Seismic Performance of Circular And Rectangular Column by Cyclic And Monotonic Loading

Samyak Patil[1], Dr. S.K. Patil[2], Dr. Atul B.Pujari[3]

[1]PG Student, Department of Civil Engineering KJCOEMR, Pune, Maharashtra, India [2]Professor, Department of Civil Engineering KJCOEMR, Pune, Maharashtra, India [3]Professor, Department of Civil Engineering KJCOEMR, Pune, Maharashtra, India

---

Abstract - *Current flexural and shear design methods for reinforced concrete members are mainly based upon the rectangular cross-sectional shape. A simplified new approach for designing circular cross sectional Reinforced Concrete (RC) members might be to convert them to equivalent area, square shapes. An experimental study was performed on reinforced concrete circular cross sections and equivalent area, rectangular cross-sectional members. The RC members were tested under nonlinear monotonic loading conditions under both flexural and shear-controlled conditions. Experimental and analytical results show that the circular RC members and its equivalent square have similar nonlinear performance (load-deflection behavior) in both flexural and shear-controlled failure conditions. A good agreement was found in nonlinear performance of main design criteria; initial stiffness, flexural capacity, and shear capacity of both types. The lateral confinement of RCC columns in monotonic and cyclic loading have shown to improve their strength and ductility for those particular loads. Capacity and corresponding drift are important parameters to compare between monotonic and cyclic tests. Capacity is the most interesting comparison for the designer since current design is based on values obtained from monotonic tests of shear walls. In the present study of behavior of circular column and rectangular columns subjected to monotonic and cyclic loading is performed. For that study finite element analysis software ETABS-2018 used for 3D modeling purpose. In ETABS, G+20 storey building is modeled in which rectangular column and circular columns used in two different models. From results obtained from the 3D modeling, comparative results are discussed.*

The work undertaken is an attempt to understand the fundamentals of monotonic and cyclic loading in the building, its design & behavior under seismic loading. Specific guidelines are available for design of building in Indian codes.

Key Words: *Monotonic and cyclic loading, Finite Element Analysis, Etabs, Ductility, Drift*

1.INTRODUCTION

Currently, one-directional (monotonic) shear wall tests are used to determine the capacity used for the design of shear walls. However, a shear wall will experience a dynamic, cyclic loading in a seismic event. For this reason, results of the monotonic and cyclic tests need to be compared. The shear strength and deformation capacities of reinforced concrete (RC) columns are governed by a multitude of variables related to material properties of the steel and concrete used in the design and construction of the columns

In the present study of behavior of circular column and rectangular columns subjected to monotonic and cyclic loading is performed. For that study finite element analysis software ETABS-2018 used for 3D modeling purpose. In ETABS, G+20 storey building is modeled in which rectangular column and circular columns used in two different models. From results obtained from the 3D modeling, comparative results are discussed.

1.1 Methodology

The present comparative study deals with equivalent static analysis and Response spectrum method for G+20 building with circular Rc column and G+20 building with rectangular Rc column subjected to cyclic and monotonic loading. The analysis of both the building models is run in software ETAB-2018. For analysis the parameter like storey Stiffness, Displacement , Time period and modal mass Participation, Drift, Overturning moment, Base shear, Reinforcement variation due to monotonic and cyclic loading studied significantly for the monotonic and cyclic loading .

1.2 Building Configuration

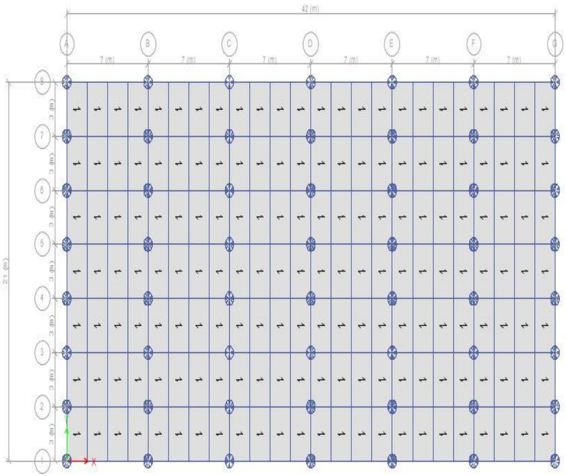
Table -1: Building Data

Descriptions	Parameter
No of Stories	(G+20)
Type of frame	Moment Resisting Frame
Total height of building	63 m
Height of each story	3.0 m
Foundation Depth	3.5 m
Plan of the building	42 m × 21 m
Floor Diaphragm	Rigid
Grade of Concrete	M25
Grade of reinforcing Steel	HYSD500
Seismic Zone factor (Z)	0.24
Soil Type	Medium soil
Importance factor	1.5
Response reduction factor	5
Damping Ratio	0.05

