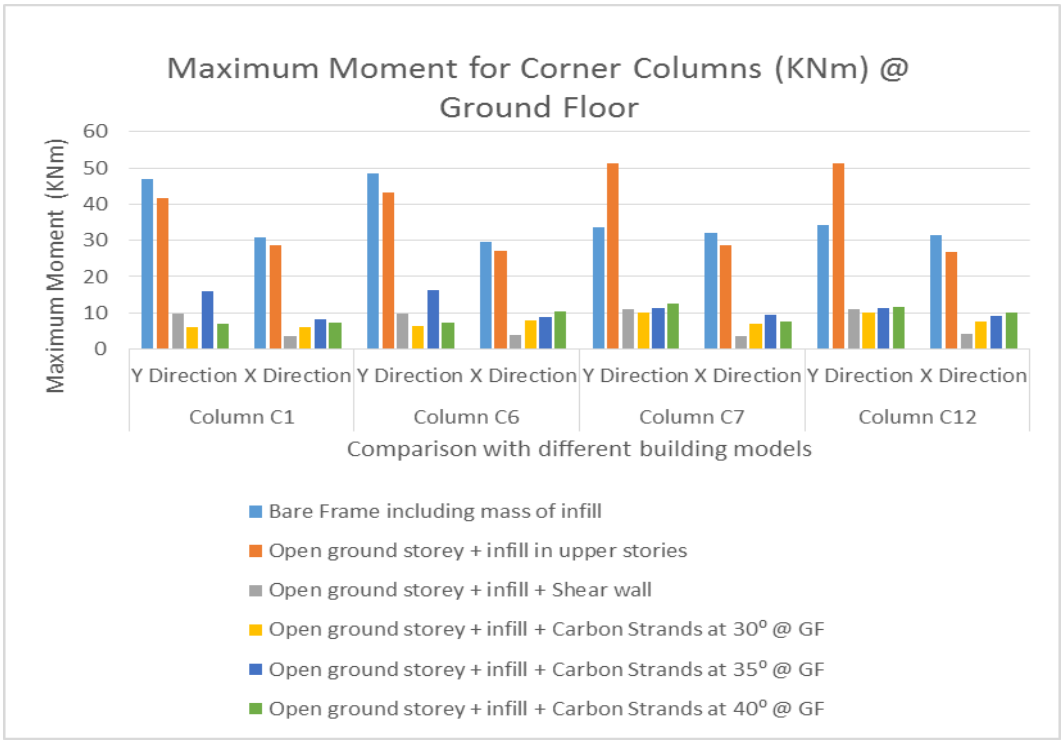


Fig 5 Maximum moment for corner columns

Maximum Shear Force

Maximum shear forces for corner columns in ground storey are shown in fig. 6.The shear forces are severely higher in bare frame and Open ground storey with infill walls in upper stories which is 26% than in other models. The use of shear walls and carbon fiber strands reduce the shear forces in columns.

