Shear Control of High Rise Buildings Using Steel Infills

B. Narendra[1], M. S. Anantha Venkatesh[2]

[1]Asst Professor, CIVIL, SVR Engineering college, NandyalaAndhrapradesh, India
[2]Head Of The Dept, CIVIL, SVR Engineering college, Nandyala, Andhrapradesh, India

Abstract: ***Earthquake load is becoming a great concern in our country as because not a single zone can be designated as earthquake resistant zone. One of the most important aspects is to construct a building structure, which can resist the seismic force efficiently. Study is made on the different structural arrangement to find out the most optimized solution to produce an efficient safe earthquake resistant building. The basic principles of design for vertical and lateral loads (wind & seismic) are the same for low, medium or high rise building. The vertical loads increase in direct proportion to the floor area and number of floors. In contrast to this, the effect of lateral loads on a building is not linear and increase rapidly with increase in height. Due to these lateral loads, moments on steel components will be very high. By providing bracing, these moments can be reduced.In the present analysis, 18 Storeys residential building is analyzed with columns, columns with steel bracings of X shape at different locations in two different earth quake zones with respect to three soil types. Displacement, shear, Moment, Base moment, Base shear was compared for different load combinations. It is observed that the deflection was reduced by providing the X shape steel bracings. A commercial package ETABS has been utilized for analyzing 18 storey's residential building for different zones. The result has been compared using tables & graph to find out the most optimized solution. Concluding remark has been made on the basis of this analysis & comparison tables.***

Keywords: steel infills, seismic, shear control

1. Introduction

Mankind has always had a fascination for height and throughout our history we have constantly sought to metaphorically reach for the stars. From the ancient pyramids to today's modern skyscraper, a civilization's power and wealth has been repeatedly expressed through spectacular and monumental structures. Today the symbol of economic power and leadership is the skyscraper. There has been a demonstrated competitiveness that exists in mankind to proclaim to have the tallest building in the world.

This undying quest for height has laid out incredible opportunities for the building profession. From the early moment frames to today's ultra-efficient mega-braced structures, the structural engineering profession has come a long way. The recent development of structural analysis and design software coupled with advances in the finite element method has allowed the creation of many structural and architecturally innovative forms. However, increased reliance on computer analysis is not the solution to the challenges that lie ahead in the profession.

The basic understanding of structural behaviour while leveraging on computing tools are the elements that will change the way structures are designed and built. The design of skyscrapers is usually governed by the lateral loads imposed on the structure. As buildings have taller and narrower, the structural engineer has been increasingly challenged to meet the imposed drift requirements while minimizing the architectural impact of the structure. In response to this challenge, the profession has proposed a multitude of lateral schemes that are now spoken in tall buildings across the globe. This study seeks to understand the evolution of the different lateral systems that have emerged and its associated structural behaviour, for each lateral scheme examined, its advantages and disadvantages will be looked at.

1.1 Engineering Seismology

Seismology is the study of the generation, propagation and recording of elastic waves in the earth and the sources that produce them. An earthquake is a sudden tremor or movement of the earth's crust, which originates shock waves caused by nuclear tests, Man-made explosions etc. About 90% of all earthquakes results from tectonic events, primarily movements on the faults. The remaining is related to volcanism, collapse of subterranean cavities or man-made effects.

The epicentres of earthquakes are not randomly distributed over the earth's surface. The epicentres of 99% earthquakes are distributed along narrow zones of interpolate seismic activity. The remainder is considered to be a seismic. According to the theory of plate tectonics, the outermost layer of the earth, known as lithosphere, is broken into numerous segments or plates. The crust and uppermost mantle down to a depth of about 70-100 km under deep ocean basins and 100-50 km under continents is rigid, forming a hard outer shell called the lithosphere. Beneath the lithosphere lies the asthenospehere, which is viscous in nature, a layer in which seismic velocities often decreases, suggesting lower rigidity. It is about 150km thick; it plays an important role in plate tectonics, because it makes possible the relative motion of the overlying lithosphere plates. The different types of lithosphere plates comprising both crust and upper mantle move relative to each other across the surface of the globe. There are three types of plate;

Margins:

- Constructive plate margin/Divergent boundaries – where new crust is generated as the plates pull away from each other.
- Destructive plate margin/Convergent boundaries – where crust is destroyed as one plate drives under another.
- Conservative plate margin/Transform boundaries – where crust is neither produced nor destroyed as the plate slide horizontally past each other.