Table -2: Section Used in Structure

Column Shape	Beam Size	Column size	Slab/ Deck Thk
RC Rectangular	450 x 750 mm	650 x 950 mm	150 mm slab
RC Circular	450x750 mm	750 mm(dia)	200 mm slab

Fig-1: Plan of circular column with monotonic and Cyclic loading



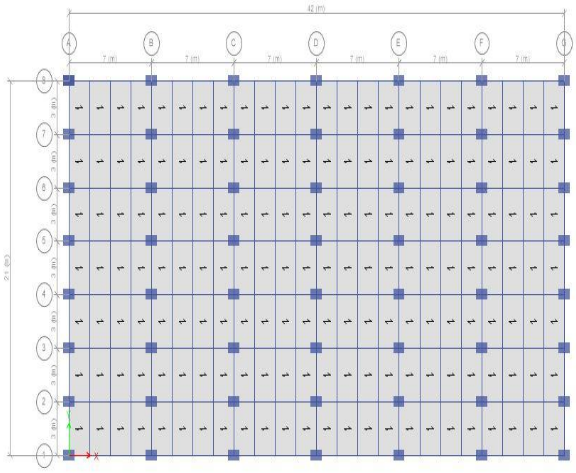


Fig -2: Plan of rectangular column with monotonic and Cyclic loading

2. Results

a. Displacement : Lateral displacement or sway is usually found when lateral load is applied to a structure. The lateral load may be seismic or wind load. In case of wind forces, circular column building shows maximum displacement which is around 25% more than the building with rectangular column. Result shows that the behavior of becomes more flexible when circular columns used in building. This absorbs more amount of energy as compare to rectangular column.

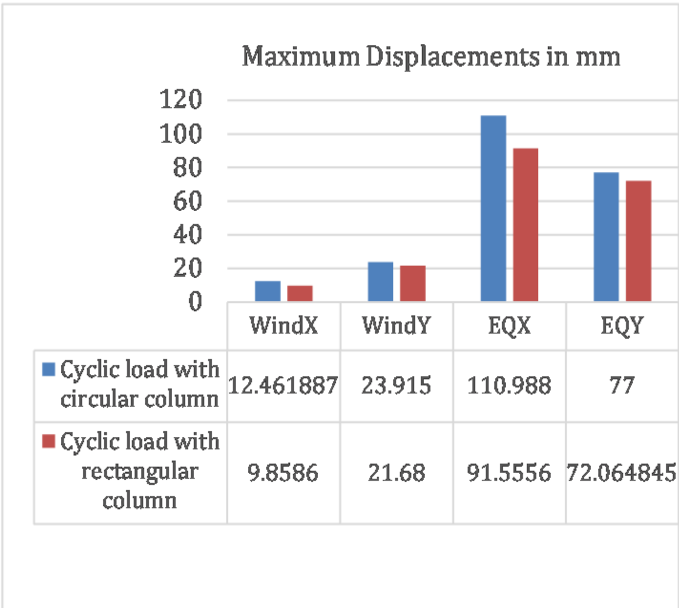


Fig-3 :Maximum horizontal displacement due to cyclic loading

b. Drift :. In case of building with circular column shows maximum drift values than building with rectangular column also as the height of building increases it might show difference in drift values.

Table 2 : Drift calculation

Storey	Drift due to cyclic load with circular column		Drift due to cyclic load with rectangular column	
	EQ-X	EQ-Y	EQ-X	EQ-Y
Terrace	0.000504	0.000665	0.000444	0.000569
Story20	0.000734	0.000789	0.000616	0.000691
Story19	0.000964	0.000909	0.000801	0.00081
Story18	0.001174	0.001018	0.000977	0.000919
Story17	0.001362	0.001114	0.001136	0.001015
Story16	0.00153	0.001198	0.001279	0.001099
Story15	0.001677	0.00127	0.001404	0.001172
Story14	0.001805	0.00133	0.001514	0.001233
Story13	0.001916	0.001378	0.001607	0.001282
Story12	0.002009	0.001414	0.001687	0.001321
Story11	0.002086	0.001439	0.001752	0.001349
Story10	0.002148	0.001454	0.001806	0.001367
Story9	0.002196	0.001458	0.001847	0.001376
Story8	0.002232	0.001451	0.001877	0.001375
Story7	0.002256	0.001435	0.001898	0.001365
Story6	0.002269	0.00141	0.001908	0.001347
Story5	0.002273	0.001376	0.001906	0.00132
Story4	0.002265	0.001333	0.001881	0.001286
Story3	0.002232	0.001277	0.001801	0.001239
Story2	0.002083	0.001178	0.00156	0.001147
Story1	0.001283	0.000769	0.000818	0.000741

c. Overturning Moment : Overturning moment is the force on the structure which causes overturning of the whole structure. Torsion is induced due to high overturning moment it can be observed that the value of overturning moment is less in circular column building due to less lateral stiffness since circular column does not show variation in stiffness in major and minor direction. The value of overturning moment is reduced about 3 to 4% in case of earthquake force, which shows reduction in torsion.

