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ANALYSIS OF EARTHQUAKE RESISTANT BUILDING USING BRACING TECHNIQUE FOR ALL ZONE

[1] Vishal Kumar , [2]Prajwal Magotra, [3]Adarsh Singh, [4] Tarun Sagar [5]Nitin Shinde

[1]BE Student Dr. D. Y. Patil Institute of Technology, Pimpri, Pune,
[2] BE Student Dr. D. Y. Patil Institute of Technology, Pimpri, Pune,
[3] BE Student Dr. D. Y. Patil Institute of Technology, Pimpri, Pune,
[4] BE Student Dr. D. Y. Patil Institute of Technology, Pimpri, Pune,
[5] Professor Dr. D. Y. Patil Institute of Technology, Pimpri, Pune,

[1]Department of Civil Engineering,
[1]Dr. D. Y. Patil Institute of Technology, Pimpri, Pune, India

Abstract: The earthquake is a natural disaster that has been known to humankind for many years since ancient researchers sought many ways to protect buildings. It was necessary to limit the damage to existing and new structures caused by the earthquake. Many existing reinforced concrete buildings require refurbishment to overcome defects and withstand seismic loads.

Brace is the most effective way to incorporate it into a reinforced concrete building. Steel braces are a very efficient and economical way to resist the horizontal forces of the RC frame structure. Brace was used to stabilize the tallest building structure laterally. The brace frame can withstand large lateral forces and has less lateral deflection, resulting in less breakdown. Steel brace frames increase the rigidity and strength of RCC buildings and reduce deformation.

In this study, we used G + 3 Residential Building 15 m in the X direction and 7.7 m in the Y direction. Equivalent static linear seismic analysis is performed using Sated Pro software, and result comparisons are performed between bare frame, X brace frames, V brace frames, and inverted V brace. G + 3 analysis is evaluated in terms of lateral displacement and base thrust. The survey will be conducted on Zone 2, Zone 3, Zone 4, Zone 5, and moderate soils according to the IS Code.

Keywords: RCC multi-layer construction, brace, X brace system, V brace system, reverse V system, displacement, base shear

I. Introduction

When it comes to earthquakes, an engineer will tell you better safe than sorry. Earthquakes can be incredibly devastating, and throughout history, there have been countless examples of entire cities being brought low, with damage even causing fires and flooding afterwards. Less than a century ago, a strong earthquake could sometimes result in the deaths of many thousands of people.

World's First Earthquake Proof Building

Kengo Kuma, famous Japanese architect, protects Japanese office building with carbon fibre curtain. He has renovated an office building in Nomi City which is recognized as the first earthquake resistant building. It is strengthened by carbon fibre beams as seen in the picture below:

Thanks to advances in civil engineering, the construction of buildings, bridges, roads and highways has progressed resulting in safer structures for our society. In the past couple of decades, our nation has been under several threats from natural calamities. Therefore, it is important to protect yourself from such disasters by finding a safe shelter, whether it is at work, home or school. An earthquake resistant building, one is able to save the property from damage, injuries, and lives that accrue in the event of an earthquake. A safe building is necessary especially in areas that are prone to hurricanes or earthquake. In this project we must be throwing light on earthquake its magnitude, types of earthquake effects of earthquake on structure and Braced structure as a remedies to nullify the hazards of earthquake

For this time history analysis of braced and unbraced steel structures is an effective solution for designing the most economic and safe structure which can reduce the damage to a desirable outcome. Steel braced frame is one of the structural systems used to resist lateral loads in multistorey buildings. Concentrically braced frames increase the lateral stiffness of the frame and usually decrease the lateral drift.

II. Objective

- We have to analyse and check the G+3 Residential Building for all zones in India
- Select proper type of Bracing to make the structure safe for all zones
- Economically, Finalize the type of Bracing used for each Zone

III. Methodology

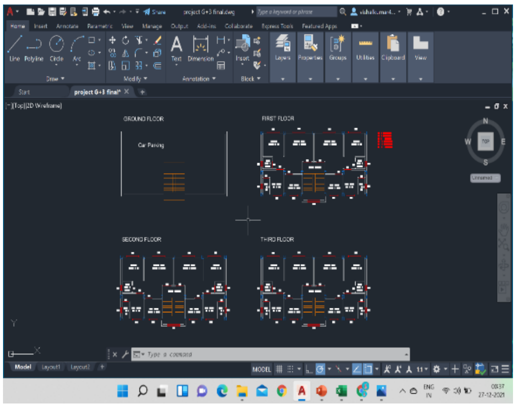
To achieve the objective of study, it has been proposed to follow methodology
Structural Planning
Modelling and analysis in Staad Pro

