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Seismic Analysis of Irregular RC Structure with Cross-Bracing System

Rohan Chavan[1], Prachi Sohoni[2]

[1]M.Tech Structure, Walchand College of Engineering, Sangli , Maharashtra, India

[2]Assistant Professor, Department of Applied Mechanics, Walchand College of Engineering, Sangli, Maharashtra, India

ABSTRACT

Steel bracing system is one of the most suitable methods for improvement of reinforced concrete structures against lateral loading. Bracing systems is very efficient in reducing lateral displacements by increasing stiffness and strength. In proposed problem G+11 story irregular RC buildings are analysed with and without cross bracing system, which is one of the best of concentric bracing systems. Non-linear time history analysis is carried out in order to find out response of structure for various ground motions. ETABS 2016 software is used for analysis purpose. The performance of the building is evaluated in terms of story drifts, lateral displacements, bending moments, axial forces and base shear.

Keywords: Irregularity, Bracing Systems, Maximum Story Displacement, Story Drift, Time History Analysis.

I. INTRODUCTION

The primary design of structural systems used in building is to transfer gravity loads. Besides these vertical loads, buildings are also subjected to lateral loads caused by earthquake, wind, blasts etc. Hence the major concern in the design of the multi-storey buildings is to have enough lateral stability of the structure to resist lateral forces and to control the lateral drift. Currently, there are many structural systems such as rigid frame, braced frame and shear-walled frame, frame-tube, braced-tube, bundled-tube and outrigger systems that can be used to enhance the lateral resistance in tall buildings.

In many cases laterally braced systems make a building stiffer against horizontal forces, and thus minimize the amount of relative lateral movement and consequently the damage. It is seen that both structural and non-structural damages are observed during earthquake ground motions are primarily produced by lateral displacements. Therefore, in order to increase the seismic strength of framed structures, steel bracing or shear walls are often used. However, considering the ease of construction and the relatively low cost, steel bracing appears to be a better alternative. Steel bracings can be arranged like diagonal, cross bracing or X, V, inverted V or Chevron. In this study, irregular reinforced concrete buildings are analysed with cross bracing system, which is one of the effective bracing types.

A. Proposed Work

This work is focused on the analysis of multi-storeyed RC structures with different plan irregularities provided with cross-bracing system. The non-linear time history analysis is to be performed in order to assess the response of the structures to various earthquakes. After optimising the locations of bracings the optimised section is to be found out with the help of ETABS and is used in further analysis.

The main purpose is to find effect of bracing in terms of displacement, drift, base shear and column forces.

II. MODELLING OF BUILDING

For this study G+11 storied RCC buildings with irregular plans of Plus, L and C shapes with cross bracing system. ETABS software has been used for modelling and analysis purpose. The optimised section for bracings is found out from various IS sections with the help of ETABS.

A. Building Plan and Dimensions

G+11 storey building located in zone V is used for the study. Floor height is provided as 3m. Fixity is provided at all supports. The details and dimensions of buildings are given in Table I.

TABLE I

DIMENSIONAL DETAILS OF THE BUILDINGS

Grade of concrete	M30
Grade of steel	Fe415
Size of beam	300mmx400mm
Size of column	300mmx700mm
Thickness of slab	125mm
Type of bracing used	Cross bracing (X)
Storey height	3m
No. of story	12

For each irregular shape building, 2 models have been prepared one is without bracing and another is with bracing. The difference in behaviour of the structures before and after bracing is analysed using time history analysis. The optimised locations for bracings are found out after various trials and the further analysis is carried out with these final locations. ETABS auto-select command is used to find the most optimised section out of all IS sections. The most efficient section was found to be ISHB-225.

Model 1: PLUS shape building without bracing
Model 2: PLUS shape building with bracing
Model 3: L shape building without bracing
Model 4: L shape building with bracing
Model 5: C shape building without bracing
Model 6: C shape building with bracing

For further clarification about geometry, the plans and 3D views of the building models 2, 4 and 6. Model 1, 3 and 5 are same except bracings.

