International Journal of Research in Engineering and Science (IJRES)
ISSN (Online): 2320-9364, ISSN (Print): 2320-9356
www.ijres.org Volume 9 Issue 7 ǁ 2021 ǁ PP. 01-10

Comparative Study of Steel Bracing and Its Effects on Irregular Building Under Wind Load

Pattewar Manik Hemant[1], Prof. K. S. Upase[2]
[1.] *Student M.tech structure, M. S. Bidve college of Engg. Latur-413512*
[2.] *Associate Professor, M.tech structure, M. S. Bidve college of Engg. Latur-413512*

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. The wind load is an integral part for such a tall buildings. In this comparative study we are going to analysis a high rise building with wind load. We are going to use IS 875(part 3):1987 with wind speed 39 m/s for a sixteen storied building (G+15).
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 wind analysis is displacement. This parameter can be achieved with the help of bracing systems. Bracing is useful to resist lateral displacement 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 system
Keywords: *RCC Framed structure, Bracings, Wind Analysis, Lateral displacement.*

Date of Submission: 06-07-2021 Date of acceptance: 19-07-2021

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.

Wind is also major parameter causing lateral forces of high rise building. So it is necessary to take in account the wind speed in that area, so as to reduce lateral forces on tall building occurring due to wind. Also, structure higher than 15m must be designed for the local wind speed according to Indian Standards.

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

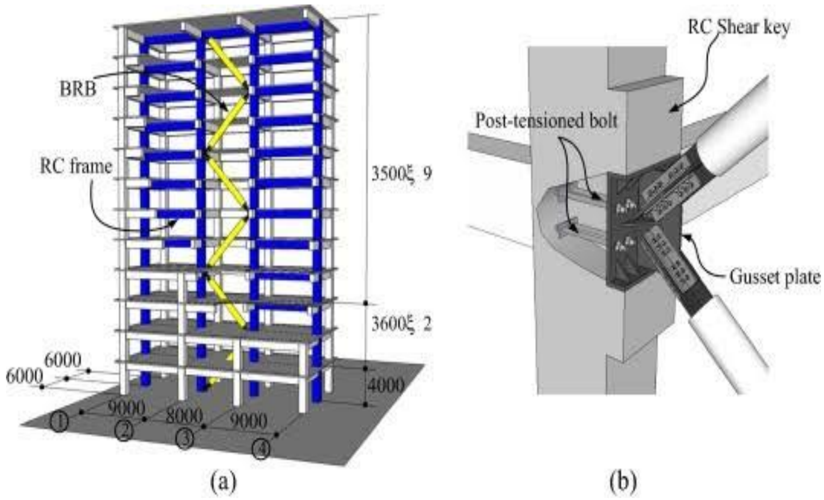

Fig.1. Arrangement and Joint between RCC structure and Steel Bracing

II. LITERATURE REVIEW

2.1 General:

Several researchers studied the effects on irregular shape building by using steel bracing in high rise reinforced cement concrete structures. A brief review of previous studies on effect of use of steel bracing as a retrofitting structure on wind behavior of structures is presented in this section. Also past efforts mostly closely related to the need of the present work is shown.

2.2 Literature Survey:

1 **Mayank Walia et al. (2019)** (1) 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.

2 **K. Anitha et al. (2018)** (2) 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.

3 **Amol S. Rajas et al. (2016)** (3) analyzed high rise regular type of buildings (G+19) with difference bracing system under the influence of wind load. They studied X, V, diagonal and chevron bracing at different locations by using STAAD Pro V8i for shear force and bending moment parameters. As per IS 456-2000 for reinforced concrete design and IS 800- 2007 for steel design of bracing elements. They assumed the wind speed 44 m/s. They concluded that chevron bracing proves to be most effective among other bracing systems in reduction of bending moment by 34.2% in y direction and 37.7% in z direction and also mentioned that provision of bracing system can be effectively improve the performance of the structure with negligible increase dead load on the structure.

4 **K. S. K. Karthik Reddy et al. (2015)** (4) 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.

5 **Nitin N. Shinde and R. M. Phuke (2013)** (5) 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

3.1 Introduction:

Force Based analysis a traditional approach to wind analysis of a building. Using the wind analysis is determined and the member is designed to withstand these forces. In this approach, there is measure of the lateral displacement of building under the design forces.

