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Earthquake Analysis of Reinforced Concrete Oblique Columns and Y-Shaped Columns using ETABS: A Comparative Study

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ABSTRACT

This dissertation work deals with the comparative study of behavior of oblique columns with Y-shaped RC column for a high rise structures. Now a day's utility or floor area of Residential RC Structure is very costly. Any analysis and design approach which enhances the utility area of residential or commercial buildings is highly appreciable. Many researchers/design engineers attempted to achieve it. Strategies like floating columns, central core columns and cantilever beam structures are one of the usual techniques. In the present study, oblique columns and Y-shaped columns are adopted instead of conventional (rectangular or square) columns, 6 storied structures is considered for analysis and comparative study between oblique columns and Y-shaped columns is to be adopted. All the analysis and design work is conducted using ETABS 2013 version.

The project concluded that Maximum Storey Displacement in oblique columns is 6.3 mm and in Y-shaped columns is 50.27 mm. Results show that maximum storey displacement is increased in Y-shaped Columns by 43.97 mm. It means maximum storey displacement is increased in Y-shaped columns by 697.94%. Hence oblique columns give better results in storey displacement. Maximum Storey Drift in oblique columns is 0.000162 mm and in Y-shaped columns is 0.000248 mm. The difference of maximum storey drift between oblique columns and Y-shaped is 0.000086 mm. Maximum Storey Drift in Y-shaped columns is increased by 53.08 % as that of oblique columns. The lower base shear is getting in oblique columns and the higher base shear is getting in Y-shaped columns. Base shear in oblique column is 831.22 kN while 1096.68 in y-shaped column. It means that base shear value is increased by 32.07% in Y-shaped column as compared to oblique columns. The joint of the Y-shaped holds to be weak under seismic loading. Necessarily requires the strengthening the joins of Y-shaped column. Maximum Storey Stiffness in oblique columns is 17 1757254.595 kN/m and 733562.715 in Y-shaped columns. Results of maximum storey stiffness show that stiffness gets deceases in y-shaped columns as compared to oblique columns. It is decreased by 58.25%. Oblique columns offer best resistance to lateral loads. Hence, it needs optimum design procedure to proceed for further studies and also for construction. The oblique columns and Y-shaped columns can be used for architectural purpose by giving the pleasing appearance to inclined support members, which increases the aesthetic appearance of the structure.

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KEYWORDS: *Columns, Oblique Columns, Y-shaped Columns, Equivalent Static Method, Response Spectrum Method, Displacement, Storey Drift, Stiffness, Base Shear, Time Period, etc*

INTRODUCTION

A column or pillar in architecture and structural engineering is a structural element that transmits, through compression, the weight of the structure above to other structural elements below. In other words, a column is a compression member. The term column applies especially to a large round support (the shaft of the column) with a capital and a base or pedestal, which is made of stone or appearing to be so. A small wooden or metal support is typically called a post, and supports with a rectangular or other non-round section are usually called piers. Simply, a vertical member whose effective length is greater than 3 times Its least lateral dimension carrying compressive loads is called as a column. Columns transfer the loads from the beams or slabs to the footings or foundations. The inclined member carrying compressive loads as In the case of frames and trusses is called as struts. The pedestal is a vertical compression member whose effective length is less than 3 times it's least lateral dimension.

For the purpose of wind or earthquake engineering, columns may be designed to resist lateral forces. Other compression members are often termed "columns" because of the similar stress conditions. Columns are frequently used to support beams or arches on which the upper parts of walls or ceilings rest. In architecture, "column" refers to such a structural element that also has certain proportional and decorative features. A column might also be a decorative element not needed for structural purposes; many columns are engaged, that is to say form part of a wall. A long sequence of columns joined by an entablature is known as a colonnade.

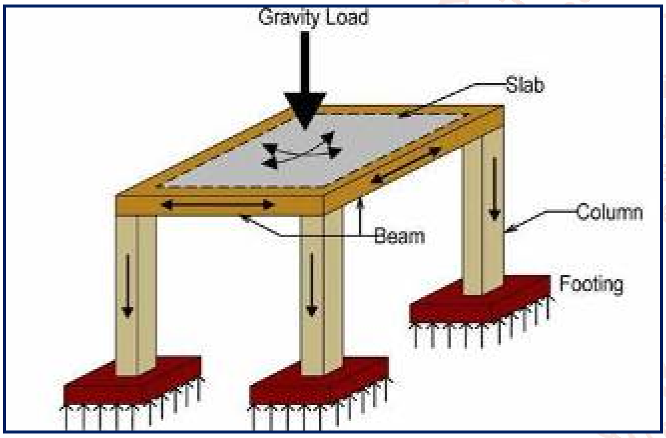


Fig. 1 Columns

A. Classification of Columns

There are several types of columns which are used in different parts of structures. Column is a vertical structural member that carries loads mainly in compression. It might transfer loads from a ceiling, floor slab, roof slab, or from a beam, to a floor or foundations. Commonly, columns also carry bending moments about one or both of the cross-section axes. In this article, different types of columns used in building construction will be discussed.