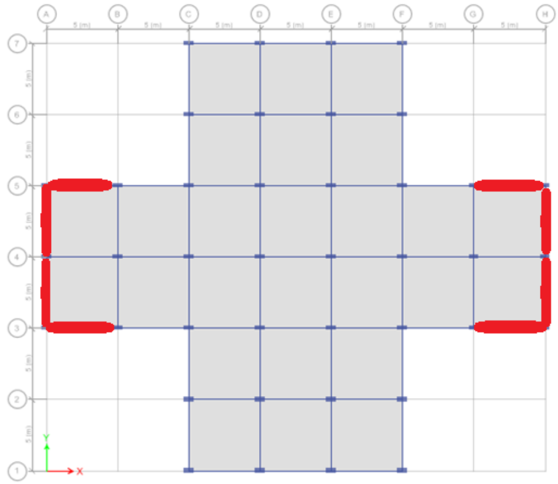

Figure 1: Plan of Model 2 (bracing locations are marked with red line)

The bracing positions are marked with red colour. Equal number of bracings provided in Model No. 2, 4 and 6 to keep the weight of the structure same during comparison.

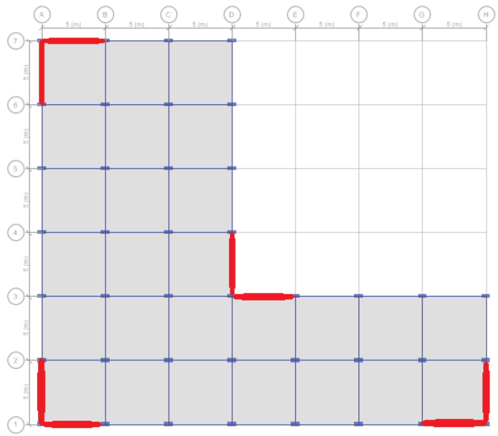

Figure 2: Plan of Model 4 (locations of bracings marked with red line)

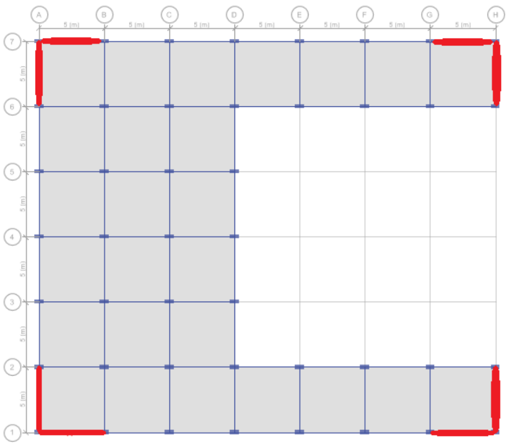

Figure 3: Plan of Model 6 (bracing locations are marked with red line)