3.2 Wind Analysis:

Buildings are subjected to horizontal load due to wind pressure acting on the buildings. Wind load is calculated as per IS 875(Part 3):1987. The horizontal wind pressures act on vertical external walls and exposed area of the buildings. Some of the pressure acting on exposed surfaces of structural walls and columns is directly resisted by bending of these members. The infill walls act as vertical plate supported at top and bottom by floor beams, thus transferring the loads at slab level. The parapet wall is at the terrace transfers the wind loads to the surface slab by cantilever action. For simplicity, the wind loads acting on exposed surfaces of a given storey are idealized to be supported by upper and lower floors.

3.2.1 Design Wind Speed (V_z):

The basic wind speed map of India is applicable to 10m height of building above mean ground level for different zones of country. Basic wind speed is based on peak gust velocity averaged over a short time interval of about 3 seconds and corresponds to mean height above ground level in an open terrain (Category 2). Basic wind speeds presented in map have been worked out for 50 year return period. Basic wind speed for some important cities/town is also given in Appendix A and shall be modified to include the following effect to get design wind velocity at height (V_z) for chosen structure:

a. Risk level.
b. Terrain roughness, height and size of structure and
c. Local topography.

It can be mathematically expressed as follows;

$$V_z = V_b \times k_1 \times k_2 \times k_3$$

Where,

V_z = Design wind speed at height z in m/s
k_1 = Probability factor (risk coefficient)
k_2 = Terrain, height and structure size factor
k_3 = Topography factor

3.2.1.1 Basic wind speed (Appendix A of IS 875.Part 3-1987):

APPENDIX A

(*Clause* 5.2)

BASIC WIND SPEED AT 10 m HEIGHT FOR SOME IMPORTANT CITIES/TOWNS

City/Town	*Basic Wind Speed* (m/s)	*City/Town*	*Basic Wind Speed* (m/s)
Agra	47	Jhansi	47
Ahmadabad	39	Jodhpur	47
Ajmer	47	Kanpur	47
Almora	47	Kohima	44
Amritsar	47	Kurnool	39
Asansol	47	Lakshadweep	39
Aurangabad	39	Lucknow	47
Bahraich	47	Ludhiana	47
Bangalore	33	Madras	50
Barauni	47	Madurai	39
Bareilly	47	Mandi	39
Bhatinda	47	Mangalore	39
Bhilai	39	Moradabad	47
Bhopal	39	Mysore	33
Bhubaneshwar	50	Nagpur	44
Bhuj	50	Nainital	47
Bikaner	47	Nasik	39
Bokaro	47	Nellore	50
Bombay	44	Panjim	39
Calcutta	50	Patiala	47
Calicut	39	Patna	47
Chandigarh	47	Pondicherry	50
Coimbatore	39	Port Blair	44
Cuttack	50	Pune	39
Darbhanga	55	Raipur	39
Darjeeling	47	Rajkot	39
Dehra Dun	47	Ranchi	39
Delhi	47	Roorkee	39
Durgapur	47	Rourkela	39
Gangtok	47	Simla	39
Gauhati	50	Srinagar	39
Gaya	39	Surat	44
Gorakhpur	47	Tiruchchirrappalli	47
Hyderabad	44	Trivandrum	39
Imphal	47	Udaipur	47
Jabalpur	47	Vadodara	44
Jaipur	47	Varanasi	47
Jamshedpur	47	Vijaywada	50
		Visakhapatnam	50

Fig 2. Basic Wind Speed

3.2.1.2 Risk Coefficient (IS 875.Part 3-1987):

The risk coefficient k_1 takes in to account the degree of reliability required and the expected life of structure.

a. All general buildings (Design life 50 years)
b. Temporary sheds (Design life 5 years)
c. Less important buildings (Design life 25 years)
d. Important buildings (Design life 100 years)

Class of Structure	Mean Probable Design Life of Structure in Years	k_1 Factor for Basic Wind Speed (m/s) of					
		33	39	44	47	50	55
All general buildings and structures	50	1·0	1·0	1·0	1·0	1·0	1·0
Temporary sheds, structures such as those used during construction operations (for example, formwork and falsework), structures during construction stages and boundary walls	5	0·82	0·76	0·73	0·71	0·70	0·67
Buildings and structures presenting a low degree of hazard to life and property in the event of failure, such as isolated towers in wooded areas, farm buildings other than residential buildings	25	0·94	0·92	0·91	0·90	0·90	0·89
Important buildings and structures such as hospitals communication buildings / towers, power plant structures	100	1·05	1·06	1·07	1·07	1·08	1·08

... which take account of the degree of reliability requ

Fig 3. Risk Coefficients For Different Classes Of Structures In Different Wind Speed Zones

3.2.1.3 Terrain, height and structure size factor (IS 875.Part 3-1987):

It depends of terrain category and building class/size of structure.