Columns are classified based on the several conditions which include:

A. Based on Types of Reinforcement
B. Based on Types of Loading
C. Based on Slenderness Ratio
D. Based on Shape
E. Based on Construction Material

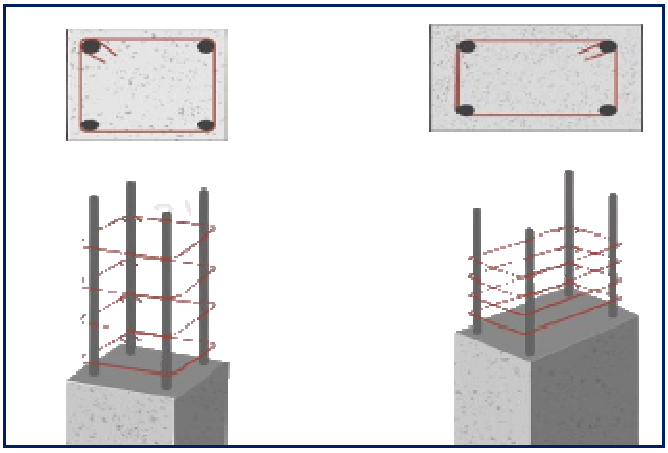


Fig. 2 Square and Rectangular Columns

METHODOLOGY

A. Problem Statement

Sophisticated construction industry is rapidly increasing due to the developments and demands for population. The new idea is that the columns are not vertical. We can build multi-storied building buildings with oblique columns. But the seismic performance should be studied to know whether these new construction techniques adaptable or not. Because, the performance of the high-rise, mid-rise and low-rise buildings will be different from each other for different angles under seismic loading. So it is very important to study the seismic performance for different types of building and also compare with the conventional method of construction. If it is replaceable for the normal constructions and with more advantages, it will be a revolutionary change in civil engineering world.

B. Aim of the Study

The aim of design is the achievement of an acceptable probability that structures being designed will perform satisfactorily during their intended life. With an appropriate degree of safety, they should sustain all the loads and deformations of normal construction and use and have adequate durability and adequate resistance to the effects of seismic and wind. Structure and structural elements shall normally be designed by Limit State Method. Account should be taken of accepted theories, experiment and experience and the need to design for durability. Design, including design for durability, construction and use in service should be considered as a whole. The realization of design objectives requires compliance with clearly defined standards for materials, production, workmanship and also maintenance and use of structure in service. Analyzing the behavior of oblique columns and Y-shaped columns is the main aim of this study.

C. Objectives of the Study

The main purpose of analysis is to compare the response of the oblique columns and Y-shaped columns under seismic loading. Following are the objectives of the present study:-

A. To analyse G+5 storied reinforced concrete (RC) structure under seismic loading with oblique columns.
B. To analyse G+5 storied reinforced concrete (RC) structure under seismic loading with Y-shaped columns.
C. Comparative analysis of oblique columns and Y-shaped columns under seismic loading with respect to displacement, base shear, storey drift, stiffness and time period.

D. Methodology of the Work

The different phases of this project of work are shown in the following diagram. The figure simply describes the experimental strategy of this study step by step.

A. Review the existing literatures on oblique columns and Y-shaped columns,
B. Analysis of G+5 storied reinforced concrete (RC) structure under seismic loading with oblique columns.
C. Analysis of G+5 storied reinforced concrete (RC) structure under seismic loading with Y-shaped columns.
D. Comparative study of oblique columns and Y-shaped columns under seismic loading with respect to displacement, base shear, storey drift, stiffness and time period.
E. Interpretation of results and conclusion.

E. Scope of the Study

The scope of this study is as follows:

A. RC building is considered.
B. Linear elastic analysis is to be done on the structures.
C. Column is modeled as fixed to the base.
D. Loading due to infill walls were taken into account.
E. Time History Analysis is to be done to obtain displacements.

F. Configuration of the Models

In the current study, buildings are modeled using the finite element software ETABS. The analytical models of the building include all components that influence the mass, strength, stiffness and deformability of structure. The building structural system consists of beams, columns, and slab. The non-structural elements that do not significantly influence the building behavior are not modeled. Modal analysis and seismic coefficient analysis are performed on models. It is proposed to study the effectiveness of oblique columns and Y-shaped columns. The beam and column are modeled are two nodded line element with 6 DOF at each node. The slab is modeled using 4 nodded area elements.

In present work, reinforced concrete G + 5 storied buildings with oblique columns and Y-shaped columns are taken which has situated in zone V (very severe zone), is taken for the study.