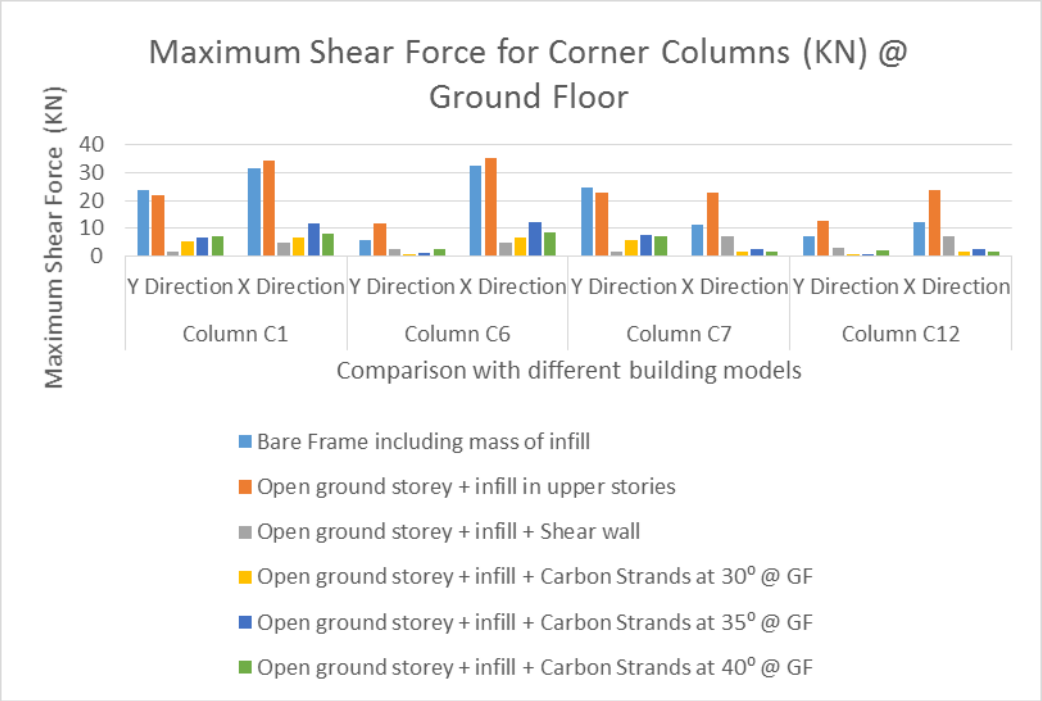


Fig 6 Maximum shear force for corner columns

Maximum Axial Force

Maximum axial forces for corner columns in ground storey are shown in fig. 7.The axial forces are severely higher in bare frame and Open ground storey with infill walls in upper stories which is 23% than in other models. The use of shear walls and carbon fiber strands reduce the axial forces in columns.

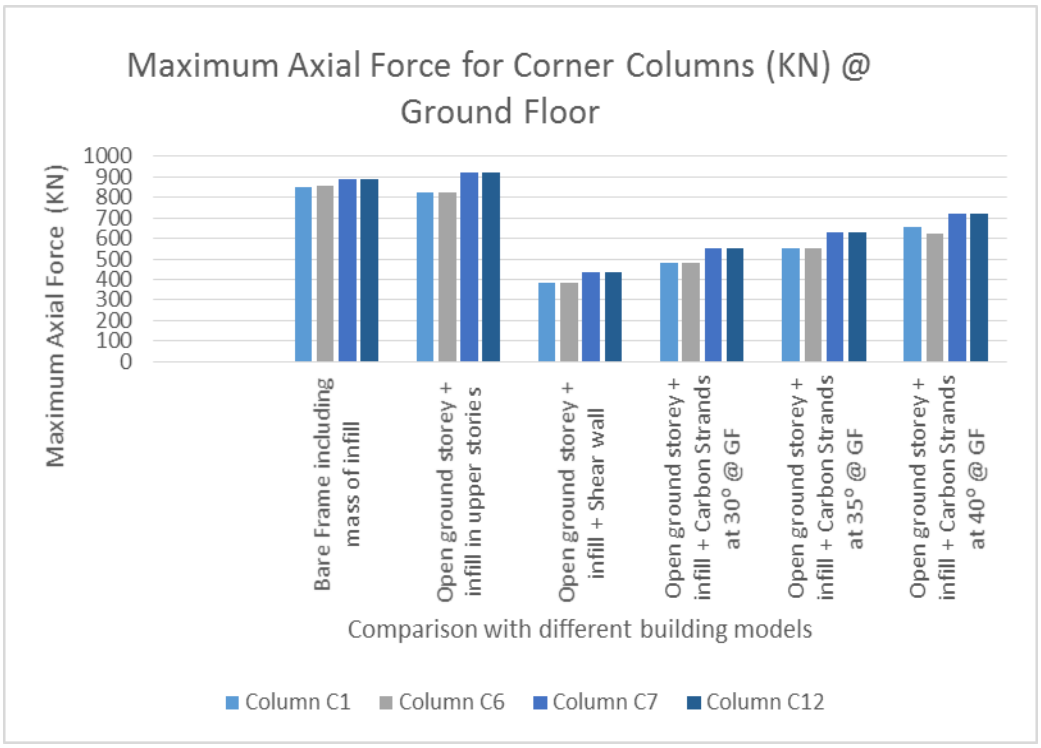


Fig 7 Maximum axial force for corner columns

Maximum Torsion

Maximum torsion for corner columns in ground storey are shown in fig. 8.The torsion values are severely higher in bare frame and Open ground storey with infill walls in upper stories which is 15% than in other models. The use of shear walls and carbon fiber strands reduce the torsion in columns.