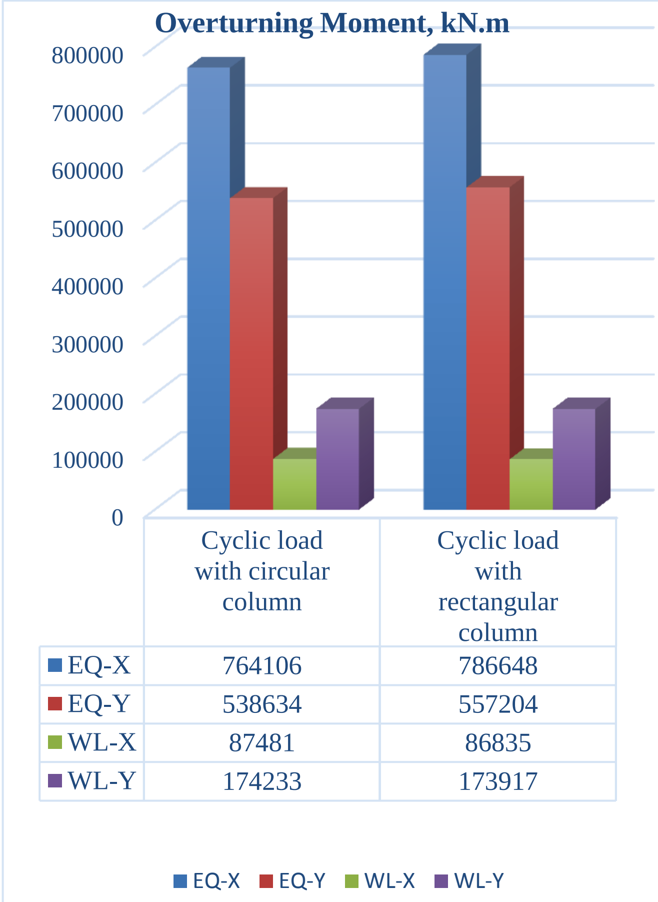


Fig-4: Overturning moment comparisons

d. Time Period and Modal Mass Participation- Time period play important role in earthquake resisting building design. It is the most important factor affecting seismic performance of building frame. Time period is depending upon mass and stiffness of structure in which time period is directly proportional to mass and inversely proportional to the stiffness. it is observed that for a typical column shape time period and modal mass participation does not vary based on monotonic or cyclic loading. Also, analytical time period for first mode is 2.061 seconds in building with circular column. If observe carefully then the values of analytical time period of building with circular column is more than the modular building with rectangular column irrespective of type of loading

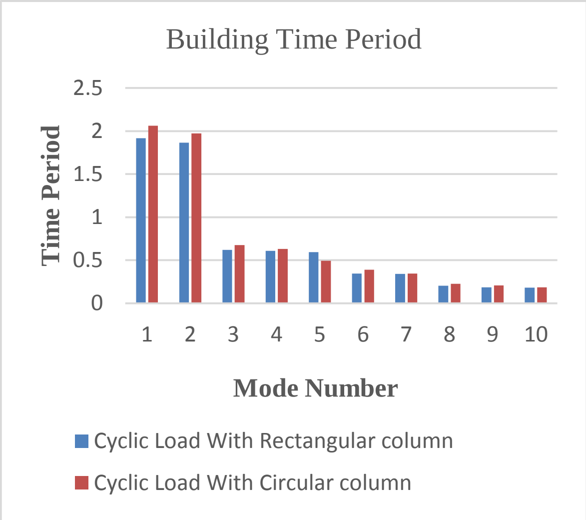


Fig-5: Time period Compassions

e. Base shear : Base shear is the maximum lateral force at the base of the structure due to seismic/wind activities. Based on base shear value, behavior or responses of building can be determined. When base shear value is very high then the structure is either very heavy or very stiff Base shear due to wind forces does not show any variation, hence for wind forces, it can be assumed that the both systems will become more effective as the building height get increased.