Details of models are shown below:

1. **Model 1:** G + 5 storied RC structure with Oblique columns
2. **Model 2:** G + 5 storied RC structure with Y-shaped columns

Table -1: Structural Data for both Models

Sr. No.	Description	Specifications
1	Type of Structure	G + 5 Storied RC Structure
2	Structure Type	Plan Regular Structure
3	Plan Dimensions	12 m X 12 m
4	Total Area	144 sq. m
5	Bay Width in Longitudinal Direction	4 m
6	Bay Width in Transverse Direction	4 m
7	No. of Bays in Longitudinal Direction	3 bays of 4 m length
8	No. of Bays in Transverse Direction	3 bays of 4 m length
9	Height of Building	19.2 m (G + 5 Storey)
10	Height of Each Storey	3.2 m
11	Plinth Height	1.2 m
12	Depth of Foundation	2 m
13	Size of Beams	230 mm X 450 mm
14	Size of Columns	C1 = 300 mm X 600 mm C2 = 450 mm x 450 mm
15	Thickness of Slab	150 mm
16	External Wall thickness	200 mm
17	Internal Wall thickness	100 mm
18	Height of Parapet Wall	1 m
19	Density of Concrete	25 kN/m^3

20	Concrete Grade	M30
21	Grade of Steel	Fe 500
22	Unit Weight of Concrete	25 kN/m^3
23	Unit Weight of Steel	78.5 kN/ m^3
24	Density of Brick Masonry	20 kN/ m^3

The plan of model of G+5 storied RC Structure with oblique columns and Y-shaped columns is as follows:

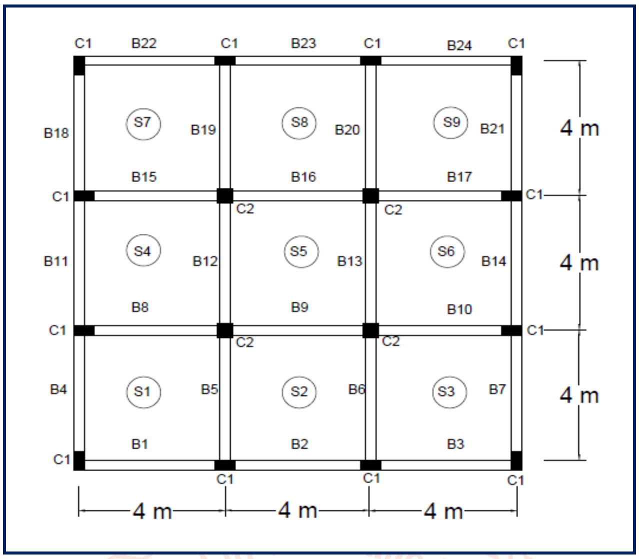


Fig. 3 Plan of Model 1 and Model 2

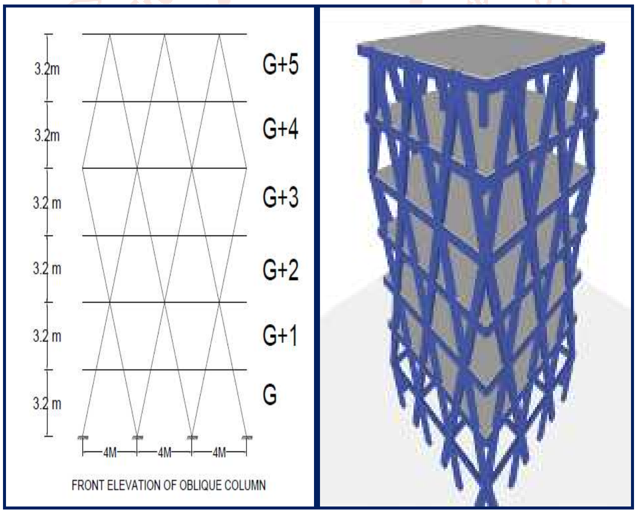


Fig. 4 Elevation and Rendered View of Model 1 (G + 5 Storied RC Structure with Oblique Columns)

The oblique columns are modeled only at periphery. Internal columns remain vertical. There is not any change in internal columns.

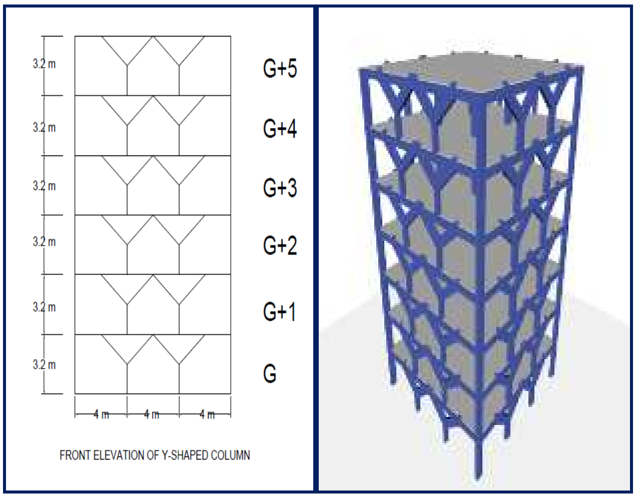


Fig. 5 Elevation of Model 2 (G + 5 Storied RC Structure with Y- shaped Columns)

The Y-shaped columns are modeled only at periphery. Internal columns remain vertical. There is not any change in internal columns.