Four terrain categories are specified by the code defending on the availability of obstruction to the flow of wind.

Category 1: Refers to no obstruction available to the building.
Category 2: Refers to open terrain with scattered obstruction of 1.5m to 10m height.
Category 3: Refers to areas of closed spaced buildings of height up to 10m.
Category 4: Refers to area with highly closed building of large heights.

Class A: Maximum of l, b, h < 20m
Class B: Maximum of l, b, h – 20m to 50m
Class C: Maximum of l, b, h > 50m

TABLE 2 k_2 FACTORS TO OBTAIN DESIGN WIND SPEED VARIATION WITH HEIGHT IN DIFFERENT TERRAINS FOR DIFFERENT CLASSES OF BUILDINGS/STRUCTURES

(*Clause* 5.3.2.2)

Height	Terrain Category 1 Class			Terrain Category 2 Class			Terrain Category 3 Class			Terrain Category 4 Class		
m	A	B	C	A	B	C	A	B	C	A	B	C
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
10	1·05	1·03	0·99	1·00	0·98	0·93	0·91	0·88	0·82	0·80	0·76	0·67
15	1·09	1·07	1·03	1·05	1·02	0·97	0·97	0·94	0·87	0·80	0·76	0·67
20	1·12	1·10	1·06	1·07	1·05	1·00	1·01	0·98	0·91	0·80	0·76	0·67
30	1·15	1·13	1·09	1·12	1·10	1·04	1·06	1·03	0·96	0·97	0·93	0·83
50	1·20	1·18	1·14	1·17	1·15	1·10	1·12	1·09	1·02	1·10	1·05	0·95
100	1·26	1·24	1·20	1·24	1·22	1·17	1·20	1·17	1·10	1·20	1·15	1·05
150	1·30	1·28	1·24	1·28	1·25	1·21	1·24	1·21	1·15	1·24	1·20	1·10
200	1·32	1·30	1·26	1·30	1·28	1·24	1·27	1·24	1·18	1·27	1·22	1·13
250	1·34	1·32	1·28	1·32	1·31	1·26	1·29	1·26	1·20	1·28	1·24	1·16
300	1·35	1·34	1·30	1·34	1 32	1·28	1·31	1·28	1·22	1·30	1·26	1·17
350	1·37	1·35	1·31	1·36	1·34	1·29	1·32	1·30	1·24	1·31	1·27	1·19
400	1·38	1·36	1·32	1·37	1·35	1·30	1·34	1·31	1·25	1·32	1·28	1·20
459	1·39	1·37	1·33	1·38	1·36	1·31	1·35	1·32	1·26	1·33	1·29	1·21
500	1·40	1·38	1·34	1·39	1·37	1·32	1·36	1·33	1·28	1·34	1·30	1·22

... of Class A, Class B and Class C structures.

Fig 4. k_2 Factors to obtain design wind speed variation with height in different terrain for different classes of buildings/structures

3.2.1.4 Topography Factor (IS 875.Part3-1987):

It depends on the topography i.e. hill region, cliffs and ridges.

If the upward slope $0 \leq 3^0$, value of k_3 shall be taken 1.0.
For 0 > 3, value of k_3 lies between 1.0 to 1.36.

3.2.2 Design Wind Pressure (P_z):

The design wind pressure at any height above mean ground level shall be obtained by the following relationship between wind pressure and wind velocity:

$$P_z = 0.6 \text{ x } V_z^2$$

Where,

P_z = Design wind pressure in N/m^2 at height z and
V_z = Design wind speed velocity in m/s at height z.

IV. MODELLING AND ANALYSIS

4.1 General:

In the present study we are investigating the behavior of different shapes of irregular high rise structure subjected to wind 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.