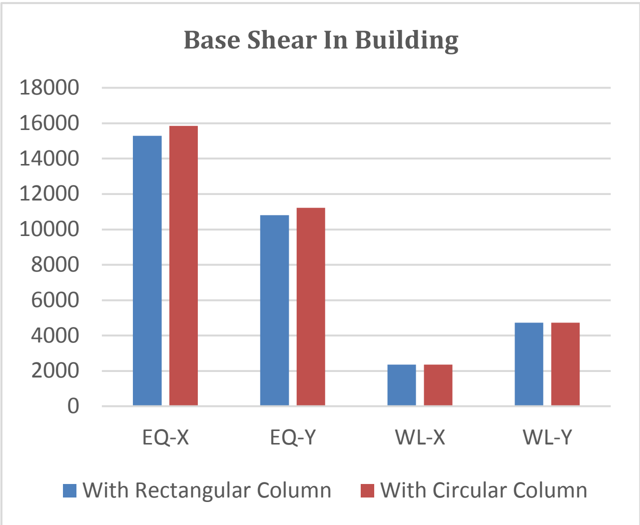


Fig-6 :Base shear

f. Reinforcement variations due to monotonic and cyclic loading : It is observed that the percentage variation in circular and rectangular column is very drastic and this difference can affect the economy of the structure. circular and rectangular column shows slight variation when any particular column is subjected to those two types of loadings When compare both types of columns, for monotonic and cyclic loading, rectangular column shows economical design as compare to circular column.

Table 3 : column Reinforcement in percentage

Type of Column	Loading	Edge column	Mid column	Corner column
Circular column	Monotonic Loading	2.69	3.72	0.87
	Cyclic Loading	2.94	3.79	1.56
Rectangular column	Monotonic Loading	1.37	2.28	0.8
	Cyclic Loading	1.73	2.33	0.8

3. CONCLUSIONS

Around 15 to 17% displacement increased in building with circular column for both monotonic and cyclic loading as compared to building with rectangular columns. Flexible and ductile behavior of building can also be observed by values of time period in both the structures. Building with circular column show more ductile and flexible behavior than the building with rectangular column. The ductility of the corner columns is also a critical criterion to maintain in order to achieve a better performance under high cyclic loads.

At 5^{th} to 10^{th}storey of structure with both rectangular and circular columns, drift values are maximum but as the storey increased in structure drift shows declination, which shows that floor systems absorb lateral forces at the base and behaves accordingly, but transfer less forces at top.

Building with circular column shows better lateral resistance and ductility than the building with rectangular column.

Base shear and overturning moment in both the structure shows less difference. In case of earthquake force, base shear is reduced about 30% in rectangular columns but in case of wind force 3 to 4% base shear reduction observed. Finally, it is concluded that the rectangular column building and circular column building has their own advantages but the rectangular column building found to be more stable in case of cyclic load resistance.

For monotonic and cyclic loading, circular column shows maximum reinforcement than the rectangular columns.

This variation in reinforcement is about 30 to 50% which can make drastic difference in economical perspective.

REFERENCES

1. Prakash, S., Belarbi, A., and You, Y. M. (2010). "Seismic performanceof circular RC columns subjected to axial force, bending, and torsionwith low and moderate shear." Engineering Structures, Elsevier,Vol. 32, No. 1, pp. 46-59, DOI: 10.1016/j.engstruct.2009.08.014.

2. Sun, L. Z., Wu, D. Y., Zhao, J. L., Yang, F., and Li, W. (2017). "Behavior ofcircular RC columns with two layers of spirals." KSCE Journal ofCivil Engineering, KSCE, Vol. 21, No. 3, pp. 955-963, DOI:10.1007/s12205-016-0928-0.

3. Tirasit, P. and Kawashima, K. (2007). "Seismic Performance of squarereinforced concrete columns under combined cyclic flexural and torsionalloadings." Journal of Earthquake Engineering, Taylor & Francis, Vol. 11,No. 3, pp. 425-452, DOI: 10.1080/13632460601031813.

4. Toongoenthong, K. and Maekawa, K. (2004). "Interaction of pre-induceddamages along main reinforcement and diagonal shear in RCmembers." Journal of Advanced Concrete Technology, JSCE, Vol. 2,No. 3, pp. 431-443, DOI: 10.3151/jact.2.431.

5. Mondal, T. G. and Prakash, S. S. (2015). "Effect of tension stiffening onthe behaviour of reinforced concrete circular columns under torsion."Engineering Structures, Elsevier, Vol. 92, pp. 186-195, DOI: 10.1016