PERFORMANCE ANALYSIS

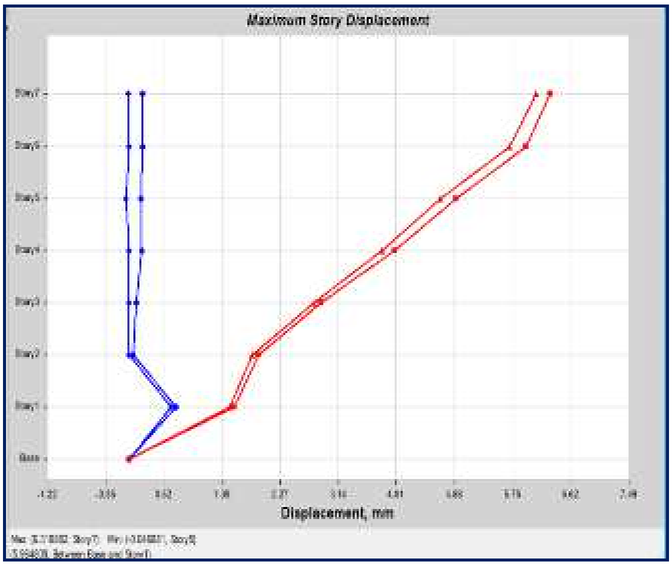
A. Loading on Model 1, Model 2 and Model 3

Table -2: Loading on Models

Sr. No.	Loads	Specifications
1	Self-Weight of the Frame elements & slabs	It is calculated & used automatically during analysis by the ETABS software
2	Super-Imposed Dead Load (IS 875 Part I : 1987)	a) Floor Finish = 1.5 kN/m^2 b) External Wall Load = 12.8 kN/m c) Internal Wall Load = 6.4 kN/m d) Parapet Wall Load = 4 kN/m e) Water Proofing Load = 2 kN/m^2
3	Live Load (IS 875 Part II : 1987)	a) Live Load for Floors = 3.0 kN /m^2 b) Live Load for Roof = 4.0 kN /m^2
4	Wind Load (IS 875 Part III : 2015)	a) V_b, Basic Wind Speed = 50 m/sec (Bhuj City) b) Probability Factor, $k_1 = 1$ c) Terrain Roughness and Height Factor, $k_2 = 1$ (Terrain Category = III) d) Topography factor, $k_3 = 1$ e) Importance Factor, $k_4 = 1$ *Design Wind Speed,* $V_z = V_b \cdot k_1 \cdot k_2 \cdot k_3 \cdot k_4$ $V_z = 50 \times 1 \times 1 \times 1 \times 1$ $V_z = 50$ m/sec^2 *Design Wind Pressure,* $P_z = 0.6 \times V_z^2$ $P_z = 0.6 \times 50^2$ $P_z = 1500$ N/m^2 = 1.5 kN/m^2
5	Earthquake Load or Seismic Load (IS 1893 Part I: 2016)	a) City :- Bhuj (Gujrat) b) Seismic Zone = Zone V (Very Severe Zone) c) Zone Factor , $Z = 0.36$ d) Importance Factor, $I = 1.2$ e) Damping Ratio = 0.05 (5%) f) Response reduction Factor, $R = 5$ (SMRF) g) Soil Type = II, Medium or Stiff Soils h) Seismic Source Type = B i) Period in X – *direction* = $0.09h / \sqrt{dx}$ seconds = 0.50 seconds j) Period in Y – *direction* = $0.09h / \sqrt{dy}$ seconds = 0.50 seconds Where, h = height of the building dx = length of building in x direction dy = length of building in y direction

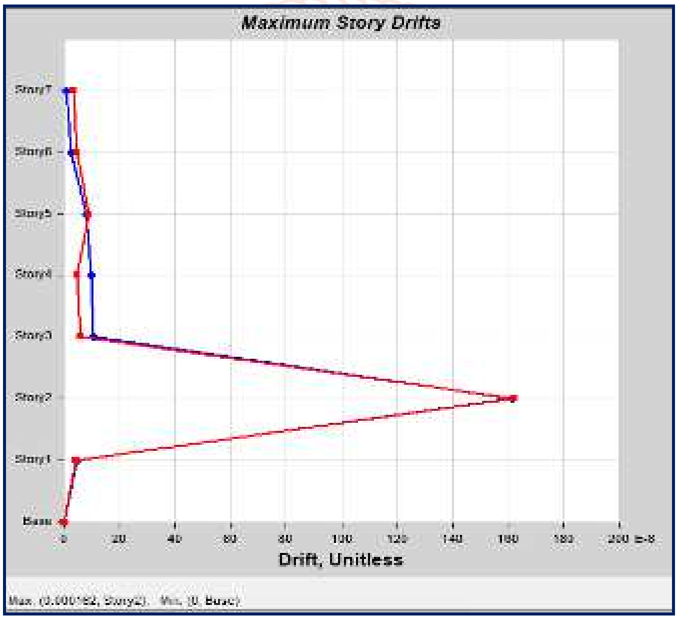
B. Analysis Results of Model 1: G+5 Storied RC Structure with Oblique Columns

