Comparative Study of Steel Bracing and Its Effects on Irregular Building under Seismic Load

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Abstract— In practical Civil engineering work, we classify high rise building as regular shaped (symmetrical) and irregular shaped (unsymmetrical) building. The introduction of irregularity in structure create complex while it's design. Also its behavior varies under different kind of loadings and other integral design factor. So it is very important to study behavior of unsymmetrical buildings with respect to different kind of loading and other design parameter. Usually Plus shape, C-shape, L-shape, H-shape etc. building can be seen. Among them, we are going to have a comparative study of plus shape, C-shape and L-shape unsymmetrical building. When a high rise building is constructed it is subjected to various loads like dead load, live load, seismic load, wind load, snow load etc. These different types of loadings cause lateral or torsional deflections. Seismic loading must be taken into account for the design of high rise buildings. It can resist base shear, story drift and story displacement as well. In this comparative study we are going to analysis a high rise building with seismic load. For seismic analysis we are going to use zone IV using equivalent static analysis method as per IS 1983:2002 for G+15 building. Karthik Reddy studied a 16 storey regular building with 62 m/s wind speed and zone II seismic activity and found that x bracing arrangement is more suitable. Kartik K. M. noticed that irregular buildings show in increase in storey drift, lateral displacement but reduction in base shear, inverse for regular building. Loveneesh Sharma realized that L shape building shows poor resistance to the lateral forces with minimum swaying of columns requiring almost equal cost for heavy mass transfer. Masood Ahmed Shariff discovered cross bracing shows minimum lateral displacement and storey shear for the irregular multi storey building. The main parameter which are to be considered for seismic analysis of a high rise structure include structural stiffness, storey drift etc. These parameters can be achieved with the help of bracing systems. Bracing is useful to resist base shear of the high rise building. There are X shape, V shape, K shape, Diagonal shape bracing commonly can be seen. In this comparative study we are comparing X shape and diagonal shape steel bracing.

Keywords: RCC Frame Structure, Bracing, Lateral Displacement, Storey Drift, Base Shear

I. INTRODUCTION

Now days to accommodate continuous urban sprawl, it is necessary to construct multi-storey and tall building. These high rise buildings are defined as a building whose design is governed by the lateral force that are introduced by seismic and wind. The structural system designed to carry only vertical loads may not have tendency and capacity to resist lateral forces as mentioned above. But if it is designed for lateral load, it will increase the structural cost substantially with increase of number of storey.

A structural steel framed building is a better choice for many reasons. It is a very strong material with a high strength to weight ratio. Also steel is shop fabricated and maintenance tight tolerances itself. It also gives maximum flexibility to engineers and designers during designing and layout. It also provide a wide range of options to the owners according to their need.

Earthquakes are considered to be most destructive and life damaging phenomenon at all the time. The large release of strain energy by the movement of geological fault, shacking of ground mainly causes the earthquake. It causes seismic waves carrying different levels of energy, amplitudes and approach at various instants of the time to ground surface. As earthquake can be classified depending on its size and occurrences as strong, moderate and minor. Magnitude (M) is a parameter use to measure size of earthquake with is recorded by seismograph, when earthquake occur, building undergo dynamics motion generating inertia forces. This inertia forces are called as seismic force. According to previous seismic activities, India is divided into five seismic zones, zone I to zone V. Among these, zone I is neglected for the design purpose. The increasing number of indicates the higher magnitude earthquake. There are two method of analysis, as equivalent static analysis and response spectrum analysis. In case of multi storied building it is necessary to use earthquake (seismic) analysis as they are subjected to higher lateral forces at the time of occurrence of earthquake. But for short building lateral forces are not considered as compare to tall buildings. Also it proves uneconomical to provide seismic design that is why short buildings are mainly designed for vertical loads.

Steel bracing frames is one of the structural system which is use to resist lateral load in multi storied buildings. It is economical, flexible and requires less space to meet strength and stiffness. There are mainly two type of bracing system is,

1) Concentric bracing system
2) Eccentric bracing system
   1) Concentric bracing system increases natural frequency, lateral stiffness and decreases lateral storey drift.
   2) Eccentric bracing system improves the energy dissipation capacity and reduces lateral stiffness due to earthquake.

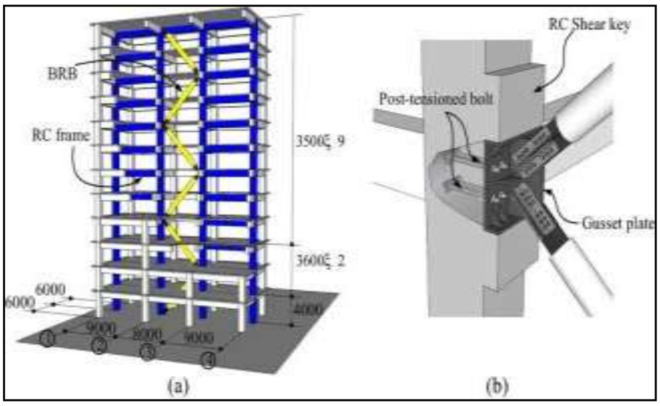


Fig. 1: Arrangement and Joint between RCC structure and Steel Bracing

II. Literature Review

A. Literature Survey:

Loveneesh Sharma et al. (2019) (1) investigated the dynamic seismic evaluation of irregular multi storey building with bracing, zone IV for a G+12 building. They investigated the H, L and O geometrical irregular buildings. They realized that L shape building shows poor performance while resisting lateral forces and heavy mass transfer showing the large sway in the column. Also, the cost is consistent for heavy mass transfer from lower storey to higher storey of the building.

Masood Ahmad Shariff et al. (2019) (2) analyzed the seismic loading in the G+4 multi storey building for zone IV and medium soil specifying IS code with the bracing arrangement using ETAB. They used equivalent static analysis method with X-bracing system for H geometrical shape of building. They discovered that X bracing increases the storey shear but reduces the lateral displacement. They also concluded that X bracing is safe and sustains the seismic loads easily than another kind of bracing arrangements as displacement is 45.66% at x direction and 37.21% at y direction

Mayank Walia et al. (2019) (3) performed the analysis of composite regular and irregular buildings with bracing system. They analyzed the 12 storey irregular and 16 storey regular building subjected to 44 m/s wind speed. They used X bracing, V bracing and zigzag (diagonal) bracing system for analysis. They concluded that x bracing system is most effective than other kind of bracing systems for both the regular and irregular high rise building except requirement of increased quantity of materials

K. Anitha et al. (2018) (4) comparatively studied the different framing system for multi storey composite buildings (G+10) with the introduction of irregular geometry. They analyzed the above mentioned structure subjected to basic winds speed of 50 m/s and zone III seismic activity with the help of ETAB software. They stated that double diagonal bracing system i.e. X bracing provides minimum increase in load for steel bracing as compared to K, V etc. types of eccentric bracing arrangements. Also, they concluded that double diagonal (concentric) bracing system reduces the storey drift more effectively

K. S. K. Karthik Reddy et al. (2015) (6) studied that a comparative study on behavior of multi storied building with different types and arrangement of bracing system. They studied a (G+15) regular shaped multi storied building with using wind speed of 62m/s and seismic load applied on it for zone II by using equivalent static analysis. In this study they concluded that X-bracing is more effective as it reduces the nodal deflection by 80%. Also V and inverted V bracing do not show much different in increase of weight and base shear of structure.