Plan Details: An Residential building in plan 15m in X direction and 7.7 m in Y direction with G+3 in z direction is modelled in AUTOCAD and carried analysis using Staad Pro Software. The height of each story is kept as 3m in the structure with the plinth story as 1.65m and the total height of the structure is 12.6m. The building plan in AUTOCAD and structure diagram in Staad Pro is shown below.

Geometrical Data

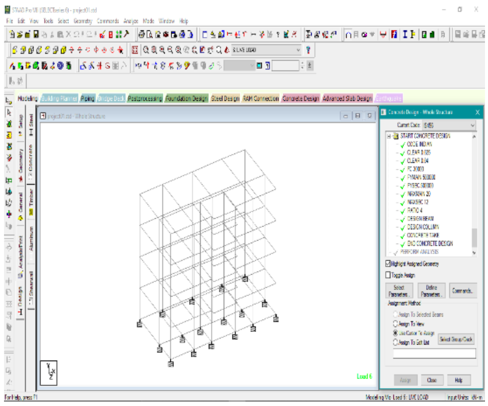
Type of Building: Residential Building
Building Dimensions: 15m along x and 7.7m along y direction

Typical story height: 3m
No of Storey: G+3
Foundation or Plinth Height: 1.65m
Beam Size: 0.3m x 0.23m
Column Size: 0.3m x 0.3m
Slab Thickness: 0.15m
Wall Thickness: 0.23m
Steel Brace: ISA (120x120x12) mm

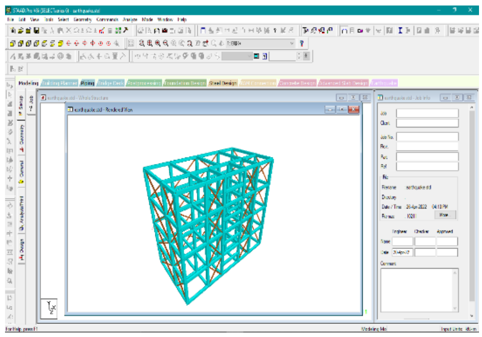


Floor Plan

3.1 MODEL DETAILS:



Earthquake Data
(Based on Indian seismic code, IS 1893-2002)
Seismic Zone: Zone 5(Table2 of IS 1893-2002(Part1))
Seismic Zone Factor: 0.36 (table 2 of per IS 1893-2002(Part1))
Importance Factor: 1.5(Table 6 of per IS1893-2002(Part1))
Response Reduction Factor: 3 for ordinary moment resisting frames and 4 for concentrically braced frames (Table 7 of oer IS 1893 – 2002(part 1))
Type of Soil: Medium Type 2
Seismic Zone: Zone 4(Table2 of IS 1893-2002(Part1))
Seismic Zone Factor: 0.24 (table 2 of per IS 1893-2002(Part1))
Importance Factor: 1.5(Table 6 of per IS1893-2002(Part1))
Response Reduction Factor: 3 for ordinary moment resisting frames and 4 for concentrically braced frames (Table 7 of oer IS 1893 – 2002(part 1))
Type of Soil: Medium Type 2



Seismic Zone: Zone 3(Table2 of IS 1893-2002(Part1))
Seismic Zone Factor: 0.16 (table 2 of per IS 1893-2002(Part1))
Importance Factor: 1.5(Table 6 of per IS1893-2002(Part1))
Response Reduction Factor: 3 for ordinary moment resisting frames and 4 for concentrically braced frames (Table 7 of oer IS 1893 – 2002(part 1))
Type of Soil: Medium Type 2
Seismic Zone: Zone 2(Table2 of IS 1893-2002(Part1))
Seismic Zone Factor: 0.10 (table 2 of per IS 1893-2002(Part1))
Importance Factor: 1.5(Table 6 of per IS1893-2002(Part1))
Response Reduction Factor: 3 for ordinary moment resisting frames and 4 for concentrically braced frames (Table 7 of oer IS 1893 – 2002(part 1))
Type of Soil: Medium Type 2
Material Data