1. Maximum Storey Displacement



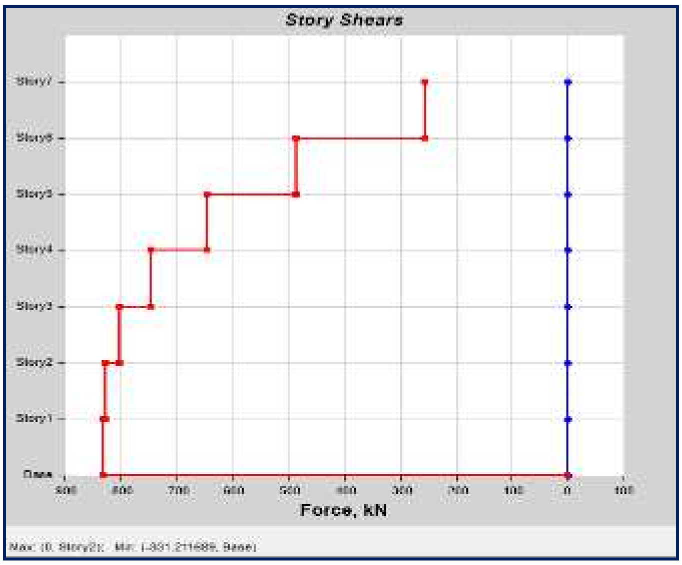
Graph 1 Graph of Maximum Storey Displacement

2. Maximum Storey Drift



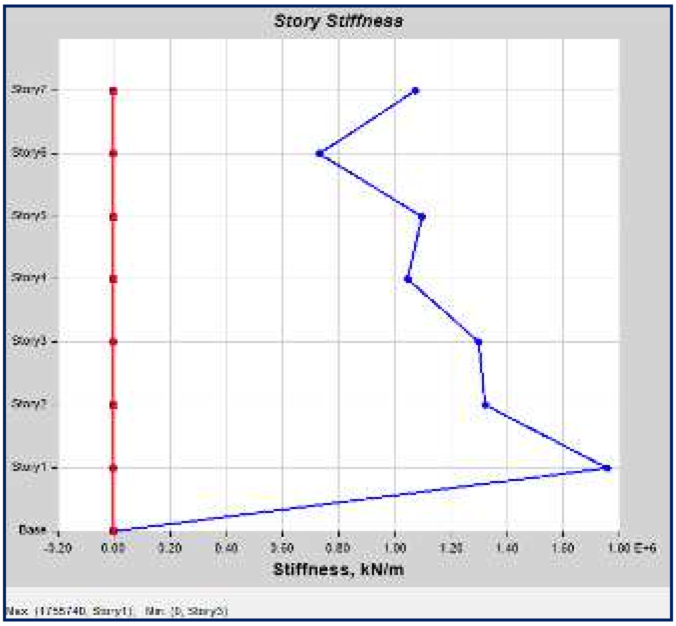
Graph 2 Graph of Maximum Storey Drift

3. Base Shear



Graph 3 Graph of Base Shear along EQX & EQY

4. Maximum Storey Stiffness



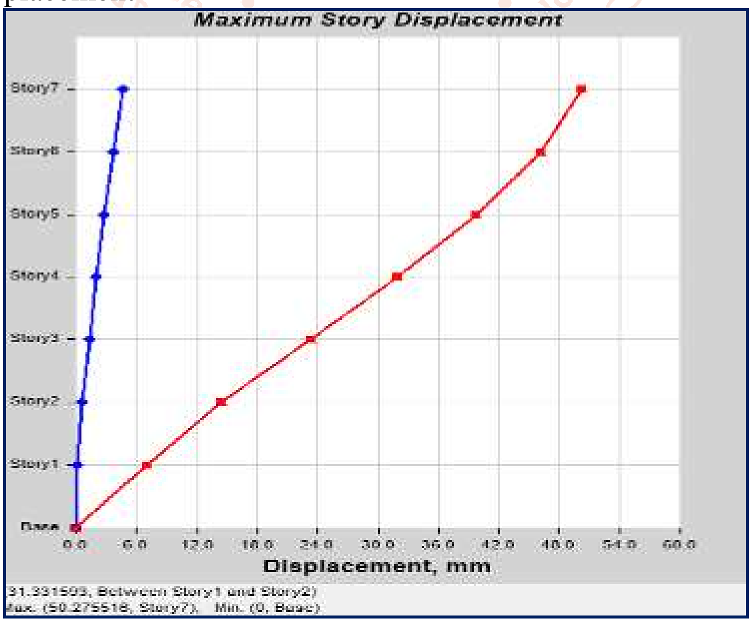
Graph 4 Graph of Storey Stiffness along EQX

Table -3: Summary Results of Analysis Results of Model 1: G + 5 Storied RC Structure with Oblique Columns