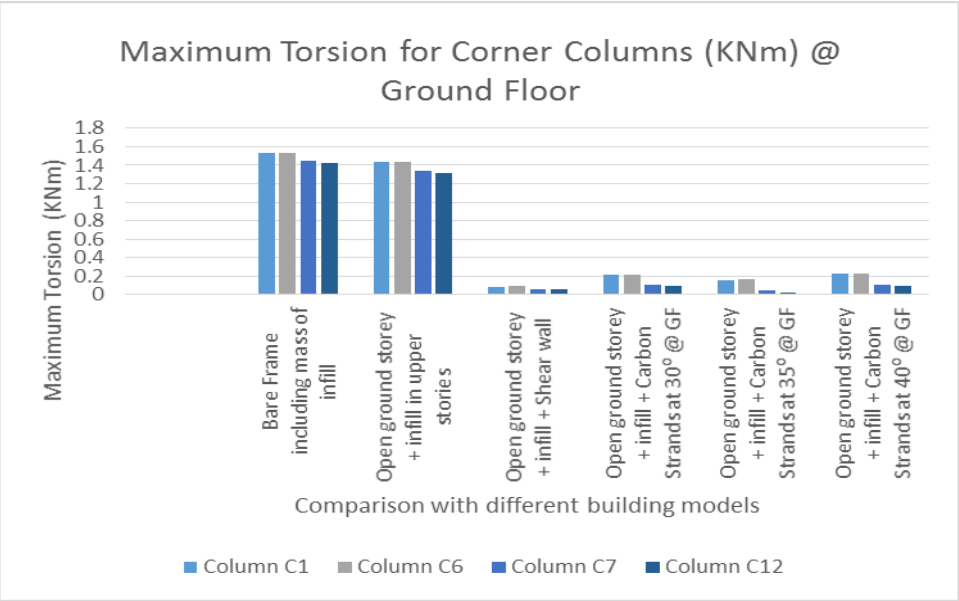


Fig 8 Maximum torsion for corner columns

VI. CONCLUSIONS

RC frame building with open ground storey is very vulnerable during earthquake. The storey drift and lateral displacement are higher for open ground storey. The requirement of open ground storey in modern urban society cannot be avoidable. Thus Alternative measures adopted to increase the stiffness of storey by provision of carbon fiber strands. The Storey stiffness, Maximum storey displacement, Maximum storey drift, Base shear, Maximum moment, axial forces, shear forces and torsion values of carbon fiber strands with different angle are closure to shear wall. Here by increasing the angle of strands the number of strands also decrease to a limit. The economical angle of strand adopted is 40°. Thus Stiffening by shear wall is also balanced by using carbon fiber strands.

REFERENCES

[1] Jaswant. N. Arlekar, Sudhir K. Jain and C. V. R Murty, "Seismic Response of R.C Frame Building with Soft First Storey," *Department of Civil* Engineering, IIT Kanpur, Kanpur 208016.
[2] Hemant. B. Kaushik, Durgesh C Rai and Sudhir. K Jain, "Effectiveness of some strengthening options for masonry infilled RC Frames with open first storey" *Department of Civil* Engineering, IIT Kanpur, Kanpur 208016.
[3] Vijayanarayanan AR and Rupen Goswami, "Estimation of Storey Stiffness in Multi Storey Building" IIT Madras. 16th World Conference on Earthquake, Santiago Chile, January 9th to 13th 2017
[4] Yuto Nakashima, Hirofumi Suganuma1, Shinichiro Yamashita and Jun Takahashi, "Influence of strand dispersion method on mechanical properties of randomly oriented carbon fibre strand Thermoplastic composite" The University of Tokyo, 21th International Conference on composite materials August 2017
[5] Prof. G. M. Savaliya, Prof. (Dr.) A. K. Desai and Prof. (Dr.) S. A. Vasanwala, "Static & Dynamic Analysis of Cable stayed suspension hybrid bridges & Validation, International journal Research in Engineering and Technology 2015. Volume 6, Issue 11, Nov 2015, pp. 91-98
[6] Galo E. Valdebenito and Angel C Aparicio, "Seismic Behavior of cable stayed Bridges - A state of Art Review" Universitat Politècnica de Catalunya, 4th International Conference on Earthquake Engineering Taipei, Taiwan October 12-13, 2006
[7] Johannes Fritz Noisternig, "Carbon Fiber Composite as Stay Cables for Bridge", DYWIDAG-Systems International GmbH, Munich, Germany.
[8] Habibullah A, (1995), ETABS – Three Dimensional Analysis of Building Systems, User's Manual, Computer and Structures, Inc. Berkeley, CA, USA.
[9] Murty C V R and Jain S.K, "Draft IS 1893 Provisions on Seismic Design of Buildings." Bureau of Indian Standards, New Delhi.
[10] Pankaj Aggarwal & Manish Shrikhande, "Earthquake Resistant Design of Structures", PHI Learning Private Limited New Delhi 110001 2009.