4.2 Description of structure:
4.2.1 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.

Table 1. Different Models for Present Study

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

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

Model:
- ✓ Type of building: commercial building
- ✓ Foundation or Plinth height: 3.2 m
- ✓ Beam Size: 400 mm x 400 mm
- ✓ Column Size:

01st to 04th Floor: 800 mm x 800 mm
05th to 10th floor: 750 mm x 750 mm
11th to 16th floor: 600 mm x 600 mm
- ✓ Slab thickness: 150 mm
- ✓ Wall thickness:

External wall: 230 mm
Internal wall: 150 mm
- ✓ Steel bracing: ISMC 250

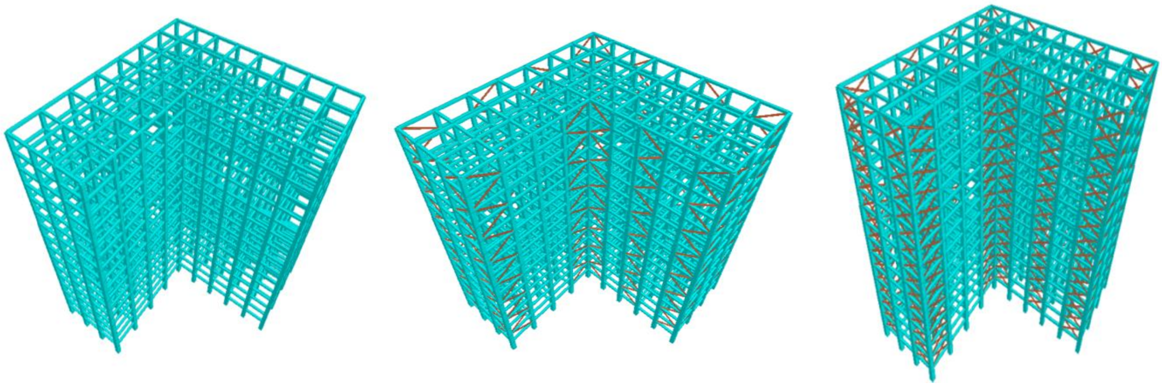

Fig 5. L Shape model 1 with arranement of Bracing system

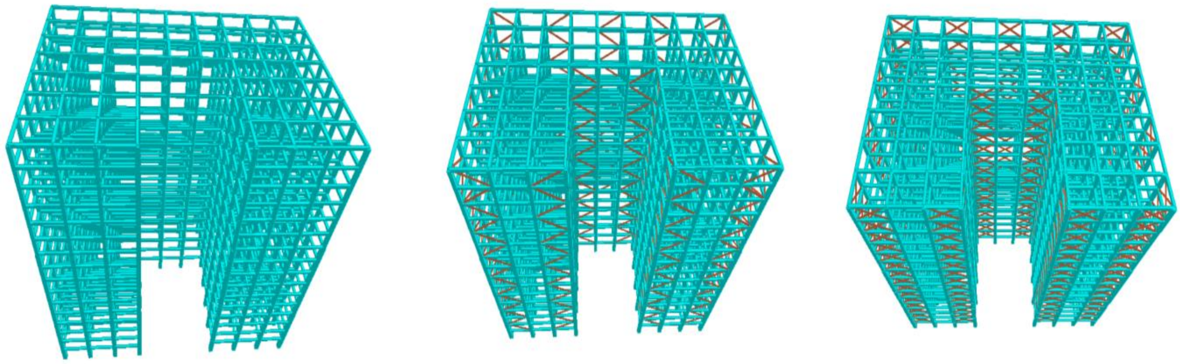

Fig 6. C Shape model 1 with arrangement of Bracing system

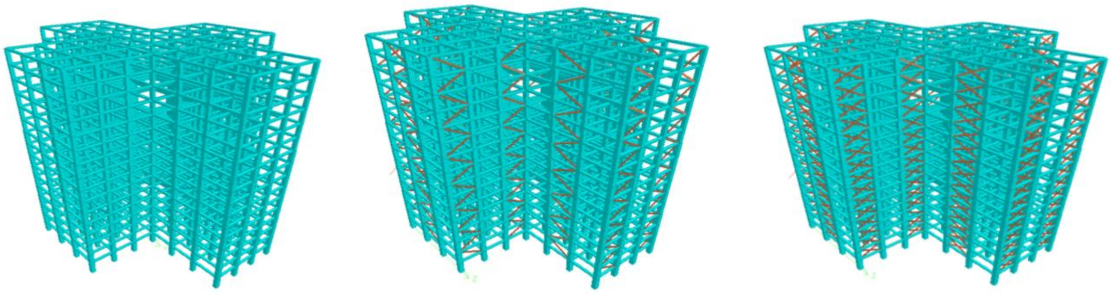

Fig 7. Plus Shape model 1 with arrangement of Bracing system

4.2.2 Wind Data:
(Based on Indian Wind Code, IS 875 (Part 3):2002)
- ✓ Basic Wind Speed (V_b): 39m/s
- ✓ Design Wind Speed (V_z): V_b x k_1 x k_2 x k_3
- Terrain Categories: Category 1
- Class of Structure: Class C
- Probability Factor (k_1): 1.06 (Table 1, IS 875 (Part 3): 1987)
- Structure Size Factor (k_2): (Table 2, IS 875 (Part 3): 1987)
- Topography Factor (k_3): 1 (Table 3, IS 875 (Part 3): 1987)
- ✓ Design Wind Pressure (p_z): 0.6 $(V_z)^2$

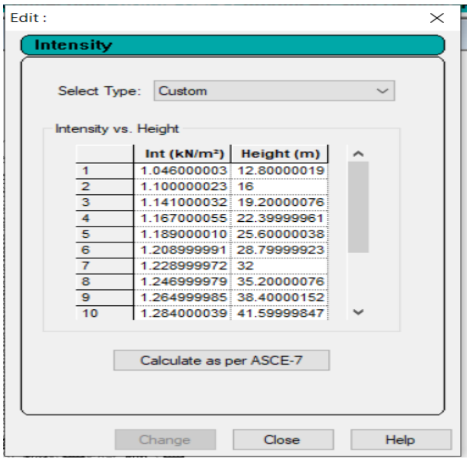

Fig 11. Wind Parameter

4.2.3 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

4.2.4 Loading Data:

4.2.4.1 Wind Loading:

- ✓ Wind Load:

Four Load cases Formed for Wind Analysis in STAAD.pro.V8i as mentioned below,
Wind in ± X Direction
Wind in ± Z Direction

- ✓ Wind Factor: ±1
- ✓ 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 (cl. no. 3.2.1, IS 875(Part 2):1987)
- ✓ Load Combination based on IS 875(Part 3): 1987
- DL+LL
- 1.2 (DL+LL+WL)

