Seismic Analysis of Multi Storey Irregular RCC Buildings with Bracing System

PROF ABHIJEET PATIL[1], RUSHIKESH SUTAR[2]
[1] *Assistant Professor, Department of CIVIL Engineering, KIT College of Engineering, Kolhapur, Maharashtra, India.*
[2] *P.G. Student, Department of CIVIL Engineering, KIT College of Engineering, Kolhapur, Maharashtra, India.*

Abstract – Steel bracing systems are a crucial method for strengthening reinforced concrete structures against lateral stresses. They increase strength and stiffness, preventing lateral displacements. A linear static analysis investigation was conducted to assess the structure's response to seismic zone V using ETABS 20. The evaluation criteria included basis shear, axial forces, bending moments, story drifts, and lateral displacements. The same bracing size and quantity were applied to all constructions. Plan and vertical irregularities are the main types of irregularities in structures, which pose challenges in design and construction due to their unique behavior. Understanding these buildings' behavior is essential for developing innovative design and construction methods. The current study aims to understand how irregular structures with bracing systems behave. Three types of irregularities are identified for a twelve-story structure: L, T, and C-shaped tall buildings. X-type bracing is used in the investigation. Seismic analysis in seismic zone V was performed using ETABS 20 and linear static seismic analysis. The main objective was to assess the irregular building and the effectiveness of the bracing.

Index Terms- RC Structure, Steel bracing, seismic analysis, Wind analysis, ETABS, SAP2000.

I. INTRODUCTION

The transfer of gravitational loads is the main purpose of structural systems design in buildings. In addition to these vertical stresses, lateral loads from blasts, wind, earthquakes, etc., can also affect buildings. Because of this, the main consideration in the design of multi-story structures is to ensure that the structure has adequate lateral stability to withstand lateral stresses and manage lateral drift. To improve the lateral resistance of tall structures, a variety of structural methods are currently available, including outrigger systems, frame-tube, braced-tube, bundled-tube, rigid frame, braced frame, and shear-walled frame.

Laterally braced systems often reduce the amount of relative lateral movement and, as a result, damage by stiffening a building against horizontal stresses. Lateral displacements are the main cause of both structural and non-structural damages that are exhibited during earthquake ground motions. Therefore, shear walls or steel bracing are frequently utilized to strengthen the seismic strength of framed structures Steel bracing, however, seems to be a superior option given its ease of fabrication and affordable price. Steel bracings can be placed in the following configurations: diagonal, cross, X, V, inverted V, or chevron. This study examines the use of cross bracing, one of the most successful bracing systems, in irregular reinforced concrete buildings.
Structural analysis is the investigation of the behavior of a building/structure when it is subjected to some forces acting vertically or horizontally (external forces). These forces can be in the form of weight due to people, furniture, snow, etc, or some other excitation such as an earthquake, shaking of the ground due to a blast, etc. Structural analysis is also concerned with the safety and economy of the structure as they serve as a prime factor in any construction of a building. The structure should hold enough strength to fulfill the function for which it has been designed throughout its design period. Therefore, the structural members of a building should be designed carefully so that they can easily withstand both the forces, vertical and horizontal forces. Two major horizontal forces that may act on a building and have been proven to be hazardous calamities in the past are earthquake forces and Wind forces. With the higher magnitude of these forces, they can be a real danger to property and life. They can vanish the infrastructure within seconds when they come with its full strength. Therefore,

proper resistance to the buildings shall be given while designing and special care shall be taken during the construction phase. Due to improper designing, conventional construction techniques, and ignorance of earthquake and wind forces in the past, most of the existing infrastructure is unable to withstand the damage that will be caused if these disasters hit them.

II. IDENTIFICATION OF GAPS & OBJECTIVES

Research has not been conducted on buildings with a combination of cross-bracing and irregular structural plans, as per IS: 1893-2016. The study focuses on multi-story reinforced concrete buildings with cross-bracing systems and irregularly shaped buildings. The seismic analysis will be conducted using the Zone of Seismic Activity V, and comparative analysis will be conducted using various building-shaped structures. Further research is needed on the impact of bracing systems on torsion in structures with irregular mass, stiffness, and combined plan-shaped buildings.