Sr. No.	Parameter	Load Case/Combo	Direction	Value
1	Maximum Storey Displacement	[1.5 DL + 1.5 EQ (+Y)]	Direction Y	6.3 mm
2	Maximum Storey Drift	[1.5 DL + 1.5 EQ (+Y)]	Max Drift Y	0.000162 mm
3	Base Shear	EQ +X and EQ +Y	Seismic X and Y	831.2117 kN
4	Maximum Storey Stiffness	EQ +X 3	Story 1	1757254.595 (kN/m)
5	Time Period	EQ +X & EQ +Y	Seismic X and Y	0.5 sec

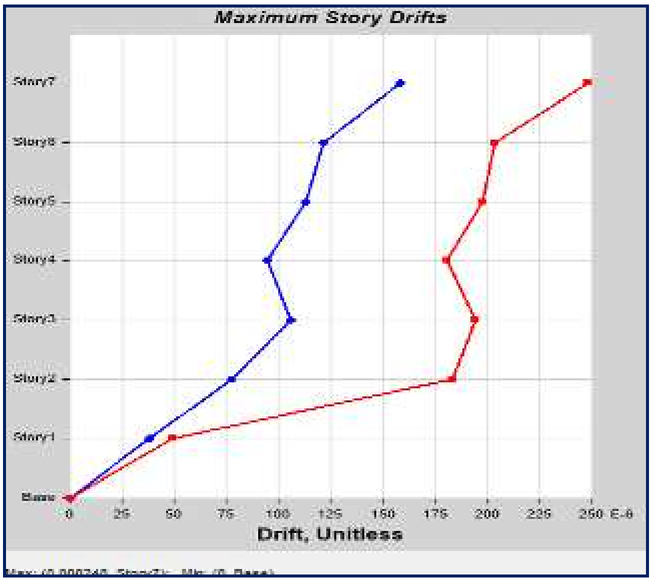
C. Analysis Results of Model 1: G+5 Storied RC Structure with Y-shaped Columns

1. Maximum Storey Displacement



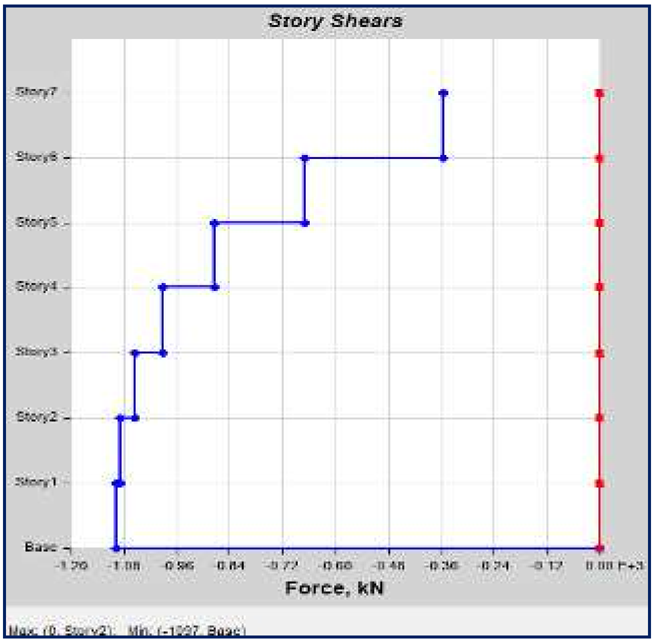
Graph 5 Graph of Maximum Storey Displacement