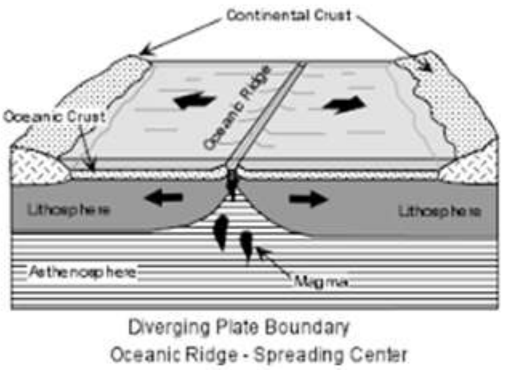


Figure 1.1: Schematic representation of divergence boundary

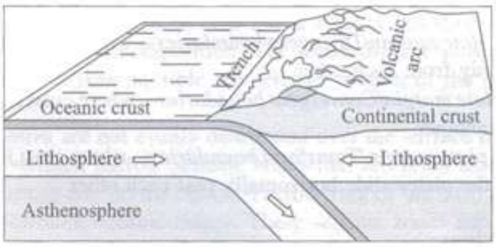


Figure 1.2: Schematic representation of oceanic-continental convergence

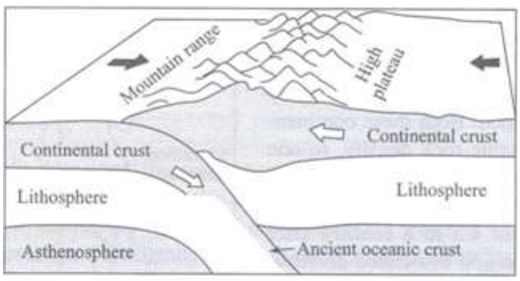


Figure 3: Schematic representation of transform boundary

2. Lateral Load Resisting Systems

A multi-storey building with no lateral bracing is shown in Fig:5 When the beams and columns shown are connected with simple beam connections, the frame would have practically no resistance to the lateral forces and become geometrically unstable. The frame would be laterally deflect as shown in the below figure even under a small lateral load.

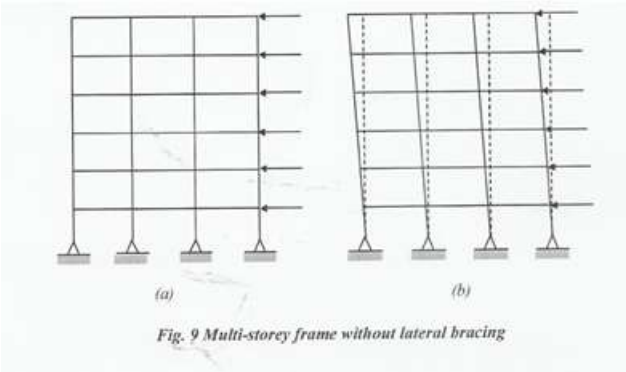


Figure 2.1: multi- storey frame without lateral bracing

Loading on tall buildings is different from low-rise buildings in many ways such as large accumulation of gravity loads on the floors from top to bottom, increased significance of wind loading and greater importance of dynamic effects. Thus, multi-storied structures need correct assessment of loads for safe and economical design. Excepting dead loads, the assessment of loads cannot be done accurately. Live loads can be anticipated approximately from a combination of experience and the previous field observations. But, wind and earthquake loads are random in nature. It is difficult to predict them exactly. These are estimated based on probabilistic approach. The following discussion describes the influence of the most common kinds of loads on multi-storied structures.

2.1 Structural Concepts

The key idea in conceptualizing the structural system for a narrow tall building is to think of it as a beam cantilevering from the earth (Figure 6). The laterally directed force generated, either due to wind blowing against the building or due to the inertia forces induced by ground shaking, tends both to snap it (shear), and push it over (bending).