1. Grade of concrete =M30 for beams, column and slabs
2. Grade of steel =Fe500
3. Density of Reinforced Concrete =25 kN/m³

Loading Data

1. Dead load: It is defined automatically software defined (Table 2, IS 875 (Part 1):1987)
2. Live load: For this residential building as per (Table1, IS 875 part 2), live load is taken as 2 kN/m2 on each floor and on roof 1.5 kN/m²
3. Floor Finish: 1 kN/m²
4. Earthquake load in X and Y direction i.e.EQX and EQY.
5. Wall load = 12.18 kN/m for without opening and 8.53 kN/m for with opening
6. Parapet load = 1.425 kN/m

Load Combinations based on IS 1893-2002:

1. 1.5(DL + LL)
2. 1.2(DL + LL)
3. 1.2(DL + LL + EQX)
4. 1.2(DL + LL - EQX)
5. 1.2(DL + LL + EQZ)
6. 1.2(DL + LL - EQZ)
7. 1.5(DL + EQX)
8. 1.5(DL - EQX)
9. 1.5(DL + EQZ)
10. 1.5(DL - EQX)
11. 0.9DL + 1.5EQX
12. 0.9DL - 1.5EQX
13. 0.9DL + 1.5EQZ
14. 0.9DL - 1.5EQZ

Models

Depending upon the provision of the concentric x bracings for the seismic analysis of the building, following models are considered.

MODEL 1: Bare frame
MODEL 2: Concentric X braced frame
MODEL 3: Concentric V braced frame
MODEL 4: Concentric Inverted V braced frame

Analysis in Staad Pro

The seismic analysis should be carried out for the buildings that have lack of resistance to earthquake forces. Seismic analysis will consider dynamic effects hence the exact analysis sometimes become complex. However for simple regular structures equivalent linear static analysis is sufficient one. This type of analysis will be carried out for regular and low rise buildings and this is sufficient one. This type of analysis will be carried out for regular and low rise buildings and this method will give good results for this type of buildings.

DESIGN PARAMETERS

There are various design parameter but we have taken following design parameters into consideration:

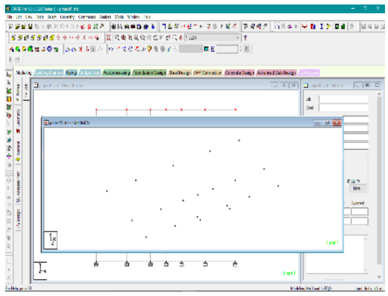
CLEAR COVERS:
0.025 M FOR BEAMS
0.040 M FOR COLUMNS

COMPRESSIVE STRENGTH OF CONCRETE
FC: 30 N/MM2

YIELD STRENGTH OF MAIN REINFORCEMENT STEEL
Fymain : 500 N/MM2

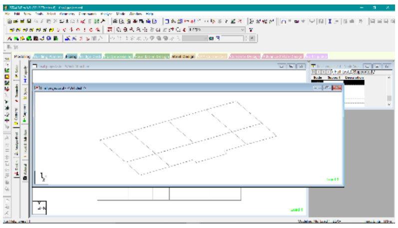
YIELD STRENGTH OF SHEAR REINFORCEMENT
Fysec : 500 N/MM2

MAX % OF LONGITUDINAL REINFORCEMENT ALLOWED
RATIO : 4%

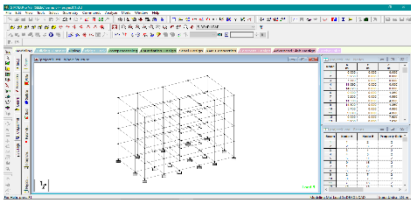


3.2 MODELING OF STRUCTURE

The first step to model a structure in staad pro to define nodes. A node is simply defined as the point where boundary condition applaid, stiffness of structure is changed ,material discontinuities,geomatrrical discontinuous etc. To model the frame we have to add node at xyz co-ordinates . and Each node shown as the position of column in a frame



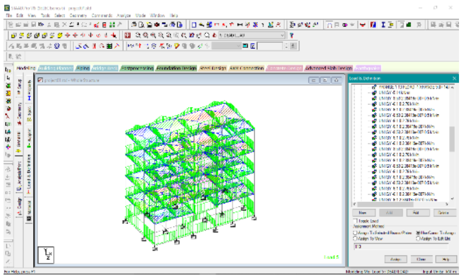
The second step is to join the nodes . By joining any two horizontly it form a beam and joining two vertical to form a column. In this we define the beams at plinth level



In next step we model the complete frame of G+3 residential building by joining the nodes horizontally and vertically . Then we define the reaction in staad pro and assign the reaction property to our frame structure

After assigning fixed reaction to our structure we have to define section property in staad pro .There are various option in defining section to define shape of beam and column .we define the rectangular beam and column . we define angle section for brace and assign to our frame. This is the last step to model the frame of the G+3 Residential Building .