Kartik K. M. et al. (2015) (7) analyzed the effect of steel bracing on vertical irregular reinforced cement concrete building framed under seismic load zone V for G+5 building by using ETAB. They used equivalent static analysis method for seismic load along with X, V and K types of bracing arrangements, concluding that increase story drift, lateral displacement and reduce the base shear, vice versa for regular shape building mentioned that X-bracing system is suitable among all type of bracing systems.

Nitin N. Shinde and R. M. Phuke (2013) (8) analyzed of braced unsymmetrical RCC building by using SAP2000. They studied different bracing section along with different bracing system are employed to study the seismic response of the building. The building analyzed for different load combination as per IS 1893:2002. The comparison is done between the braced and bare building on the basis of the floor displacement, storey drift, base shear, axial force and bending moment. It was observed that seismic performance of the braced building is improved as compared to bare building. They concluded that storey drift of the building decrease as compared to the bare building which indicates the overall response of the building decrease. Also size of bracing increase displacement and storey drift decrease for braced building. Overall performance of the X bracing is building better that other types of braced system.

III. Methodology

A. Introduction:

Force Based analysis a traditional approach to Seismic analysis of a building. Using the equivalent static analysis lateral forces on the building are determined and the member are designed to withstand these forces. In this approach, there is measure of the lateral displacement, base shear and storey drift of building under the design forces.

B. Seismic Analysis:

Earthquake motion causes vibration of the structure leading to inertia forces. Thus a structure must be able to safely transmit the horizontal and vertical inertia forces generated in the super structure through the foundation to the ground. Hence, for most of the ordinary structures, earthquake-resistant design requires ensuring that the structure has adequate lateral load carrying capacity. Seismic code will guide a designer to safety design the structure for its intended purpose.

Seismic code are unique to a particular region or country. In India, IS 1893 is the main code that provides outline for calculating seismic design force. This force depend on the mass and seismic coefficient of the structure and the latter in turn depend on properties like seismic zone in which structure lies, importance of the structure, its stiffness, the soil on which it rests, and its ductility. Part I of IS 1893:2002 (here after we refer it as the code) deals with assessment of seismic loads on various structures and buildings. In short the whole the code aims the calculation of base shear and its distribution over height. Depending on the height of the structure and zone to which it belongs, type of analysis i.e. static analysis or dynamic analysis is performed.

1) Definitions:

1) Storey: It is the space between to adjacent floors.
2) Storey Drift: It is the displacement one the level relative to the other level above or below.
3) Base Shear: It is the amount of external lateral forces acting on the base of the structure due to the earthquake.
4) Seismic weight: It is the total dead load plus appropriate amount of specified imposed load.
5) Importance Factor: It is a factor used to obtain the design seismic force depending on the functional use of the structure.
6) Zone Factor: It is a factor to obtain the design spectrum depending on the perceived maximum seismic risk characterized by Maximum Considered Earthquake (MCE) in the zone in which the structure is located. The basic zone factors included in this standard are reasonable estimate of effective peak ground acceleration.
7) Response Reduction Factor: It is the factor by which the actual base shear force, that would be generated if the structure were to remain elastic during its response to the Design Basis Earthquake (DBE) shaking, shall be reduced to obtain the design lateral force.

2) Equivalent Static Method:

This approach defines a series of forces acting on a building to represent the effect of the earthquake ground motion, typically defined by a seismic design response spectrum. It assumes that the building response in its fundamental mode. For this to be true, the building must be low rise and not twist significantly when the ground moves. The response is read from a design response spectrum, given the natural frequency of the building (either calculated or defined by the building code). The applicability of this method is extended in many building codes by applying factors to account for higher building with some higher modes, and low levels of twisting. To account for effect due to “yielding” of the structure, many codes apply modification factor that reduce the design forces.

a) Fundamental Natural period:

The approximate fundamental natural period of vibration (T_a), is second, of a moment-resisting frame building without brick infill panels may be estimated by the empirical expression:

$T_a = 0.075\ h^{0.75}$ for RC frame building

$T_a = 0.085\ h^{0.75}$ for steel frame building

The Approximate fundamental natural period of vibration (T_a), in seconds, of all other buildings, including moment-resisting frame buildings with brick infill panels, may be estimated by the empirical expression:

$$T_a = \frac{0.09\ h}{\sqrt{d}}$$

Where,

h = height of building in m. This excludes the basement storeys, where basement walls are connected with the ground floor deck or fitted between the building columns. But, it includes the basement storeys, when they are not so connected.

d = base dimension of the building at the plinth level, in m, along the considered direction of the lateral force.

b) Design Seismic Base Shear:

Along any principle direction, the design Seismic base shear or total design lateral force (V_B) can be determined by the following Expression:

$$V_B = A_h \text{ X } W$$

$$A_h = \frac{Z}{2} \text{X} \frac{S_a}{g} \text{X} \frac{I}{R}$$

Where,

A_h = Design Acceleration spectrum along horizontal with the help of fundamental natural period “T” in that particular direction of vibration.

W = Seismic weight of the structure.

S_a/g = Spectral Acceleration taken from Response Spectrum

I = Importance Factor

R = Ductility / Over-strength Reduction Factor

c) Design lateral force at each floor i:

The design lateral force, V_b shall be distributed along the height of building using equation as follow,

$$\mathbf{Q_i = V_b \text{ X } \frac{W_i \text{ X } h_i}{\sum_{j=1}^{n} W_j \text{ X } h_j^2}}$$

Where,

Q_i = Design lateral force at floor i,

W_i = Seismic weight of floor i,

h_i = Height of floor i measured from base

n = Number of storeys in the building is the number of level at which the masses are located.

d) Storey Drift Limitation:

The storey drift in any storey due to the minimum specified design lateral force, with partial load factor of 1.0 shall not exceed 0.004 times the storey height.

e) Load Combination:

When earthquake forces are considered on a structure, these shall be combined as per IS 1893 (Part 1): 2002 where the term DL, IL and EL stand for the response quantities due to dead load, impose load and designated earthquake load respectively. In the limit state design of reinforced and prestressed concrete structure, the following load combinations shall be accounted for:

1.5 (DL + LL)

1.2 (DL + LL ± EL)

1.5 (DL ± EL)

0.9 DL ± 1.5 EL

IV. MODELLING AND ANALYSIS

A. General:

In the present study we are investigating the behavior of different shapes of irregular high rise structure subjected to seismic forces with and without different types of steel bracing systems which helps us to determine more feasible and effective type of steel bracing system by using STAAD.pro.V8i.SS5. The procedure of the above mentioned investigation is described in this chapter of methodology.

B. Description of structure:

1) Geometrical Data:

Models that have been prepared for present investigational study along with other parameters for G+15 building for all is represented in the Table No. 1.