Objective Of Study:

1. To analyze the effect of cross bracings on L-shaped, T-shaped and C-shaped irregular RCC buildings under seismic loading for zone V .
2. To compare response under gravity load as well as lateral loads of irregular building under study in braced & unbraced condition.
3. To optimize bracing locations and determine the optimal sections for irregular buildings under study using ETABS 20, considering bracing's influence on displacement, drift, base shear, and column forces.
4. To identify the most and the least effective irregular building shapes for a bracing system in terms of displacement reduction.

Seismic zone factor	Zone V (0.36)
Response Reduction factor	5
Site type	2 (medium)
Important factor I	1
Period	0.54 sec

Figure 1. Types of Bracing System.

III. RESEARCH METHODOLOGY

The summary of the research paper is given below:
Modelling Various Irregular structures:

A. Building Plan and Dimensions (As per IS 456:2000) –

Type of structure	RC Building.
Grade of concrete	M30
Grade of steel	Fe450
Thickness of slab	125mm
Type of bracing system	Cross bracing (X)
Size of bracing	ISA 200 x 200 x 25 mm
Floor to Floor Height	3m
No's of floors	G+11
No. of bays	As per plan
Size of each bay	5m x 5m

Table-1

B. Loading Details (As per IS 875 part 1) –

Dead Load:	
External Wall Loading	13.8 kN/m
Interior Wall Loading	9 kN/m
Floor load	4 kN/m2
Live Load	
Floor load	2 kN/m2
Floor finish Load	1 kN/m2

Table-2

C. Earthquake Details (As per IS 1893 part 1 2016) –

Table-3

D. Wind load Details (As per IS 875 2015) ¬

Wind speed	50 m/s
Terrain category	4
Important factor	1
Risk Coefficient (k1 factor)	1
Topography (k3 factor)	1

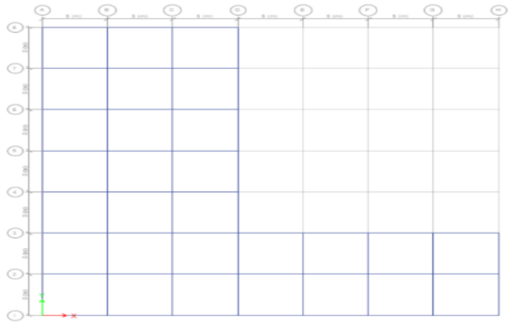
Table-4

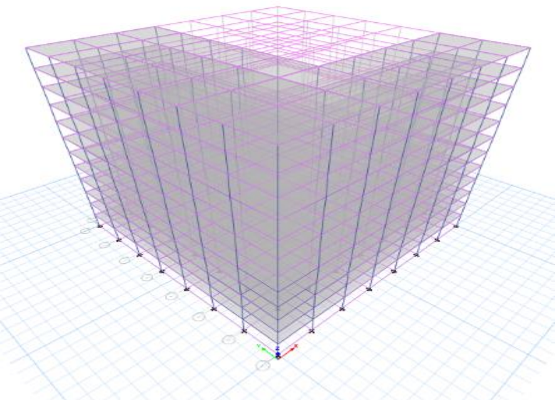
Modeling Various Irregular Structures:
Model 1: L-shaped building without bracing
Model 2: T-shaped building without bracing
Model 3: C-shaped building without bracing
Model 4: L-shaped building with bracing
Model 5: T-shaped building with bracing
Model 6: C-shaped building with bracing

SHAPED OF BUILDING	COLUMN SIZE	BEAM SIZE
L SHAPED BUILDING	300 X 1200	300 X 600
T SHAPED BUILDING	400 X 900	380 X600
C SHAPED BUILDING	300 X 1000	300 X400