After assigning all the section property to aur structure we have to assign different kind of loads to aur structure like Dead Load ,Live Load, Seismic and done calulation to assign each kind of load to aur structure



DEAD LOAD

The first vertical load that is considered is dead load. Dead loads are permanent or stationary loads which are transferred to structure throughout the life span. Dead load is primarily due to self weight of structural members, permanent partition walls, fixed permanent equipment's and weight of different materials.

The minimum values of dead loads to be assumed are given in IS 875 (part 1)–1987.

Fig 1.11 Dead Load

Dead Load calculations

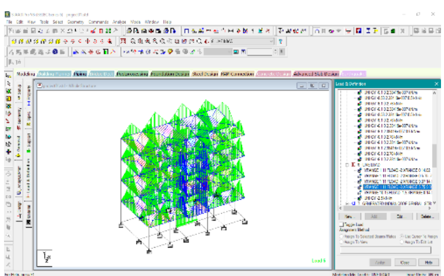
Dead load = volume of member x unit weight of material

Dead load for outer wall = 12.74kN/m

Dead load for inner wall = 6.37kN/m

Dead load for parapet wall = 4.4kN/m

Dead load for slab= 5.275kN/m



LIVE LOAD

The second vertical load that is considered in design of a structure is imposed loads or live loads. Live loads are either movable or moving loads with out any acceleration or impact. These loads are assumed to be produced by the intended use or occupancy of the building including weights of movable partitions or furniture etc..

Live loads keeps on changing from time to time. These loads are to be suitably assumed by the designer. It is one of the major load in the design. The minimum values of live loads to be assumed are given in IS 875 (part 2)–1987. It depends upon the intended use of the building.

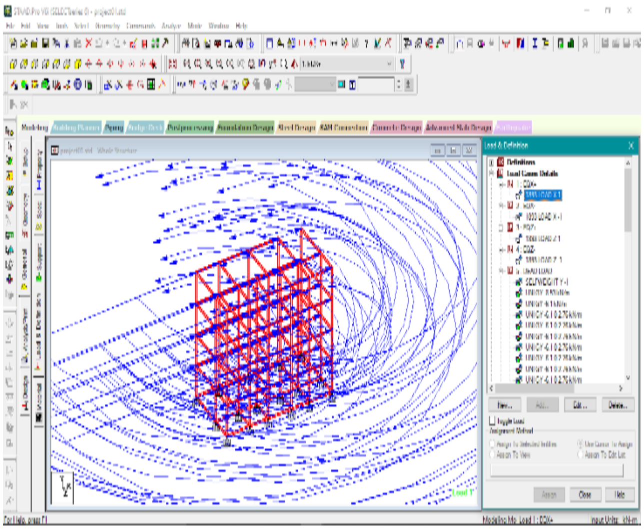
Zone	Base Shear	Floor	B.M y-axis	B.M z-axis	S.F y-axis	S.F z-axis	Dis.
Zone 2	412.23	Top	3.154	9.4547	7.248	1.947	60.017
		3rd	1.704	15.644	12.234	1.232	47.613
		2nd	0.601	19.808	15.445	0.435	29.794
		1st	0.180	17.945	13.658	0.245	10.843
Zone 3	729.09	Top	5.396	15.096	11.568	3.862	90.642
		3rd	3.003	24.965	19.522	2.135	71.872
		2nd	1.186	31.621	24.654	0.739	44.965
		1st	0.254	28.029	21.813	0.287	16.436
Zone 4	1380.97	Top	Fail	Fail	Fail	Fail	Fail
		3rd	Fail	Fail	Fail	Fail	Fail
		2nd	Fail	Fail	Fail	Fail	Fail
		1st	Fail	Fail	Fail	Fail	Fail
Zone 5	2071.46	Top	Fail	Fail	Fail	Fail	Fail
		3rd	Fail	Fail	Fail	Fail	Fail
		2nd	Fail	Fail	Fail	Fail	Fail
		1st	Fail	Fail	Fail	Fail	Fail