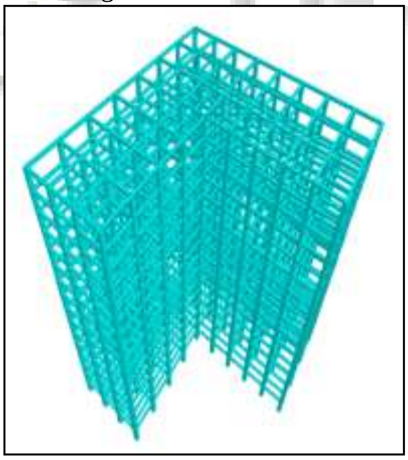
Sr. No.	Shape	Length (m)		Types of Bracing
		X	Z	
1.	L	40	42	No
2.	L	40	42	Diagonal
3.	L	40	42	X
4.	C	35	54	No
5.	C	35	54	Diagonal
6.	C	35	54	X
7.	Plus	45	54	No
8.	Plus	45	54	Diagonal
9.	Plus	45	54	X

Table 1: Different Models for Present Study

- Floor to Floor Height: 3.2 m
- Total height of Structure: 51.2 m

a) Model 1:

- Type of building: commercial building
- Foundation or Plinth height: 3.2 m
- Beam Size: 400 mm x 400 mm
- Column Size:
  - 01^{st} to 04^{th} Floor: 800 mm x 800 mm
  - 05^{th} to 10^{th} floor: 750 mm x 750 mm
  - 11^{th} to 16^{th} floor: 600 mm x 600 mm
- Slab thickness: 150 mm
- Wall thickness:
  - External wall: 230 mm
  - Internal wall: 150 mm
- Steel bracing: ISMC 250



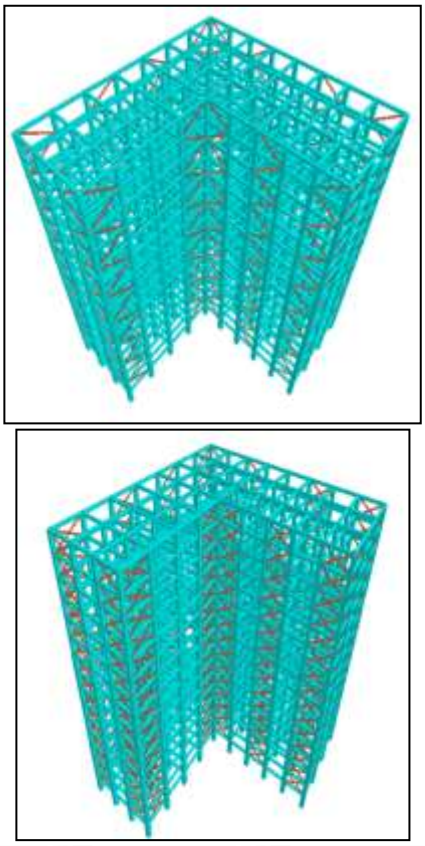
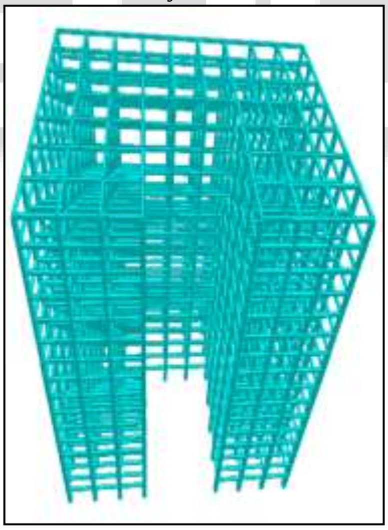


Fig. 2: L Shape model 1 with arrangement of Bracing system



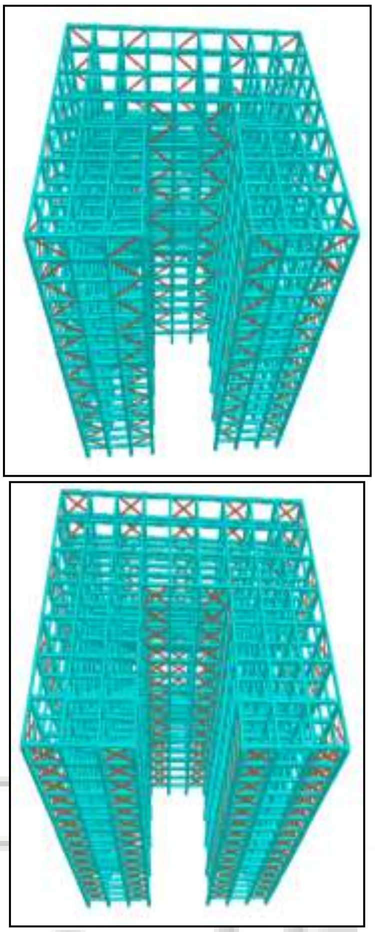
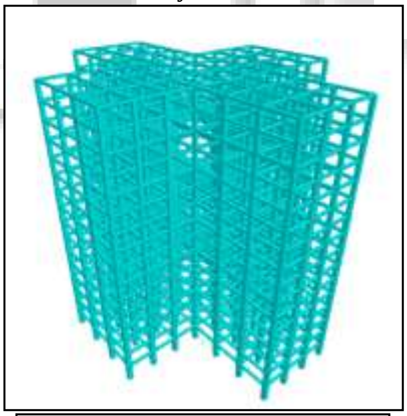
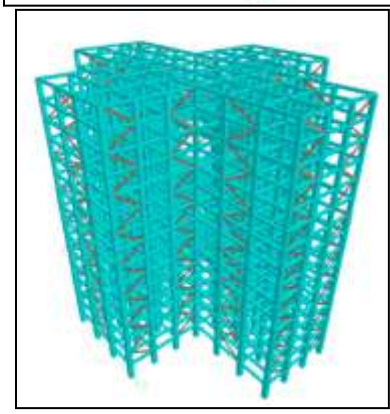


Fig. 3: C Shape model 1 with arrangement of Bracing system





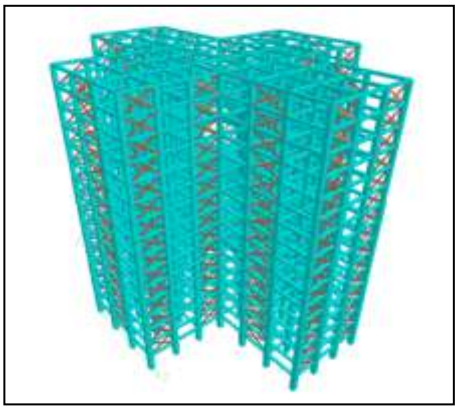
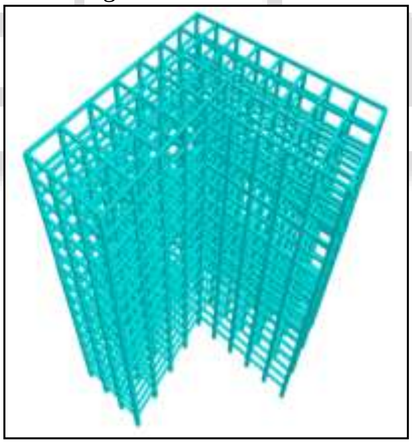


Fig. 4: Plus Shape model 1 with arrangement of Bracing system

b) Model 2:
- Type of building: commercial building
- Foundation or Plinth height: 3.2 m
- Beam Size: 500 mm x 500 mm
- Column Size:
  01st to 04th Floor: 900 mm x 900 mm
  05th to 10th floor: 800 mm x 800 mm
  11th to 16th floor: 700 mm x 700 mm
- Slab thickness: 150 mm
- Wall thickness:
  External wall: 230 mm
  Internal wall: 150 mm
- Steel bracing: ISMB 500