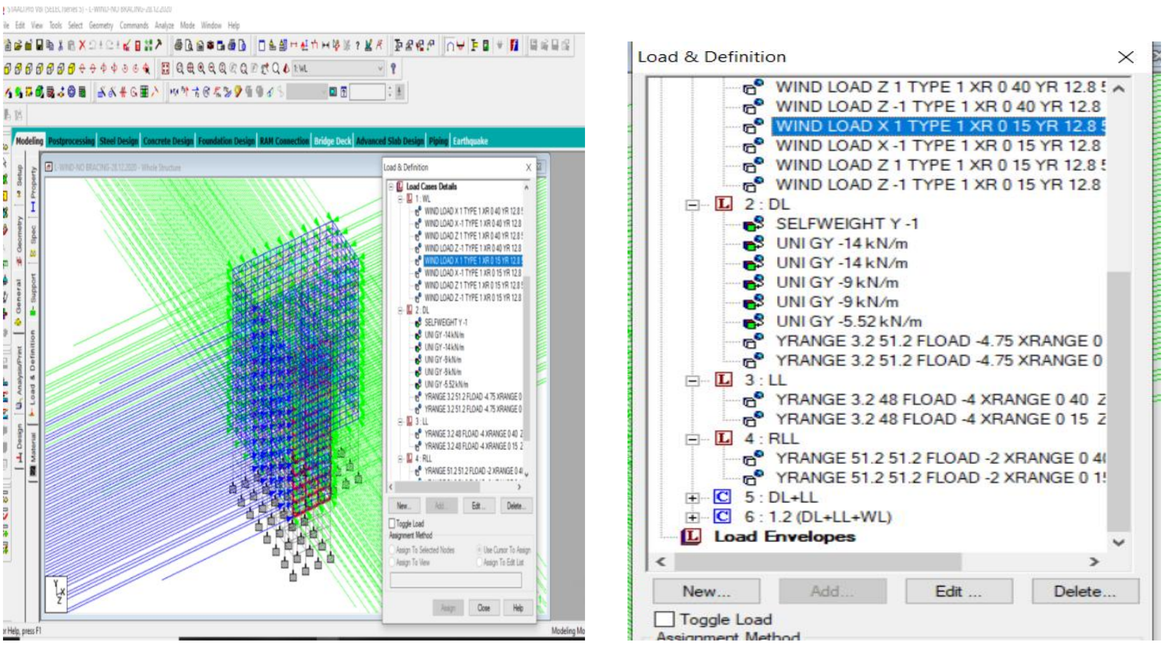

Fig 12. Wind Loading Data

4.2.5 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.

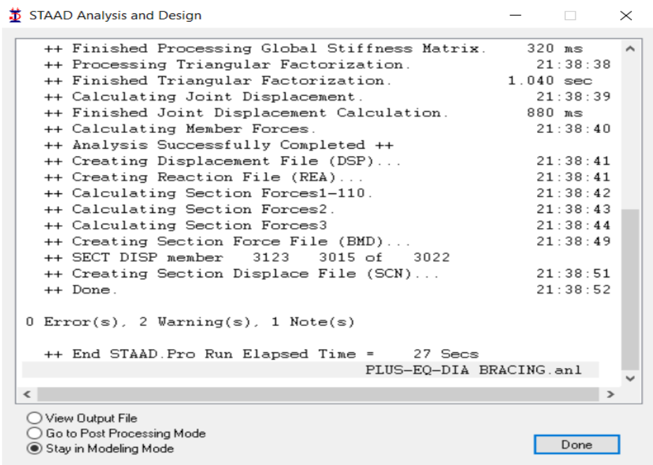

Fig 13. STAAD Analysis

V. RESULT AND DISCUSSION

5.1. General:

G+15 storied building are wind 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 and performance point.

5.2 Wind analysis:

Lateral Displacement:

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

Table 2. Comparison of lateral displacement in x direction

Model No.	Shape/Bracing	Without (mm)	Diagonal (mm)	X(mm)
Model 1	L	1.458	4.425	5.422
	C	1.646	5.043	7.058
	PLUS	0.465	0.768	1.012

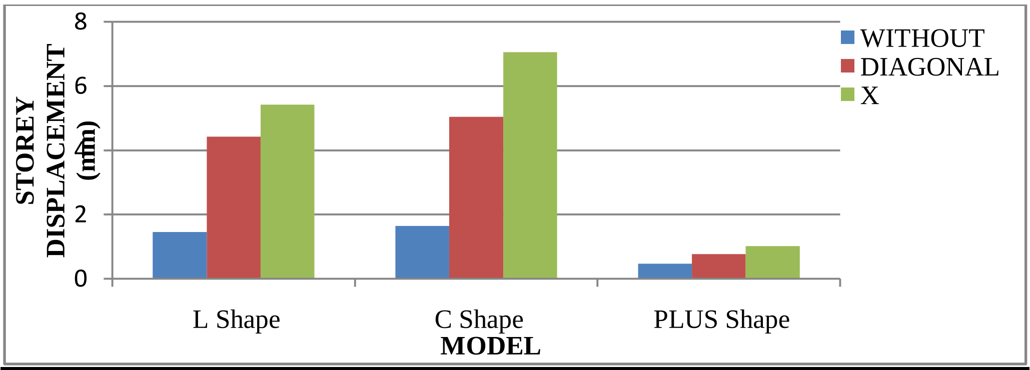

Chart 1. Comparison of lateral displacement in wind analysis (x direction)

Table 3. Comparison of lateral displacement in z direction

Model No.	Shape/Bracing	Without (mm)	Diagonal (mm)	X(mm)
Model 1	L	1.192	4.441	6.982
	C	0.679	1.268	2.463
	PLUS	0.603	0.628	0.862