EARTHQUAKE LOAD

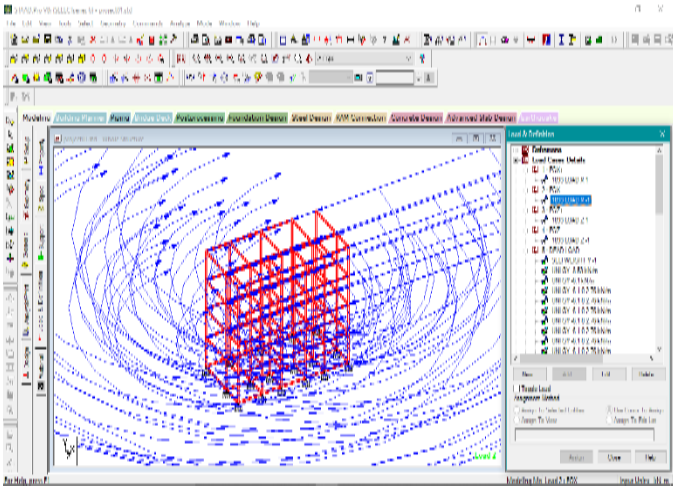
Earthquake forces constitute to both vertical and horizontal forces on the building. The total vibration caused by earthquake may be resolved into three mutually perpendicular directions, usually taken as vertical and two horizontal directions. The movement in vertical direction do not cause forces in superstructure to any significant extent. But the horizontal movement of the building at the time of earthquake is to be considered while designing.

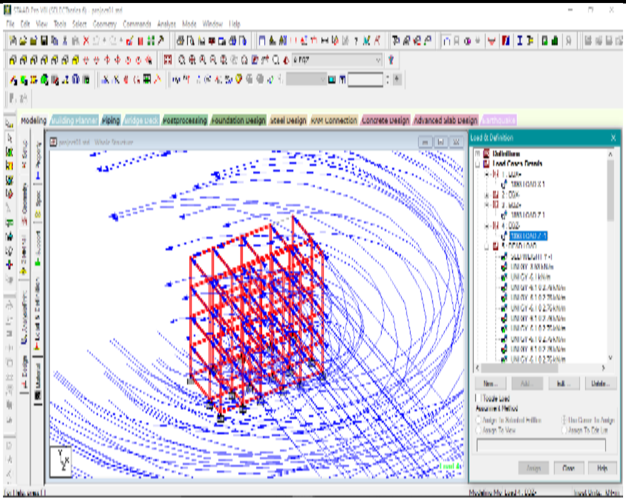
S Code 13920 for seismic requirements for design.
Also, IS Code 1893(Part 1) For Earthquake Resistant Structure.