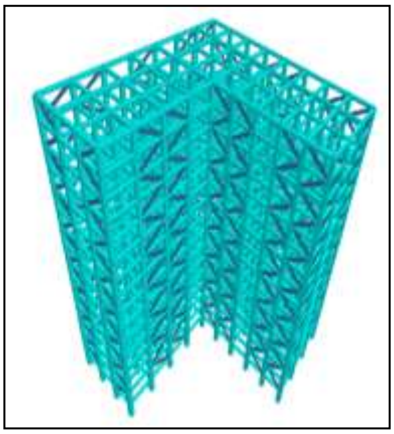


Fig. 5: L Shape model 2 with arrangement of Bracing system

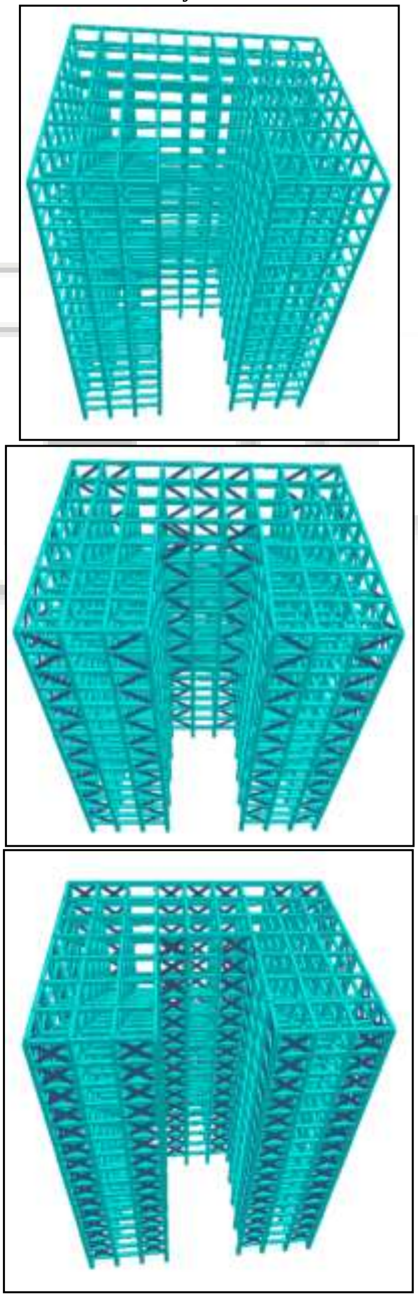


Fig. 6: C Shape model 2 with arrangement of Bracing system

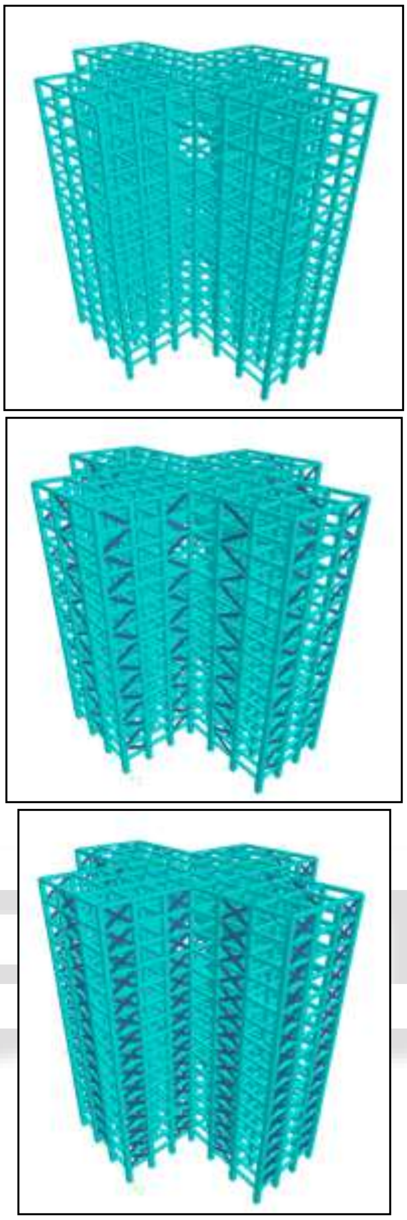


Fig. 7: Plus Shape model 2 with arrangement of Bracing system

2) *Earthquake Data:*

(Based on Indian seismic Code, IS 1893:2002)

- Seismic Zone: Zone IV (Table 2, IS1893(Part 1):2002)
- Seismic zone factor: 0.24 (Table 2, IS 1893(Part 1):2002)
- Response Reduction: Special RC Moment Resisting Frame (SMRF)
- (Table 7, IS 1893 (Part 1):2002)
- Importance Factor: 1.5 (Table 6, IS 1893(Part 1):2002)
- Type of Soil: Medium Soil (Fig. 2, IS 1893(Part 1):2002)
- Damping Ratio: 5% (Table 3, IS 1893(Part 1):2002)
- Natural Period: (cl. no.7.6.2, IS 1893(Part 1):2002
- Drift Factor: 0.004 x h = 0.2048

Shape / Direction	X direction (sec)	Z direction (sec)
L	0.728	0.711
C	0.778	0.627
Plus	0.687	0.627

Table 2: Natural Period

Fig. 8: Seismic Parameter

3) Material Data:

- Grade of Concrete: M25
- Grade of Steel: Fe500
- Density of Reinforced Concrete: 25 kN/m^3
- Density of Red Masonry: 20 kN/m^3

4) Earthquake Loading:

- Earthquake Load: In X and Z direction i.e. EQX and EQZ
- Dead Load:
- Self-weight: Automatically defined by software.
- Wall Load:
  External Wall: 20 x 1 x 0.23 x 3 = 13.8 ≈ 14 kN/m
  Internal Wall: 20 x 1 x 0.15 x 3 = 9 kN/m
  Parapet Wall: 20 x 1 x 0.23 x 1.2 = 5.52 kN/m
- Slab Load: 25 x 1 x 1 x 0.15 = 3.75 kN/m
- Floor Finish: 1 kN/m
- Live Load: 4 kN/m (Table 1, IS 875(Part 2): 1987)
- Roof Live Load: 2 kN/m (Table 8, IS 1893(Part 1):2002)
- Load Combination based on IS 1893:2002
  - 1.5 (DL + LL)
  - 1.2 (DL + LL ± EQX)
  - 1.2 (DL + LL ± EQZ)
  - 1.5 (DL ± EQX)
  - 1.5 (DL ± EQZ)
  - 0.9 DL ± 1.5 EQX
  - 0.9 DL ± 1.5 EQZ

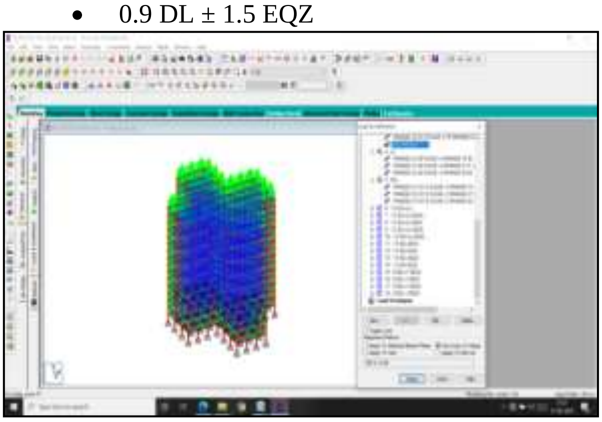


Fig. 9: Earthquake Loading Data

5) Analysis in STAAD.pro:

After computation of all of the above steps then final operation of analysis is carried out. The software studies the required data given and assumes some data automatically to analyze the structure.