2. Maximum Storey Drift



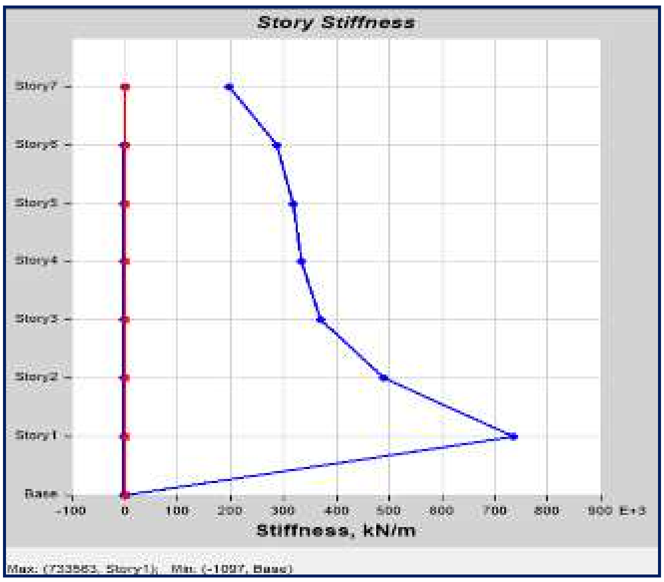
Graph 6 Graph of Maximum Storey Drift

3. Base Shear



Graph 7 Graph of Base Shear along EQX & EQY

4. Maximum Storey Stiffness



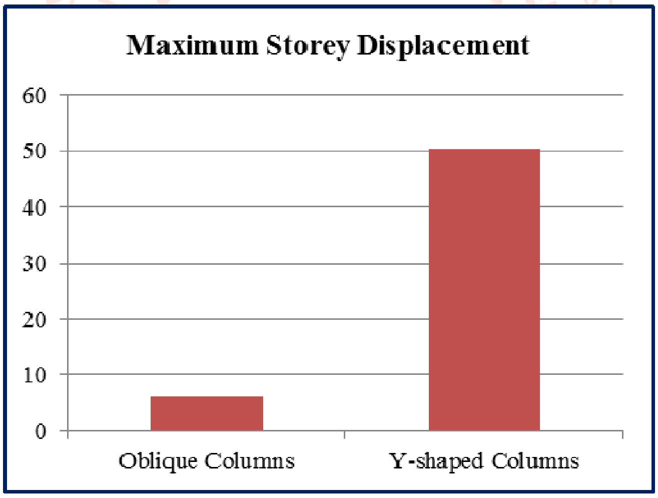
Graph 8 Graph of Storey Stiffness along EQX

Table -4: Summary Results of Analysis Results of Model 1: G + 5 Storied RC Structure with Oblique Columns

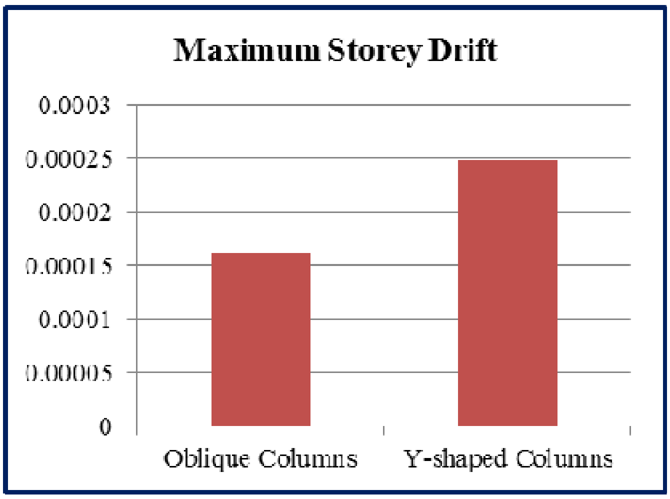
Sr. No.	Parameter	Load Case/Combo	Direction	Value
1	Maximum Storey Displacement	[1.5 DL + 1.5 EQ (+Y)]	Direction Y	50.27 mm
2	Maximum Storey Drift	[1.5 DL + 1.5 EQ (+Y)]	Max Drift Y	0.000248 mm
3	Base Shear	EQ +X and EQ +Y	Seismic X and Y	1096.6801kN
4	Maximum Storey Stiffness	EQ +X 3	Story 1	733562.715 (kN/m)
5	Time Period	EQ +X & EQ +Y	Seismic X and Y	0.5 sec

Table -5: Comparative Analysis Results of Model 1 and Model 2

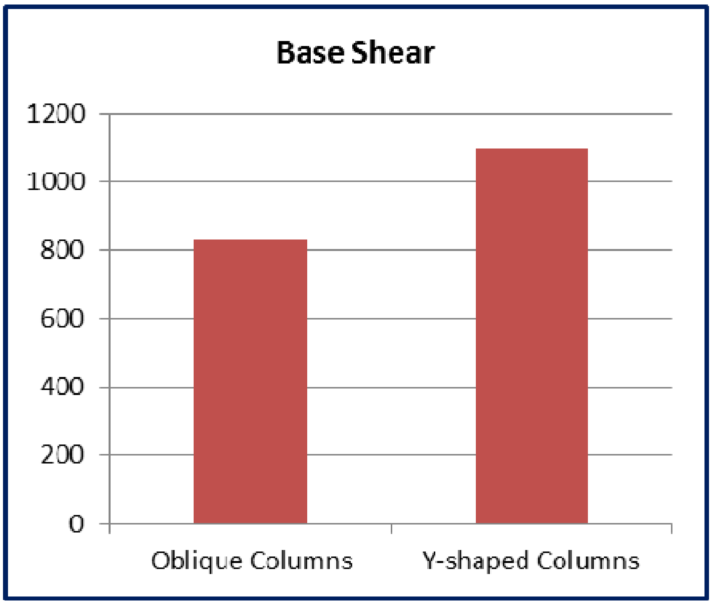
Sr. No.	Parameter	Values of Model 1 (Oblique Columns)	Values of Model 2 (Y-shaped Columns)	Difference	Percentage Increase or Decrease in Value
1	Maximum Storey Displacement	6.3 mm	50.27 mm	43.97 mm	697.94
2	Maximum Storey Drift	0.000162 mm	0.000248 mm	0.000086 mm	53.08
3	Base Shear	831.2117 kN	1096.6801kN	265.4684 kN	32.07
4	Maximum Storey Stiffness	1757254.595 (kN/m)	733562.715 (kN/m)	-1023691.88 (kN/m)	- 58.25
5	Time Period	0.5 sec	0.5 sec	0	0