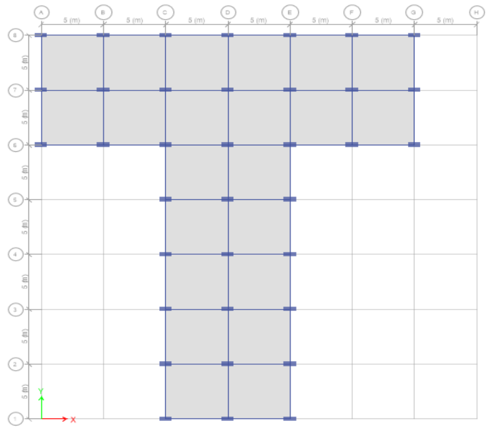
(Table 5. Optimize the size of Irregularly shaped buildings without bracing RC structure.)

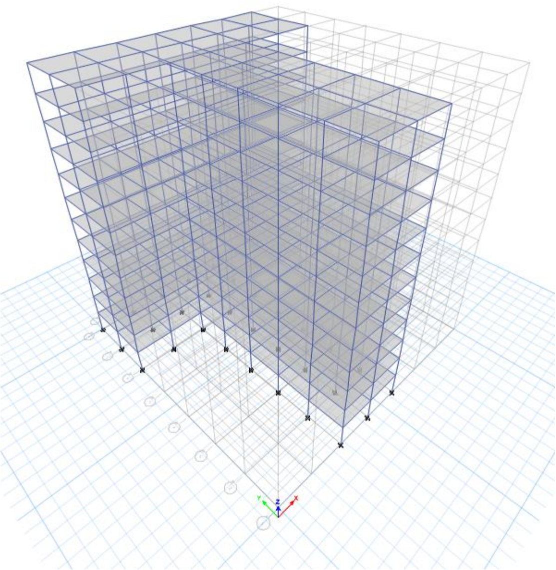
Model 1: L shaped building without bracing 2D & 3D plan



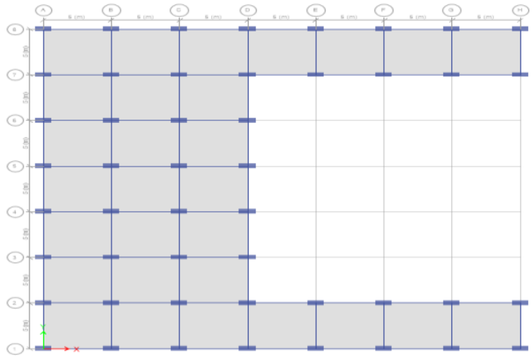


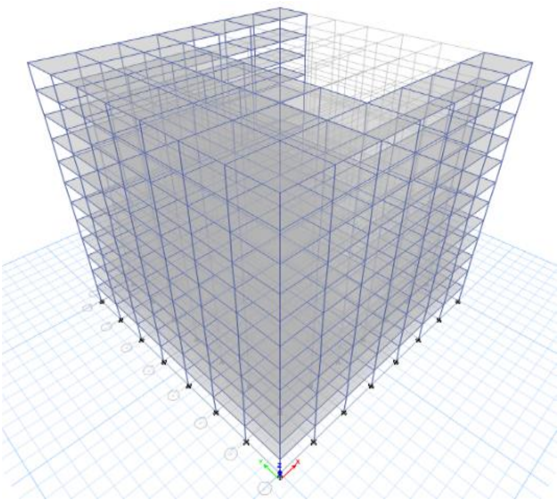
Model 2: T-shaped building without bracing 2D &3D plan