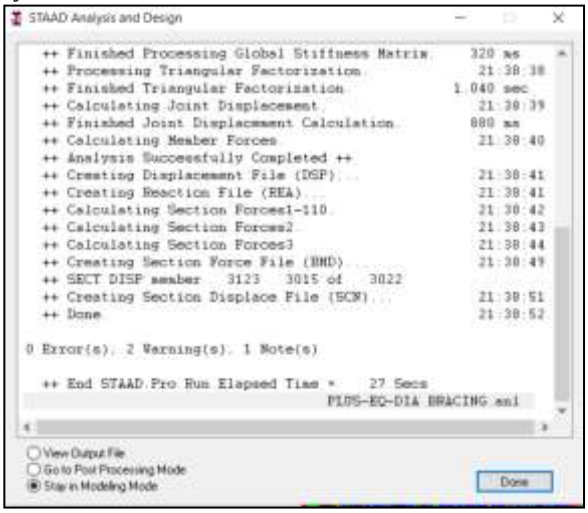


Fig. 10: STAAD Analysis

V. RESULT AND DISCUSSION

A. General:

G+15 storied building are seismic analysis with and without bracing system models for obtaining the following results. Later, results of braced and non-braced models are compared in term of displacement, storey drift, base shear and performance point.

B. Lateral Displacement:

It shows that provision of bracing system definitely reduces the lateral displacement of the structure as compared to structure without bracing system. The difference is clear from the table and chart given below.

Model No.	Shape/ Bracing	Without (mm)	Diagonal (mm)	X (mm)
Model 1	L	746.157	431.339	376.483
	C	676.644	415.354	364.829
	PLUS	763.707	427.471	249.528
Model 2	L	371.080	199.479	176.348
	C	331.333	197.274	178.214
	PLUS	376.284	219.540	134.976

Table 3: Comparison of lateral displacement in x-direction

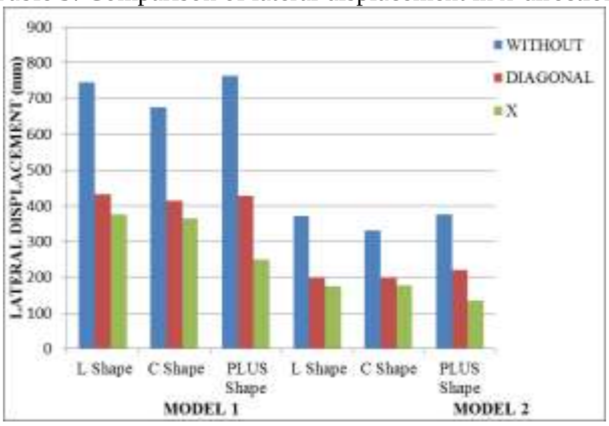
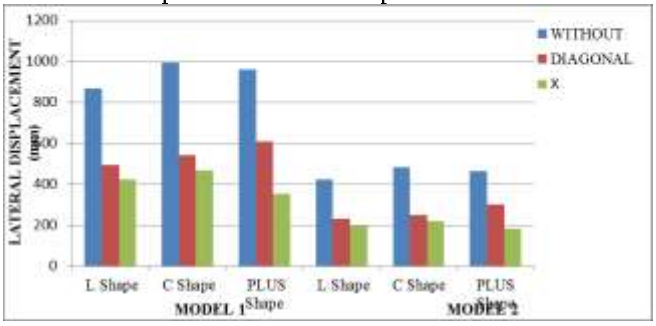


Chart 1: Comparison of lateral displacement in x-direction

Model No.	Shape/ Bracing	Without (mm)	Diagonal (mm)	X(mm)
Model 1	L	867.182	494.953	422.955
	C	991.693	543.104	466.051
	PLUS	959.602	609.704	354.014
Model 2	L	423.475	231.551	202.529
	C	482.350	248.790	219.381
	PLUS	464.899	302.432	183.597

Table 4: Comparison of lateral displacement in z-direction



Discussion said as follow:

1) The above chart shows that bare model have more displacement that model having bracing system.
2) Model 1 exceeds the permissible limit of displacement 204 mm as per IS 1893:2002. Hence we used another model 2 for analysis.
3) L shape model 1 shows 42.74% and 50.93% reduction in the displacement with diagonal and x type of bracing as compared bare model. Model 2 exhibits 45.10% and 52.05% reduction of displacement for the respective bracing system.
4) C shape model 1 shows 45.09% and 72.83% reduction in the displacement with diagonal and x type of bracing as compared bare model. Model 2 exhibits 48.24% and 54.27% reduction of displacement for the respective bracing system.
5) Plus shape model 1 shows 36.46% and 63.09% reduction in the displacement with diagonal and x type of bracing as compared bare model. Model 2 exhibits 34.92% and 60.36% reduction of displacement for the respective bracing system.

C. Storey Drift:

Storey drift is also reduced by the provision of the steel bracing like lateral displacement. The comparison of storey drift of braced and non-braced structure is shown in the following table.

Storey/Bracing/Model	L Shape					
	Without		Diagonal		X	
	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
0	0	0	0	0	0	0
1	1.6635	0.9078	1.1125	0.5586	0.9564	0.4878
2	3.8479	1.9957	2.1555	0.9035	1.6975	0.6919
3	5.0039	2.5046	2.5956	1.0276	2.0404	0.7948
4	5.5916	2.7333	2.8343	1.1024	2.2594	0.8687
5	5.9363	2.9208	2.9970	1.1821	2.4279	0.9454
6	6.0223	2.9403	3.0731	1.2143	2.5307	0.9917
7	5.9570	2.8951	3.0925	1.2347	2.5694	1.0250
8	5.7885	2.8057	3.0665	1.2362	2.6130	1.0454
9	5.5454	2.6804	3.0110	1.2263	2.6013	1.0518
10	5.2611	2.5279	2.9117	1.1945	2.5554	1.0425
11	5.0967	2.4378	2.8984	1.1935	2.5751	1.0526
12	4.4364	2.1488	2.6574	1.1110	2.4125	1.0020
13	3.7096	1.8169	2.3703	1.0131	2.1709	0.9283
14	2.8991	1.4379	2.0152	0.8756	1.9225	0.8247
15	2.0401	1.0269	1.5990	0.7161	1.5801	0.6908
16	1.2775	0.6513	1.1659	0.5345	1.2112	0.5409