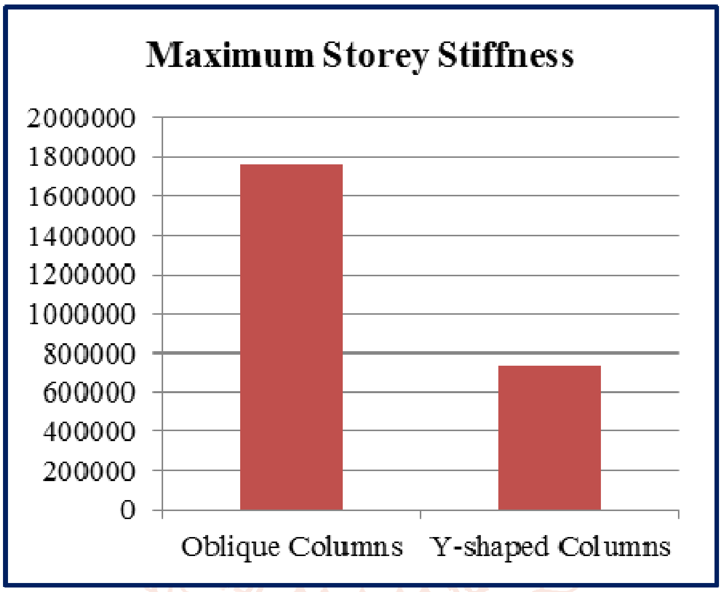
Graph 9 Comparative Analysis of Model 1 and Model 2 with respect to Maximum Storey Displacement



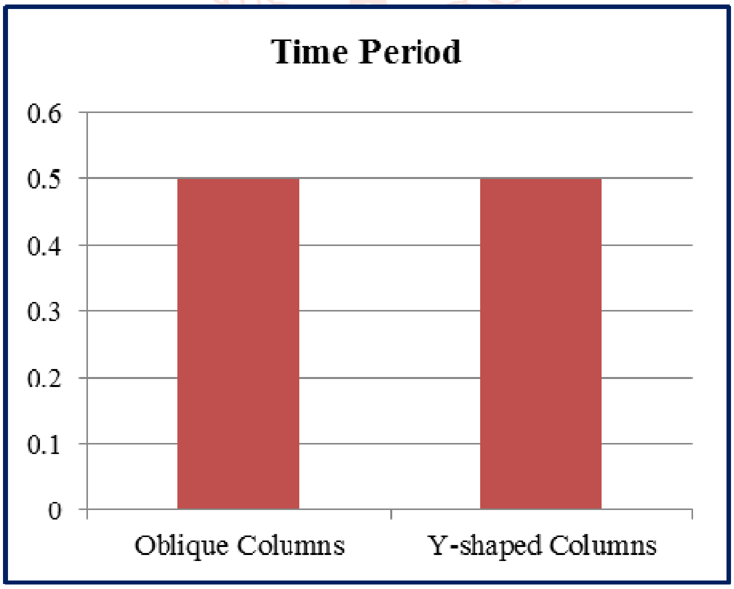
Graph 10 Comparative Analysis of Model 1 and Model 2 with respect to Maximum Storey Drift



Graph 11 Comparative Analysis of Model 1 and Model 2 with respect to Base Shear



Graph 12 Comparative Analysis of Model 1 and Model 2 with respect to Maximum Storey Stiffness



Graph 13 Comparative Analysis of Model 1 and Model 2 with respect to Time Period

CONCLUSION

Maximum Storey Displacement in oblique columns is 6.3 mm and in Y-shaped columns is 50.27 mm. Results show that maximum storey displacement is increased in Y-shaped Columns by 43.97 mm. It means maximum storey displacement is increased in

Y-shaped columns by 697.94%. Hence oblique columns give better results in storey displacement. Maximum Storey Drift in oblique columns is 0.000162 mm and in Y-shaped columns is 0.000248 mm. The difference of maximum storey drift between oblique columns and Y-shaped is 0.000086 mm. Maximum Storey Drift in Y-shaped columns is increased by 53.08 % as that of oblique columns. The lower base shear is getting in oblique columns and the higher base shear is getting in Y-shaped columns. Base shear in oblique column is 831.22 kN while 1096.68 in y-shaped column. It means that base shear value is increased by 32.07% in Y-shaped column as compared to oblique columns. The joint of the Y-shaped holds to be weak under seismic loading. Necessarily requires the strengthening the joins of Y-shaped column. Maximum Storey Stiffness in oblique columns is 171757254.595 kN/m and 733562.715 in Y-shaped columns. Results of maximum storey stiffness show that stiffness gets deceases in y-shaped columns as compared to oblique columns. It is decreased by 58.25%. Oblique columns offer best resistance to lateral loads. Hence, it needs optimum design procedure to proceed for further studies and also for construction. In time period, there is no change in both oblique columns and Y-shaped columns. It remains same 0.5 sec in both columns. The oblique columns and Y-shaped columns can be used for architectural purpose by giving the pleasing appearance to inclined support members, which increases the aesthetic appearance of the structure.

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