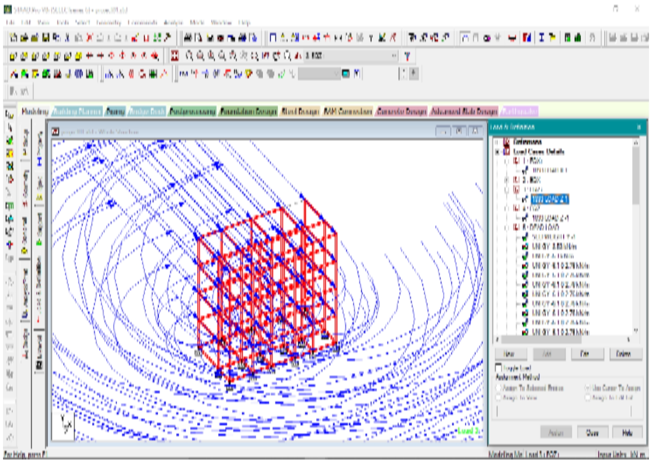
SEISMIC LOAD DIAGRAM



Earthquake along x-axis





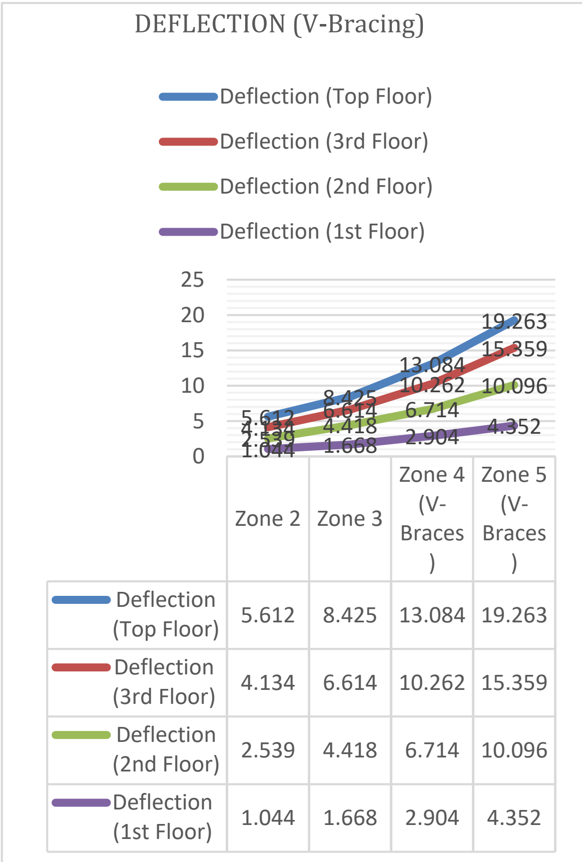


Earthquake along z-axix

IV. RESULT AND DISCUSSION

BARE FRAME RESULT

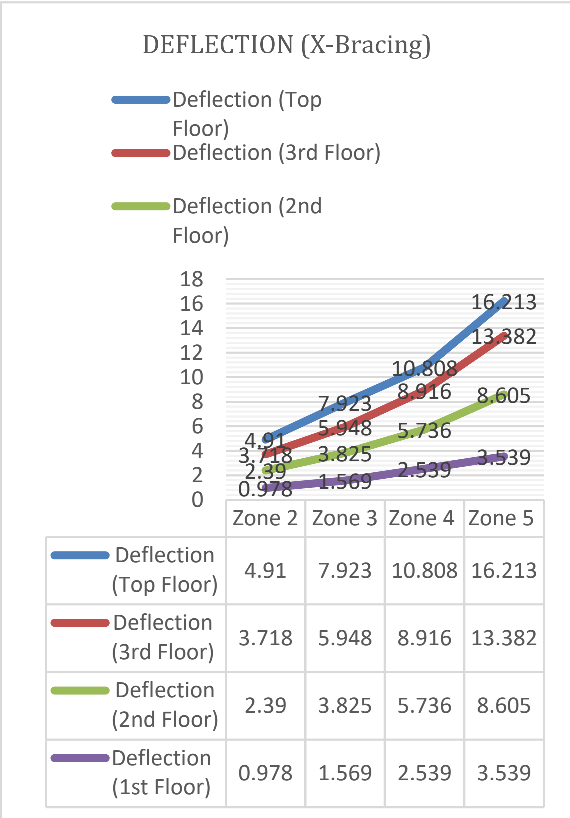
Zone	Base Shear	Floor	B.M y-axis	B.M z-axis	S.F y-axis	S.F z-axis	Dis.
Zone 4	732.84	Top	12.868	12.621	7.603	9.076	10.808
		3rd	11.904	17.625	16.494	8.407	8.916
		2nd	7.554	18.427	21.806	5.336	5.736
		1st	2.556	17.108	20.194	1.803	2.539
Zone 5	1099.26	Top	19.301	18.932	11.405	13.614	16.213
		3rd	17.855	26.438	24.741	12.611	13.382
		2nd	11.331	27.604	32.709	8.004	8.605
		1st	3.894	25.662	30.291	2.705	3.539



Bare Frame Data

The value for zone 4 and zone 5 are not available in this table because the structure fail for these zones for non-bracing or bare structure

Zone	Base Shear	Floor	B.M y-axis	B.M z-axis	S.F y-axis	S.F z-axis	Dis.
Zone 4	877.43	Top	16.816	10.289	9.213	12.478	13.084
		3rd	11.161	12.349	11.355	8.059	10.262
		2nd	6.530	12.788	14.138	4.664	6.714
		1st	1.892	21.259	21.345	1.441	2.904
Zone 5	1316.15	Top	25.224	13.879	13.819	18.808	19.263
		3rd	15.359	16.742	18.523	17.033	15.359
		2nd	9.795	21.089	21.027	7.026	10.096
		1st	2.836	27.222	37.003	2.162	4.352