Table 5. Comparison of storey drift in x-direction

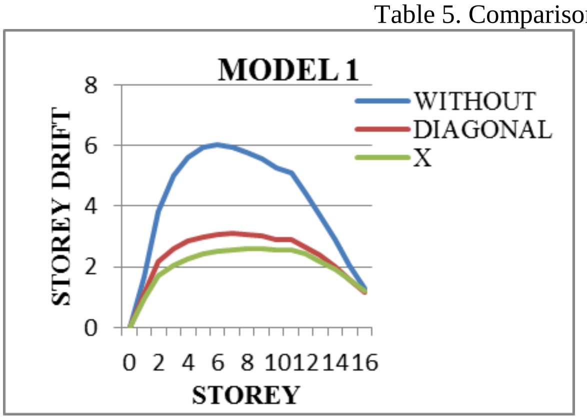


Chart 3: Comparison of storey drift in x-direction

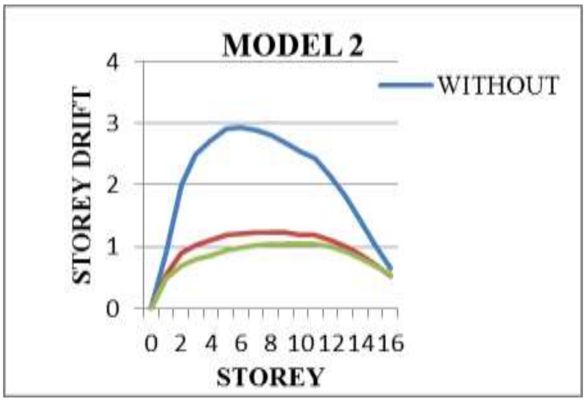


Chart 4: Comparison of storey drift in x-direction

Storey/Bracing/Model	L Shape					
	Without		Diagonal		X	
	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
0	0	0	0	0	0	0
1	1.8946	1.0317	1.2275	0.6448	1.0400	0.5538
2	4.4731	2.3216	2.4400	1.1222	1.8895	0.8672
3	5.9126	2.9623	2.9765	1.2996	2.2834	1.0043
4	6.6839	3.2669	3.2583	1.3951	2.5212	1.0893
5	7.1472	3.4993	3.4388	1.4817	2.6912	1.1723
6	7.2987	3.5372	3.5129	1.5164	2.7882	1.2183
7	7.2477	3.4871	3.5220	1.5250	2.8317	1.2489
8	7.0592	3.3787	3.4827	1.5211	2.8490	1.2646
9	6.7743	3.2252	3.4018	1.4933	2.8254	1.2641
10	6.4325	3.0354	3.2871	1.4511	2.7688	1.2459
11	6.1690	2.9009	3.23	1.4278	2.7650	1.2473
12	5.3475	2.5450	2.3586	1.3240	2.5408	1.1786
13	4.4604	2.14	2.6018	1.1857	2.3016	1.0829
14	3.4774	1.6823	2.1885	1.0169	2.0291	0.9516
15	2.4517	1.1929	1.7089	0.8062	1.6469	0.7831
16	1.5584	0.7536	1.2287	0.5901	1.2448	0.5963

Table 6. Comparison of storey drift in z-direction

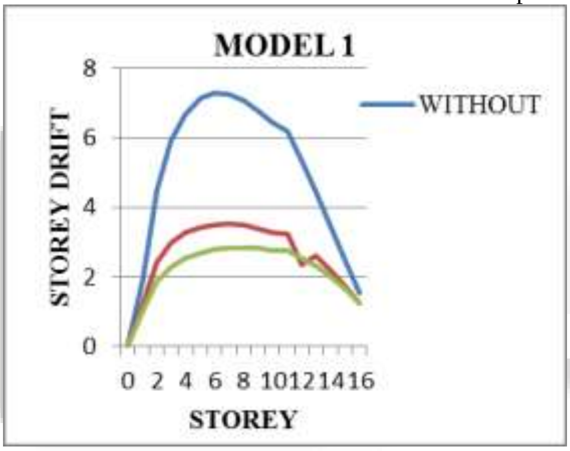


Chart 5: Comparison of storey drift in z-direction

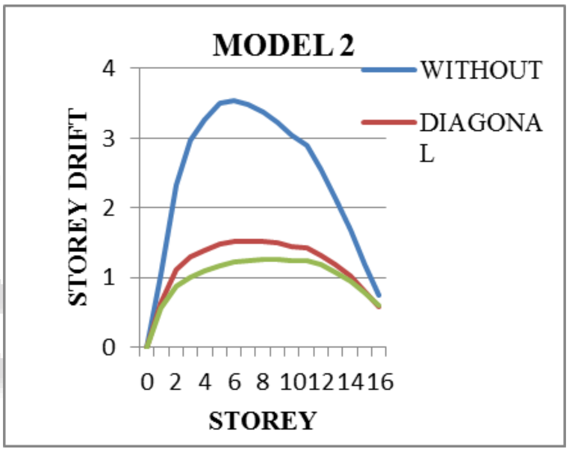


Chart 6: Comparison of storey drift in z-direction

Storey/Bracing/Model	C Shape					
	Without		Diagonal		X	
	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
0	0	0	0	0	0	0
1	1.5693	0.8551	1.0637	0.5591	0.9187	0.4930
2	3.6216	1.8743	2.0731	0.9489	1.16445	0.7509
3	4.7010	2.3466	2.5016	1.0954	1.9757	0.8758
4	5.2449	2.5563	2.7274	1.1802	2.1811	0.9609
5	5.5629	2.7292	2.8811	1.2687	2.3381	1.0495
6	5.6398	2.7441	2.9484	1.3058	2.4316	1.1010
7	5.5763	2.7000	2.9631	1.3244	2.4842	1.1359
8	5.4179	2.6155	2.9381	1.3252	2.5018	1.1545
9	5.1915	2.4963	2.8760	1.3083	2.4864	1.1563
10	4.9256	2.3562	2.4822	1.2720	2.4381	1.1398
11	4.7829	2.2761	2.4635	1.2650	2.4556	1.1463
12	4.1717	2.0081	2.3572	1.1747	2.2962	1.0834
13	3.4988	1.7004	2.2502	1.0618	2.0936	0.9981
14	2.7472	1.3433	1.9095	0.9175	1.8279	0.8831
15	1.9438	0.9661	1.5092	0.7429	1.5008	0.7351
16	1.2269	0.6117	1.0909	0.5503	1.1429	0.5706