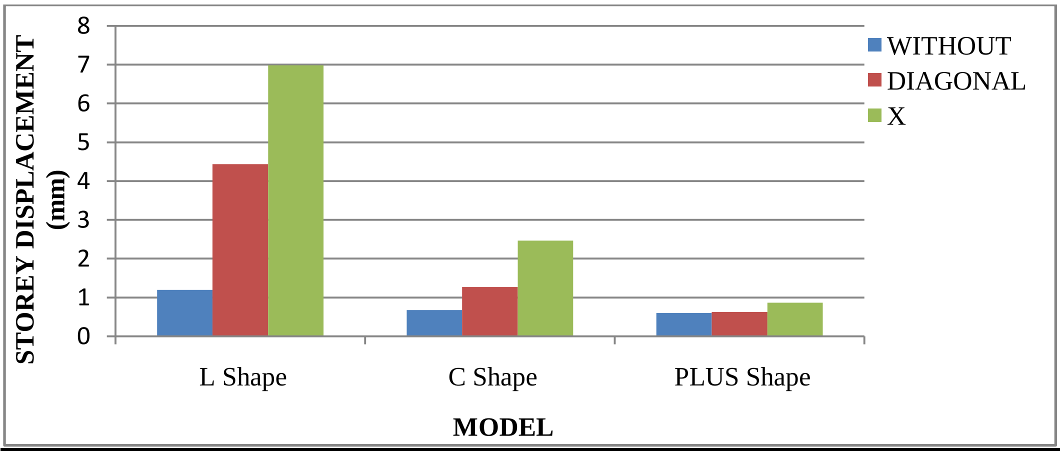

Chart 2. Comparison of lateral displacement in wind analysis (z direction)

Discussion said as follow:

1. The above chart states that the maximum displacement 7.058 mm is below the permissible limit of 204 mm as per Indian Standards i.e. negligible.
2. Also as we provide bracing system to the models, the displacement also increases.

VI. CONCLUSION

The analysis of G+15 irregular configurations of structures with the application of 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 provision of bracing system to structure subjected under wind forces increases the lateral displacement of it.

3 The wind analysis of any shape of irregular shapes of structure, there is no need to provide a bracing system as all parameters are in permissible limit as per Indian Standards.

4 The regular geometry structure is more stable than irregular geometry structure under wind activities.

REFERENCES

[1]. Mayank Walia, Nirbhay Thakur, Nitish Kumar Sharma, "Wind analysis of composite building with bracing system", IJITEE, ISSN: 2278-3075, Issue 8, Volume 8, June 2019.

[2]. K. Anitha, M. Santhiya, "Comparative study of different framing system for multistory composite building with irregular geometry", IJPAM, ISSN: 1314-3395, Issue 12, Volume 119, 2018.

[3]. Amol S. Rajas, "Wind analysis of high rise building with different bracing system", IJARSET, ISSN: 2350-0328, Issue 4, Volume 3, April 2016.

[4]. K. S. K. Karthik Reddy, Sai Kala Kondepudi, Harsha Kaviti, " A comparative study on behavior of multistoried building with different types and arrangement of bracing system", IJSTE, ISSN: 2349-784X, Issue 2, Volume 2, August 2015.

[5]. Nitin N. Shine and R. M. Phuke, "Analytical study of braced unsymmetrical RCC Building", IJSR, ISSN (online): 2319-7064, Issue 5, Volume 4, May 2015.
[6]. Lovneesh Sharma, Sandeep Nasier, "Dynamic seismic evaluation of irregular multistory building using bracing in zone 4 as per IS: 1893-2016", IJITEE, ISSN: 2278-3075, Issue 7, Volume 8, May 2019.
[7]. Masood Ahmed Shariff, Owais M., Rachana C., Vinu S., Ashish Dubay B., " Seismic analysis of multistory building with bracing using ETABS", IJIRSET, ISSN: 2319-8753, Issue 5, Volume 8, May 2019.
[8]. Karthik K. M., Vidyashree D., "Effect of steel bracing on vertically irregular R.C.C building frames under seismic loads", IJRET, pISSN: 2319-1163, Issue 6, Volume 4, June 2015.
[9]. IS 800:1984, Indian Standard Code of Practice for General Construction in Steel (first revision).
[10]. IS 875 (Part 1) "code of practice for design loads (other than earthquake) for building and structure", Dead Load, New Delhi, 1987.
[11]. IS 875 (Part 2) "code of practice for design loads (other than earthquake) for building and structure", Imposed Load, New Delhi, 1987.
[12]. IS 875 (Part 3) "code of practice for design loads (other than earthquake) for building and structure", Wind Load, New Delhi, 1987.