Model 3: C-shaped building without bracing 2D plan

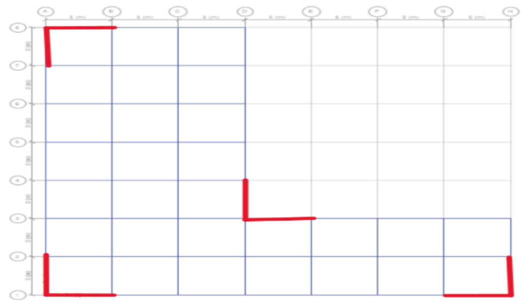


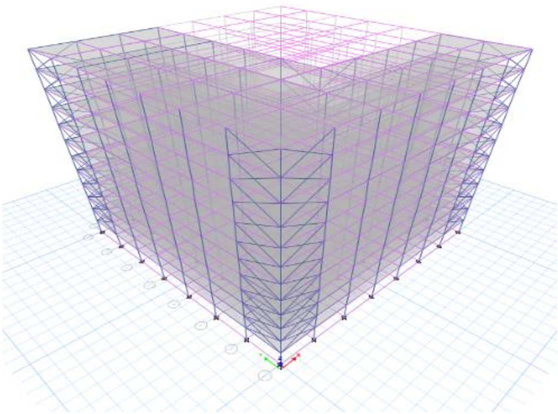


SHAPED BUILDING OF BUILDING	COLUMN SIZE	BEAM SIZE
L SHAPED BUILDING	300 X 1000	300 X 600
T SHAPED BUILDING	400 X 900	380 X600
C SHAPED BUILDING	500 X 1200	300 X400

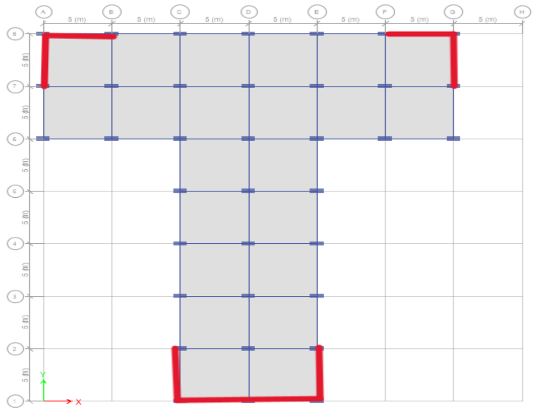
(Table 6. Optimize the size of Irregularly shaped buildings with X bracing RC structure.)

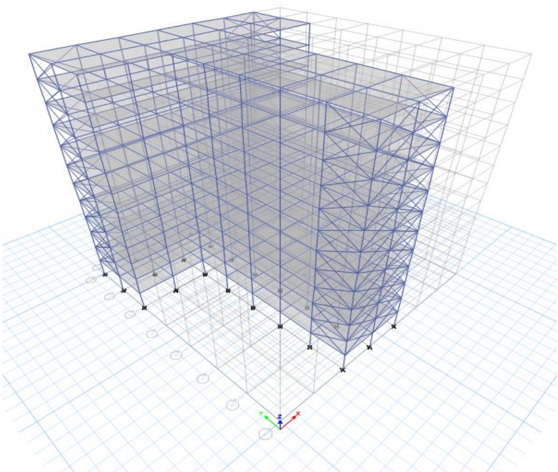
Model 4: L-shaped building with X bracing 2D&3D plan