Table 7. Comparison of storey drift in x-direction

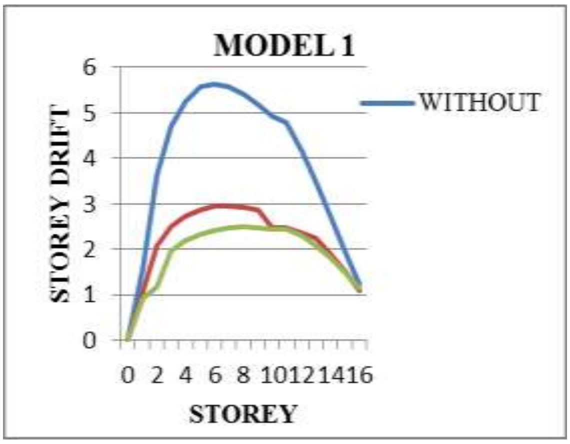


Chart 7: Comparison of storey drift in x-direction

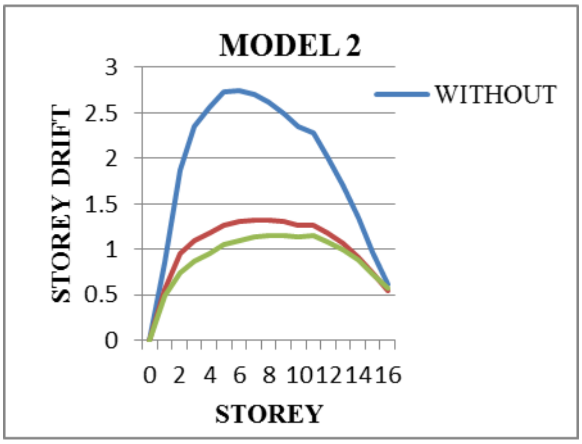


Chart 8: Comparison of storey drift in x direction

Storey/Bracing/Model	C Shape					
	Without		Diagonal		X	
	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
0	0	0	0	0	0	0
1	2.1796	1.1856	1.4084	0.7283	1.1946	0.6287
2	5.1416	2.6648	2.7979	1.2540	2.1702	0.9581
3	6.7920	3.3976	3.4074	1.4446	2.6176	1.1133
4	7.6749	3.7450	3.7274	1.5552	2.8829	1.2122
5	8.2056	4.0108	3.9246	1.6557	3.0706	1.3018
6	8.3793	4.0536	4.0026	1.6927	3.1748	1.3619
7	8.3225	3.9966	4.0074	1.7060	3.2255	1.3969
8	8.1095	3.8736	3.9571	1.6982	3.2331	1.4139
9	7.7871	3.6996	3.8603	1.6695	3.2013	1.4118
10	7.4004	3.4880	3.7250	1.6180	3.1324	1.3891
11	7.118	3.3361	3.6566	1.5954	3.1241	1.3877
12	6.1885	2.9333	3.3197	1.4728	2.9076	1.3088
13	5.1792	2.4750	2.9300	1.3211	2.6334	1.1989
14	4.0653	1.9565	2.4548	1.1375	2.2759	1.0512
15	2.8984	1.4001	1.9061	0.8960	1.8393	0.8635
16	1.8698	0.8948	1.3586	0.6518	1.3801	0.6321

Table 8. Comparison of storey drift in z-direction

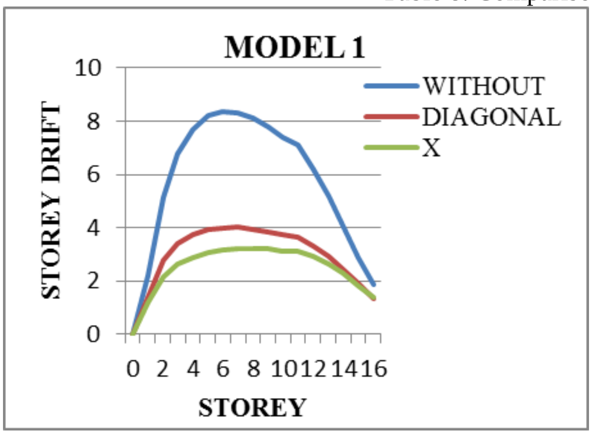


Chart 9: Comparison of storey drift in z direction

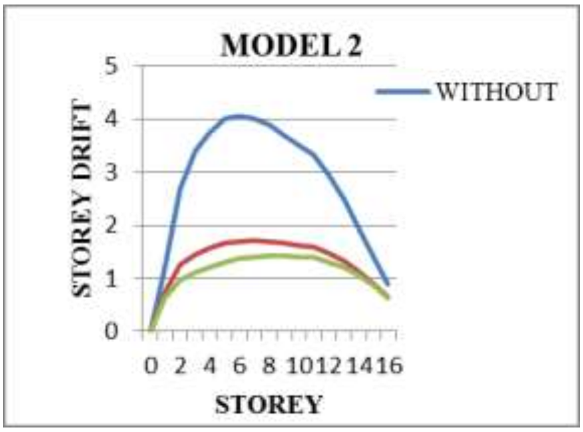


Chart 10: Comparison of storey drift in z direction

0Storey/Bracing/Model	PLUS Shape					
	Without		Diagonal		X	
	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
0	0	0	0	0	0	0
1	1.7904	0.9761	1.1652	0.6494	0.6611	0.3826
2	4.1418	2.1458	2.2290	1.1243	1.1615	0.6013
3	5.3872	2.6930	2.6689	1.3038	1.3941	0.7158
4	6.0200	2.9389	2.9106	1.4185	1.5537	0.8019
5	6.3922	3.1405	3.0792	1.5349	1.6644	0.8804
6	6.4877	3.1617	3.1626	1.5989	1.7373	0.9324
7	6.4199	3.1137	3.1890	1.6309	1.7846	0.9710
8	6.2414	3.0185	3.1761	1.6464	1.8076	0.9940
9	5.9842	2.88753	3.1211	1.6327	1.8071	1.0016
10	5.6807	2.7230	3.0324	1.5984	1.7820	1.0014
11	5.5122	2.6294	3.0214	1.5944	1.8040	0.9924
12	4.8109	2.3223	2.7868	1.4943	1.7032	0.9527
13	4.0389	1.9696	2.5027	1.3624	1.5678	0.8844
14	3.1773	1.5667	2.1474	1.1942	1.3837	0.7906
15	2.2613	1.1287	1.1237	0.9875	1.3525	0.6711
16	1.4388	0.7240	1.1755	0.7554	0.8970	0.5339

Table 9. Comparison of storey drift in x-direction

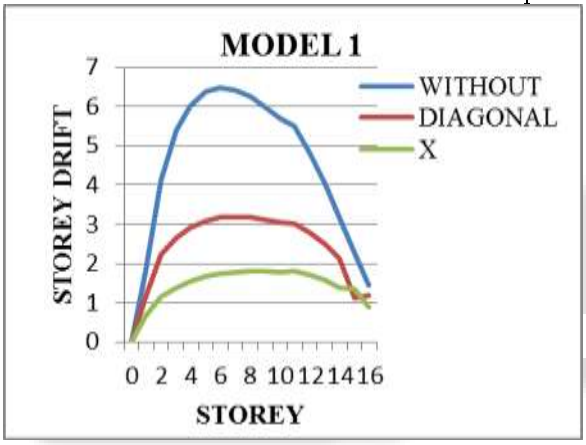


Chart 11: Comparison of storey drift in x-direction

Chart 12: Comparison of storey drift in x direction

Storey/Bracing/Model	PLUS Shape					
	Without		Diagonal		X	
	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
0	0	0	0	0	0	0
1	2.1549	1.1718	1.5745	0.8597	0.9080	0.5055
2	5.0759	2.6289	3.2967	1.6548	1.7793	0.9039
3	6.6966	3.3467	4.0778	1.9596	2.1670	1.0714
4	7.5595	3.6847	4.4671	2.1142	2.3809	1.1718
5	8.0760	3.9433	4.7046	2.2619	2.5336	1.2752
6	8.2406	3.9816	4.7891	2.3161	2.6163	1.3338
7	8.1798	3.9228	4.7827	2.3341	2.6338	1.3702
8	7.9664	3.7996	4.7084	2.3196	2.6545	1.3858
9	7.6463	3.6268	4.5781	2.2736	2.6214	1.3800
10	7.2633	3.4172	4.4014	2.1947	2.5571	1.3520
11	6.9818	3.2683	4.3141	2.1608	2.5474	1.3473
12	6.0719	2.8711	3.8954	1.9857	2.3645	1.2644
13	5.0780	2.4194	3.4261	1.7783	2.1442	1.1596
14	3.9808	1.9085	2.8678	1.5236	1.8642	1.0240
15	2.8304	1.3599	2.2259	1.2198	1.5234	0.8547
16	1.8149	0.8610	1.5744	0.8845	1.1468	0.6539