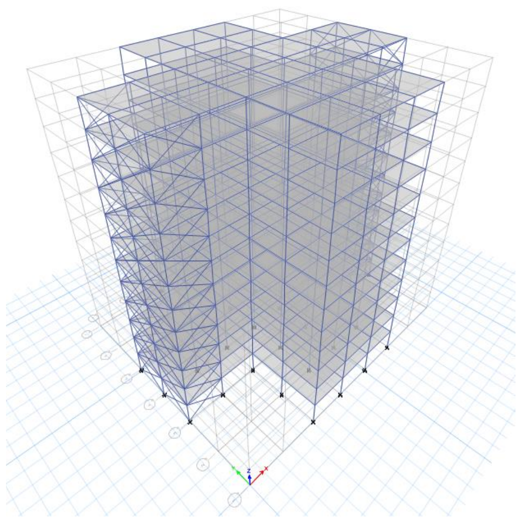

Figure 4: 3D view of Model 2

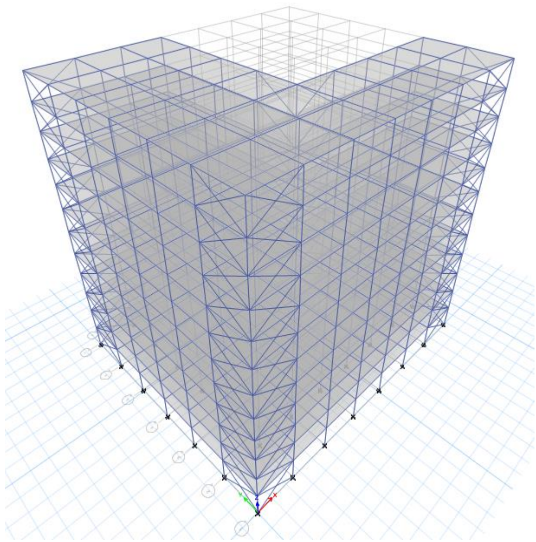

Figure 5: 3D view of Model 4

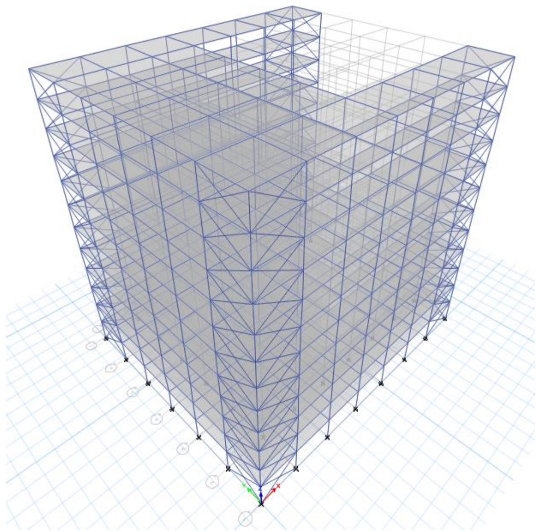

Figure 6: 3D view of Model 6

B. Loading Details

For given structure loading is applied as per IS 875 part I, part II and IS 1893:2016.

Live load: 4kN/m^2

Dead load: 1.5kN/m^2

1) Earthquake Load Parameters :

TABLE II

EARTHQUAKE LOAD PARAMATERS

Earthquake zone	V
Importance factor, I	1.2
Type of soil	Medium soil (Type II)
Response reduction factor, R	5
Zone factor, Z	0.36

2) Time History Data :

Various time histories were applied to the structure and the response was checked. The following five time histories, which gave maximum response, were selected and used in further analysis.

- Imperial Valley
- Santa Monica
- Friuli Italy
- Gazli USSR
- El centro

III. RESULTS AND DISCUSSIONS

All the six models have been analysed using time history analysis to evaluate the seismic response of structure. Five different time histories are used for the analysis. The results are found in terms of maximum story displacement, story drift, base shear and column forces.

A. Maximum Story Displacement

Comparative study of maximum story displacement is shown in Fig 7, 8 & 9 and Table III, IV & V.