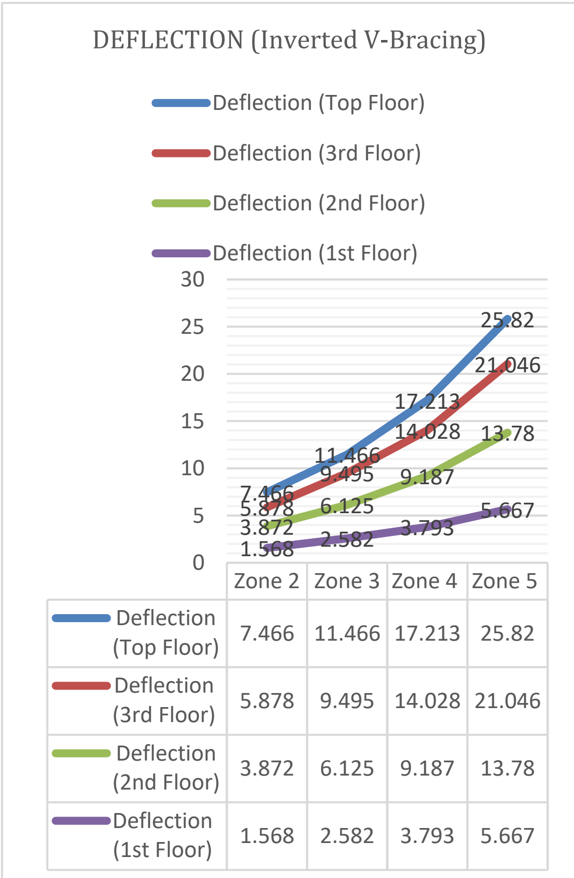


X-BRACED FRAME RESULT

V-BRACED FRAME RESULT

INVERTED V-BRACED FRAME RESULT

Zone	Base Shear	Floor	B.M y-axis	B.M z-axis	S.F y-axis	S.F z-axis	Dis.
Zone 4	909.8	Top	18.943	18.325	9.815	13.295	17.213
		3rd	17.754	24.144	24.683	13.333	14.028
		2nd	11.188	28.344	33.557	8.676	9.187
		1st	3.197	28.055	33.122	1.587	3.793
Zone 5	1364.7	Top	28.414	27.487	13.778	19.889	25.82
		3rd	21.046	**26.631**	36.214	37.022	21.046
		2nd	16.782	38.525	50.335	13.014	13.78
		1st	5.667	4.796	36.006	49.683	5.667



Finalize the type of Bracing used for each zone :

For Zone 2 and Zone 3 the structure is safe without bracing we do not need to add any bracing technique for these zones .

For Zone 4 the structure fail for bare frame and safe for each bracing case but economically we finalize V bracing or Inverted V bracing

For Zone 5 the value of base shear and deflection are high, so to make the structure stable we finalize X bracing for zone 5

Zone	Bracing Type	Max. Displacement	Max. Base shear	Bracing preffered
Zone 4	X-Bracing	10.808	732.84	V-Bracing
	V-Bracing	13.084	877.43	
	Inverted V-Bracing	17.213	909.8	
Zone 5	X-Bracing	16.213	1099.26	X-Bracing
	V-Bracing	19.263	1316.15	
	Inverted V-Bracing	25.82	1364.7	

V. CONCLUSION

- The analysis of the G+3 Reinforced Concrete framed building subjected to the seismic loads without the consideration of bracing and considering the all three type of bracing (x-bracing, v-bracing, inverted v-bracing) under the each seismic zone (Zone 2, Zone 3,Zone 4,Zone 5) consideration was carried out in Staad Pro software. The following conclusions are made
- The G+3 Reinforced Concrete framed structure subjected to the seismic loads without the consideration of bracing is safe in Zone 2 and Zone 3 but the same structure collapses under the seismic condition of Zone 4 and Zone 5 .
- From the graphical representation we observed that structure is safe in seismic Zone 4 and Zone 5 for bracing. We apply three types of bracing x-Bracing, v-bracing and inverted v-bracing
- X-Bracing structure give less value for Base Shear and Displacement from all the bracing technique we use in our structure
- From our observation of the graphical representation that as there is increase in the height of the structure there is increase in the value of Displacement which conclude that maximum value of the Displacement at Top level and minimum value at the base of the structure.

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