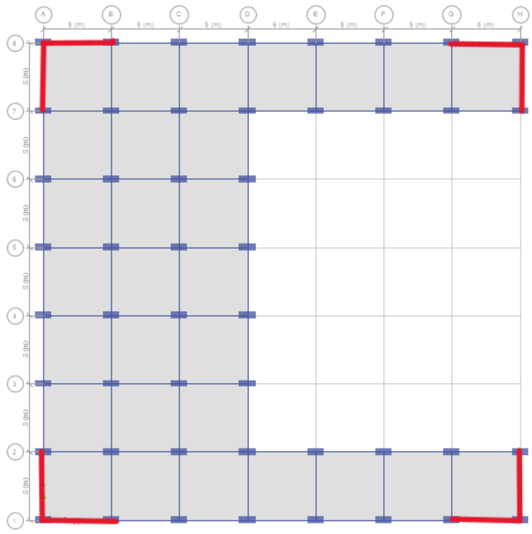


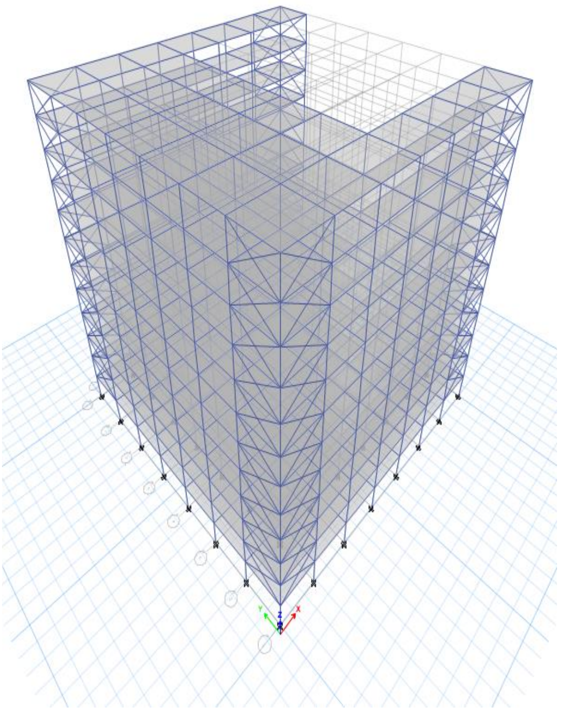
Model 5: T-shaped building with X bracing 2D&3D plan





Model 6: C-shaped building with X bracing 2D plan





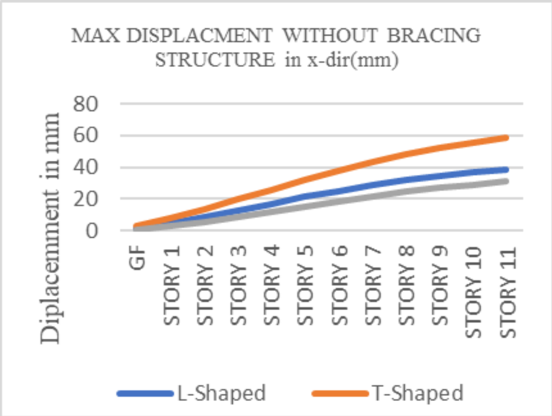
IV. RESULTS AND DISCUSSIONS

The current investigative study on the plan irregularity structures of 12-story structures has been completed well. The performance of the structure is observed, and structural members were assessed in terms of maximum displacement from the ETABS20 result. During the study, all sorts of structural irregularities were investigated using X-type bracing, which is placed at the edges. Following tabulation and figure representation of the ETABS20 results, a thorough analysis was conducted using tables and comparative figures. The results of twelve-story (L, T, and C-shaped building d) buildings that were examined with earthquake loads & wind forces will be covered in the parts that follow.

1. T-shaped buildings, both with and without RC bracing, have a maximum displacement greater than L-shaped and C-shaped buildings
2. C-shaped buildings have less displacement than L-shaped or T-shaped buildings.
3. In this study conclude that L-shaped building & T-shaped RC structure displacement decreases by 38% & 45% compared to the shaped building RC structure.
4. In L shaped RC building 1.29% increases in x-direction & 38.66% decreases y- direction lateral displacement after applied x bracing system.
5. In T shaped RC building 39.21% decreases in x-direction & 49.04% decreases y- direction lateral displacement after applied x bracing system.
6. In C shaped RC building 24.17% decreases in x-direction & 30.68% decreases y- direction lateral displacement after applied x bracing system.

Maximum Displacement in without bracing structure x direction (mm)