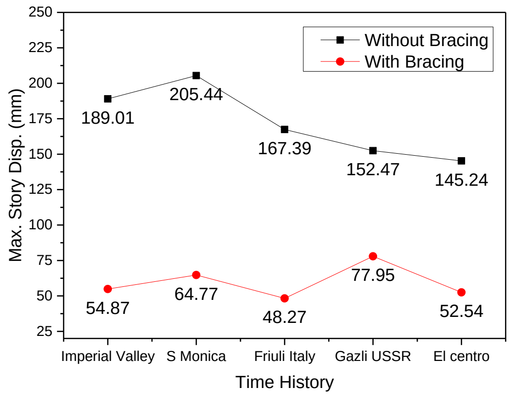

Figure 7: Plus Shape- Max. Story Displacement

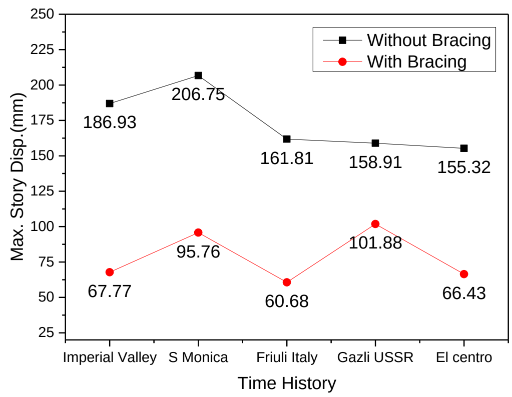

Figure 8: L Shape- Max. Story Displacement

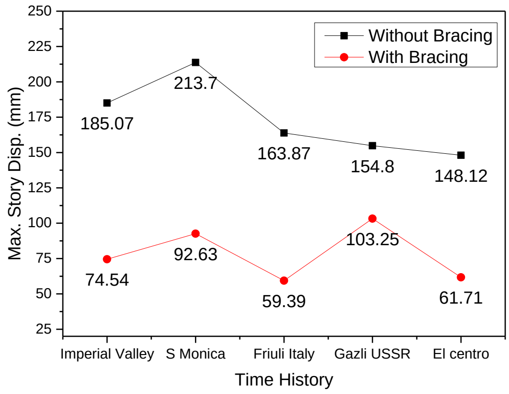

Figure 9: C Shape- Max. Story Displacement

We can observe from figure that there is reduction in maximum story displacement to great extent after application of bracings.

TABLE III

MAXIMUM STORY DISPLACEMENT-PLUS SHAPE

Max. story disp.(mm)	Plus Shape		Percentage reduction
	Model 1	Model 2	
Imperial Valley	189.01	54.87	70.97
Santa Monica	205.44	64.77	68.47
Friuli Italy	167.39	48.27	71.16
Gazli USSR	152.47	77.95	48.87
El centro	145.24	52.54	63.83

Maximum story displacement in Plus shape model is reduced by 45% to 70% after addition of bracing system.

TABLE IV

MAXIMUM STORY DISPLACEMENT-L SHAPE

Max. story disp.(mm)	L Shape		Percentage reduction
	Model 3	Model 4	
Imperial Valley	186.93	67.77	63.75
Santa Monica	206.75	95.76	53.68

Friuli Italy	161.81	60.68	62.50
Gazli USSR	158.91	101.88	35.89
El centro	155.32	66.43	57.23

Maximum story displacement in L shape model is reduced by 35% to 64% after addition of bracing system.

TABLE V

MAXIMUM STORY DISPLACEMENT-C SHAPE

Max. story disp.(mm)	C Shape		Percentage reduction
	Model 5	Model 6	
Imperial Valley	185.07	74.54	59.72
Santa Monica	213.70	92.63	56.65
Friuli Italy	163.87	59.39	63.75
Gazli USSR	154.80	103.25	33.30
El centro	148.12	61.71	58.33

Maximum story displacement in C shape model is reduced by 33% to 64% after addition of bracing system.

B. Maximum Story Drift

Comparative study of maximum story displacement is shown in Table VI, VII & VIII.

TABLE VI

MAXIMUM STORY DRIFT -PLUS SHAPE

Max. story drift (mm)	Plus Shape		Percentage Reduction
	Model 1	Model 2	
Imperial Valley	20.77	5.36	74.19
Santa Monica	25.17	6.99	72.23
Friuli Italy	18.98	4.51	76.24
Gazli USSR	23.98	8.14	66.06
El centro	18.09	5.35	70.43

Addition of bracings results in 65% to 76% reduction in maximum story drift in Plus shape model.

TABLE VII

MAXIMUM STORY DRIFT -L SHAPE

Max. story drift (mm)	L Shape		Percentage Reduction
	Model 3	Model 4	
Imperial Valley	20.48	6.77	66.94
Santa Monica	25.67	9.94	61.28
Friuli Italy	18.64	5.81	68.83
Gazli USSR	25.30	10.95	56.72
El centro	19.43	6.36	67.27

Addition of bracings results in 55% to 67% reduction in maximum story drift in L shape model.