Table 10. Comparison of storey drift in z-direction

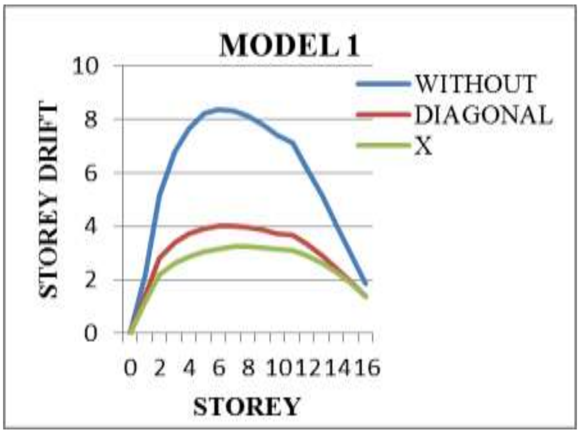


Chart 13: Comparison of storey drift in z-direction

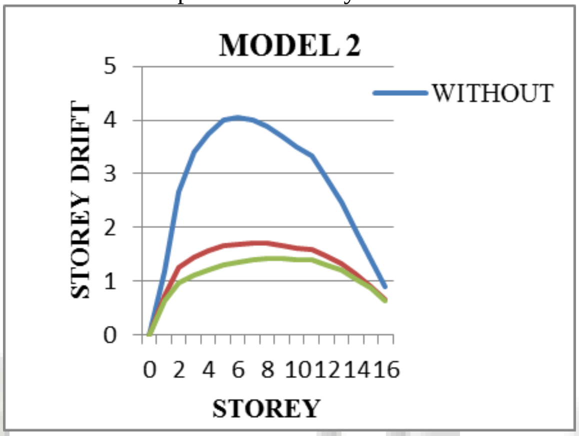


Chart 14: Comparison of storey drift in z-direction

Discussion said as follow:

1) From the above chart we can say that storey drift is negligible at base, minimum at top and maximum at centre of the structure.
2) In L shape building there is 51.74% reduction in storey drift for without and diagonal type of bracing and 60.94% for without and x type of bracing for model 1. For model 2 the percentage is 57.12% and 64.26%.
3) In C shape building there is 52.17% reduction in storey drift for without and diagonal type of bracing and 61.41% for without and x type of bracing for model 1. For model 2 the percentage is 57.85% and 64.74%
4) In plus shape building there is 41.88% reduction in storey drift for without and diagonal type of bracing and 67.28% for without and x type of bracing for model 1. For model 2 the percentage is 41.37% and 65.19%

D. Base Shear:

There is a slight increase in base shear due to provision of bracing system. This comparison is mentioned in the following table.

Model No.	Shape/ Bracing	Without (kN)	Diagonal (kN)	X (kN)
Model 1	L	19227.89	19357.32	19389.91
	C	25392.55	25433.85	25475.14
	PLUS	25465.15	25501.03	17024.52
Model 2	L	20826.17	21036.93	21150.84
	C	27480.72	27618.77	27756.82
	PLUS	27563.41	27665.54	18511.53

Table 11: Comparison of base shear in x-direction

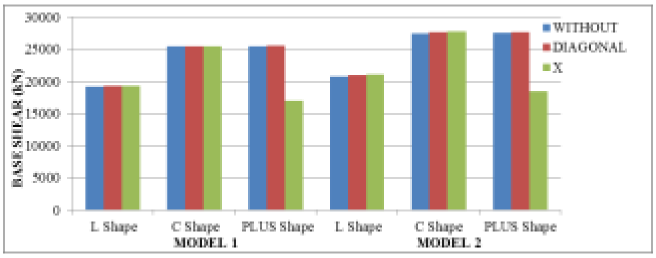


Chart 15: Comparison of base shear in x-direction

Model No.	Shape/ Bracing	Without (kN)	Diagonal (kN)	X (kN)
Model 1	L	19687.63	19820.15	19853.52
	C	31507.82	31559.06	31610.31
	PLUS	27902.00	27941.32	18653.66
Model 2	L	21324.12	21539.92	21656.55
	C	34098.89	34270.18	34441.48
	PLUS	30201.05	30312.96	20282.97

Table 12: Comparison of base shear in z-direction

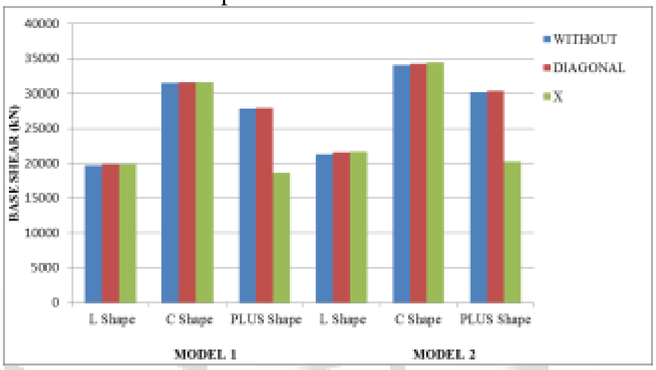


Chart 16: Comparison of base shear in z-direction

Discussion said as follow:

1) As per above mentioned chart, the L and C shape model 1 define 0.66%, 0.16% and 0.83%, 0.32% increase in base shear when diagonal and x bracing provided respectively as compared to bare model 1. For the plus shape model 1 increase in base shear is 0.16% for diagonal bracing whereas 33.14% decreased for x bracing as compared to bare model 1.
2) As per above mentioned chart, the L and C shape model 2 define 1%, 0.50% and 1.53%, 0.99% increase in base shear when diagonal and x bracing provided respectively as compared to bare model 2. For the plus shape model 2 increase in base shear is 0.36% for diagonal bracing whereas 32.84% decreased for x bracing as compared to bare model 2.

VI. CONCLUSION

The analysis of G+15 irregular configurations of structures with the application of seismic as well as wind forces along with bare and bracings give the following conclusions:

1) The irregularity in the geometry of structure affects the behavior and performance of structure.
2) The C shape of structure shows the maximum lateral displacement than L and Plus shape of structure under seismic activity.
3) -The storey drift is maximum in C shape of structure as compared to L and Plus shape of structure when subjected to seismic activity.

4) Also C shape of structure shows the maximum base shear than L and Plus shape of structure.
5) The bracing especially x type of bracing reduces more lateral displacement and storey drift than diagonal bracing system.
6) In plus shape of structure diagonal bracing increases base shear and vise versa in case of x type of bracing. But L and C shape of structures shows increase in base shear for both type of bracing as compare to bare models.
7) In all x type of bracing is most effective and feasible bracing system than other type of bracing system.
8) The structure provided with economical properties of structural members along with suitable size and arrangement of steel bracing system proves more economical and resists seismic forces more effectively.
9) The provision of bracing system to structure subjected under wind forces increases the lateral displacement of it.
10) The regular geometry structure is more stable than irregular geometry structure under seismic activities.

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