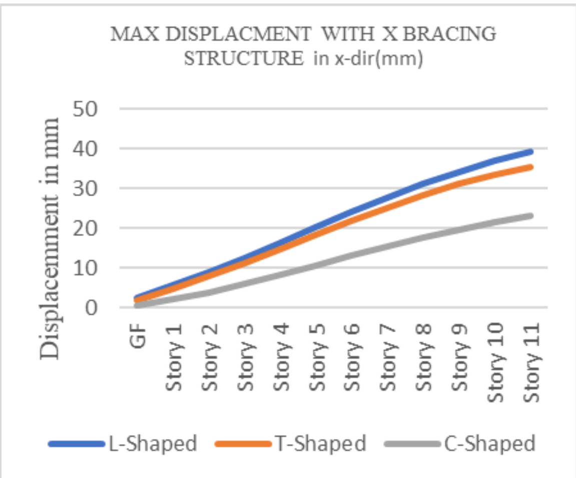
	L Shaped building	T Shaped building	C Shaped building
GF	1.5	2.59	0.79
STORY 1	4.67	7.6	2.74
STORY 2	8.55	13.42	5.42
STORY 3	12.73	19.52	8.53
STORY 4	16.93	25.67	11.85
STORY 5	21.12	31.73	15.21
STORY 6	25.06	37.56	18.48
STORY 7	28.72	43.02	21.56
STORY 8	31.98	47.96	24.35
STORY 9	34.75	52.23	26.82
STORY 10	36.97	55.69	28.95
STORY 11	38.68	58.35	30.81



Maximum Displacement in with bracing structure x direction (mm)

	L Shaped building	T Shaped building	C Shaped building
GF	2.53	1.94	0.6
Story 1	5.59	4.8	2.11
Story 2	8.93	7.95	3.96
Story 3	12.53	11.33	6.08
Story 4	16.29	14.83	8.34
Story 5	20.14	18.37	10.69
Story 6	24.06	21.86	13.05
Story 7	27.73	25.2	15.35
Story 8	31.13	28.32	17.55
Story 9	34.21	31.13	19.6
Story 10	36.89	33.55	21.47
Story 11	39.15	35.47	23.16

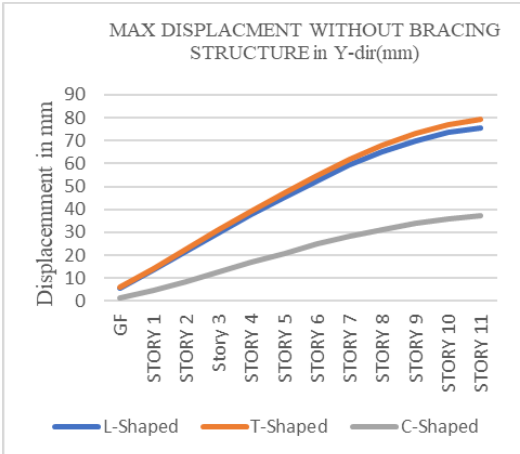
Table-8



Maximum Displacement without bracing structure in Y direction (mm)

	L Shaped building	T Shaped building	C Shaped building
GF	5.86	5.97	1.49
STORY 1	13.75	14.19	4.68
STORY 2	21.81	22.62	8.56
Story 3	29.84	31.02	12.71
STORY 4	37.74	39.29	16.88
STORY 5	45.37	47.28	20.94
STORY 6	52.58	54.84	24.77
STORY 7	59.21	61.8	28.27
STORY 8	65.06	67.94	31.34
STORY 9	69.91	73.03	33.88
STORY 10	73.51	76.83	35.85
STORY 11	75.67	79.15	37.28

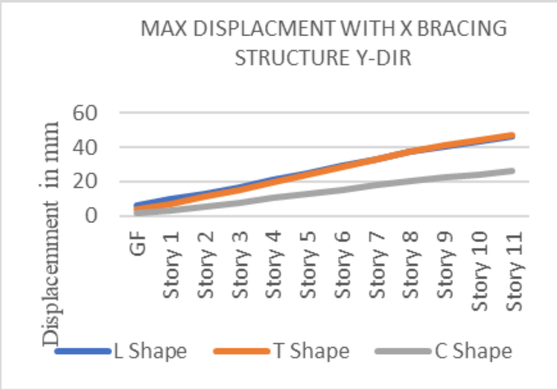
Table-9



Maximum Displacement with bracing structure in Y direction (mm)