TABLE VIII

MAXIMUM STORY DRIFT -C SHAPE

Max. story drift (mm)	C Shape		Percentage Reduction
	Model 5	Model 6	
Imperial Valley	19.65	7.57	61.48
Santa Monica	25.23	9.91	60.72
Friuli Italy	18.26	5.89	67.74
Gazli USSR	23.68	11.34	52.11
El centro	17.82	6.32	64.53

Addition of bracings results in 52% to 67% reduction in maximum story drift in C shape model.

C. Base Shear

The base shear of all the three irregular buildings increases after addition of bracings. But the bracings add up very less weight so the increase in base shear is also very less i.e. 0.64% to 0.65%.

TABLE IX
BASE SHEAR OF BUILDING MODELS

Base shear (kN)		X-Direction	Y-Direction
Plus Shape	Model 1	4625.88	4625.75
	Model 2	4655.57	4656.44
L Shape	Model 3	4625.88	4625.75
	Model 4	4656.11	4655.98
C Shape	Model 5	4715.38	4715.25
	Model 6	4745.61	4745.48

D. Column Forces

Addition of bracings reduces the bending moments in the columns. All the three buildings show reduction in BM as shown in Table X. On the contrary, there is increase in axial force as shown in Table XI.

TABLE X
MAXIMUM BENDING MOMENTS IN COLUMNS

Bending Moment (kNm)	Without Bracing	With Bracing	Percentage Reduction
Plus Shape	541.36	293.43	45.79%
L Shape	546.17	308.816	43.46%
C Shape	499.2739	285.297	42.86%

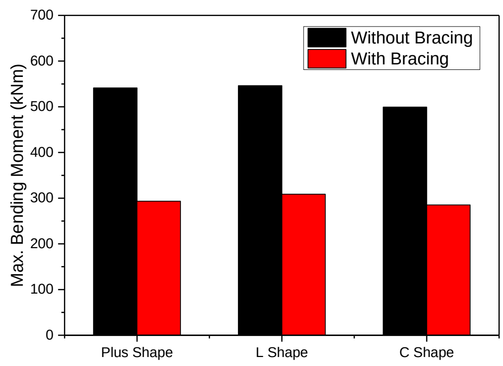

Figure 10: Max. Bending Moment in Columns

TABLE XI
MAXIMUM AXIAL FORCE IN COLUMNS

Axial Force (kN)	Without Bracing	With Bracing	Percentage Increase
Plus Shape	4631.91	5385.76	16.28%
L Shape	4559.86	6136.37	34.57%
C Shape	4486.62	5880.82	31.07%

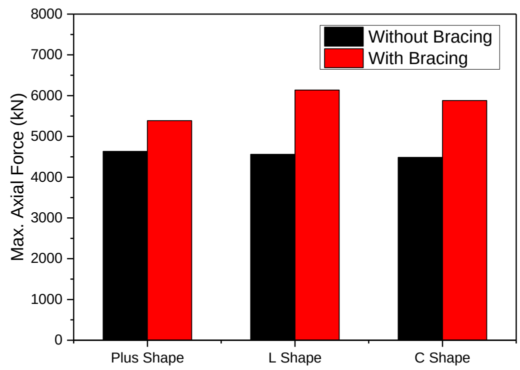

Figure 11: Maximum Axial Force in Columns

IV. CONCLUSIONS

The analysis of G+11 storied buildings with different types of irregularities is carried out. The analysis of all the models with five different time histories shows that steel bracings effectively improve the response of the structure. Steel bracings reduces significant amount of lateral displacement, bending moment. Following conclusions can be drawn from this study.

1) The additional weight of bracings applied is 473.44kN which is less than 1% of self-weight of structure. This little addition improves the performance considerably.
2) Bracing system effectively reduces lateral displacements (up to 70%) and story drift (up to 75%) of the structure compared to bare frame.
3) Steel bracing also helps to reduce member forces considerably.
4) In all the concept of using steel bracings in reinforce concrete structures is advantageous to resist the earthquake forces.

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