	L Shaped building	T Shaped building	C Shaped building
GF	5.96	3.78	1.37
Story 1	9.47	7.12	3.31
Story 2	12.98	11.01	5.45
Story 3	16.86	15.2	7.77
Story 4	20.95	19.63	10.23
Story 5	25.13	24.17	12.76
Story 6	29.29	28.71	15.3
Story 7	33.34	33.12	17.77
Story 8	37.17	37.3	20.13
Story 9	40.7	41.14	22.32
Story 10	43.83	44.57	24.27
Story 11	46.43	47.46	25.91

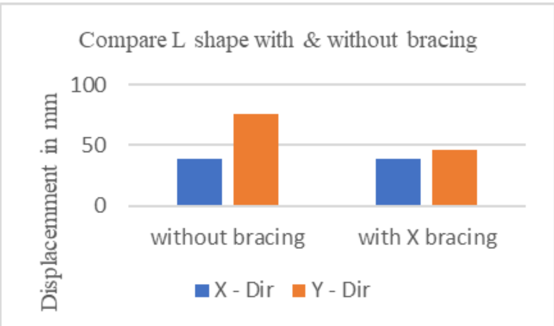
Table-10



Compare Displacement of the L-shaped building with & without the bracing system

Table-11

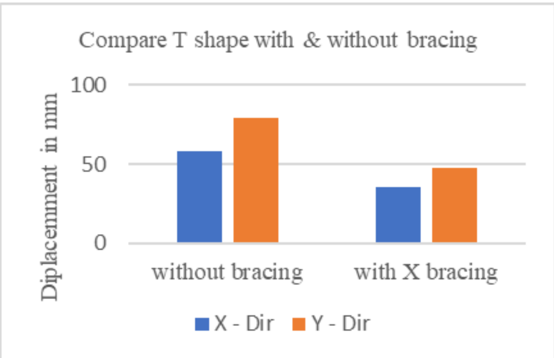
	X – Dir (mm)	Y - Dir(mm)
without bracing	38.68	75.67
with X bracing	39.18	46.43



Compare the Displacement of a T-shaped building with & without the bracing system

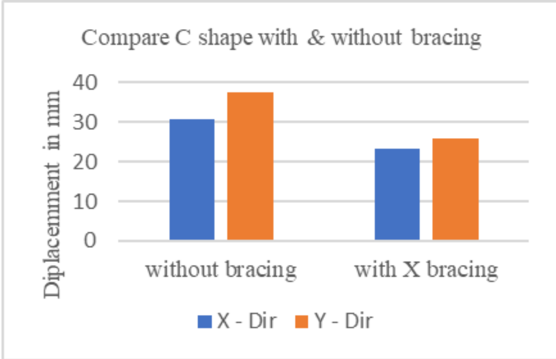
	X – Dir (mm)	Y - Dir(mm)
without bracing	58.35	79.15
with X bracing	35.47	47.46

Table-12



Compare the Displacement of a C-shaped building with & without the bracing system

	X – Dir (mm)	Y - Dir(mm)
without bracing	30.81	37.38
with X bracing	23.16	25.91



CONCLUSION

Analysis is done on G+11 story structures, Steel bracings significantly enhance the structure's reaction, according to the examination of every model with linear static analysis. Steel bracings significantly reduce bending moment and lateral displacement. From this investigation, the following conclusions can be made.The study analyzed multi-storeyed RC structures with plan irregularities using a cross-bracing system. linear static analysis is conducted to assess earthquake &wind force response. After optimizing bracing locations, the optimized section is determined using ETABS 20.

1. The study reveals that T-shaped buildings have a greater maximum displacement than L-shaped and C-shaped buildings, while C-shaped buildings have less displacement.
2. L-shaped and T-shaped buildings experience a 38% and 45% decrease in displacement compared to C-shaped structures.
3. The application of the x-bracing system results in a 1.29% increase in x-direction and a 38.66% decrease in y-direction lateral displacement, respectively.
4. The application of the x-bracing system significantly reduced lateral displacement in both T and C-shaped RC buildings, with 39.21% and 49.04% decreases in x- and y-directional displacement, respectively.

The application of an x-bracing system resulted in a 24.17% decrease in the x-direction and a 30.68% decrease in the y-direction lateral displacement in a C-shaped RC building.

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