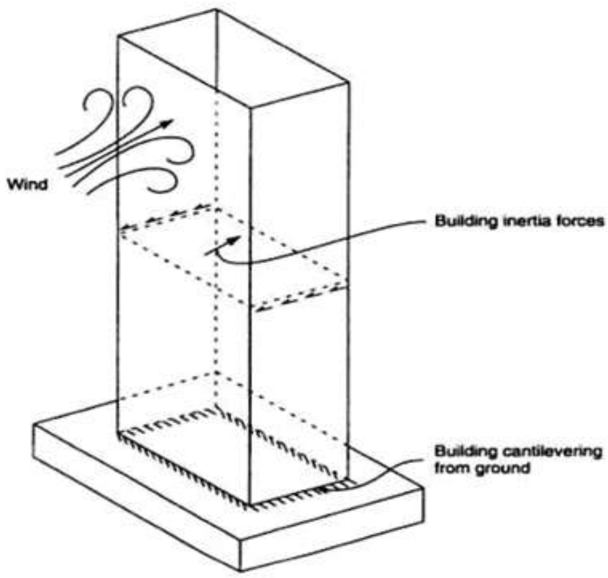


Figure 2.2: Structural concept of tall building

Therefore, the building must have a system to resist shear as well as bending. In resisting shear forces, the building must not break by shearing off and must not strain beyond the limit of elastic recovery.

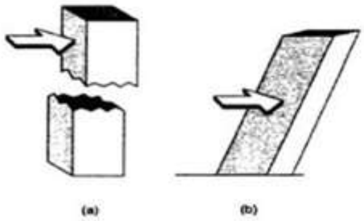


Figure 2.3: Building shear resistance; (a) building must not break

(b) Building must not deflect excessively in shear.

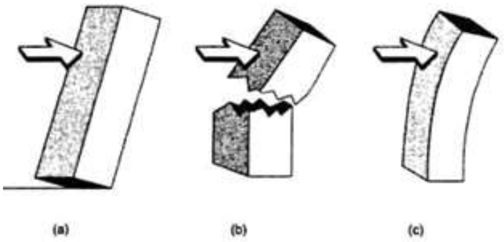


Figure 2.4: bending resistance of building

a. Building must not overturn
b. Columns must not fail in tension or compression
c. Bending deflection must not be excessive

In the structure's resistance to-of bending-war ensues that sets and the shear Building in motion, thus creating a third engineering problem; motion perception or Vibration. If the building sways too much, human comfort is sacrificed, or more importantly, non-structural elements may break resulting in expensive damage to the building contents and causing danger to the pedestrians.

A perfect structural form to resist the effects of bending, shear and excessive vibration is a system possessing vertical continuity ideally located at the farthest extremity from the geometric centre of the building. A concrete chimney is perhaps an ideal, if not an inspiring engineering model for a rational super-tall structural form. The quest for the best solution lies in translating the ideal form of the chimney into a more practical skeletal structure.

3. Lateral Force Resisting Systems

There are several systems that can be used effectively for providing resistance to seismic lateral forces. Some of the more common systems are shown in figures below. All of the systems rely on a complete, three –dimensional space frame; a coordinated system of moment frames, shear walls, or braced frames with horizontal diaphragms; or a combination of the systems.

1. In buildings where a space frame resists the earthquake forces, the columns and beams act in bending. During a large earthquake, storey to storey deflection (storey drift) may be accommodated within the structural systems without causing failure of columns or beams. However, the drift may be sufficient damage elements that are rigidly tied to the structural system such as brittle partitions, stairways, plumbing, exterior walls, and other elements that extend between floors. Therefore, buildings can have substantial interior and exterior non structural damage and still be structurally safe. Although there are excellent theoretical and economic reasons for resisting seismic forces by frame.

2. A shear wall (or braced frame) building is normally more rigid than a framed structure. With low design stress limits in shear walls, deflection due to shear forces is relatively small. Shear wall construction is an economical method of bracing buildings to limit damage, and this type of construction is normally economically feasible up to about 15 stories. Notable exceptions to the excellent performance of shear walls occurs when the height-to-width ratio becomes great enough to make overturning a problem and when there are excessive openings in the shear walls. Also, if the soil beneath its footings is relatively soft, the entire shear wall may rotate, causing localized damage around the wall.

3.1 Wind load

The wind loading is the most important factor that determines the design of tall buildings over 10 storey's, where storey height approximately lies between 2.7 - 3.0 m. Buildings of up to 10 storey's, designed for gravity loading can accommodate wind loading without any additional steel for lateral system. Usually, buildings taller than 10 storeys' would generally require additional steel for lateral system. This is due to the fact that wind loading on a tall building acts over a very large building surface, with greater intensity at the greater heights and with a larger moment arm about the base. So, the additional steel required for wind resistance increases non-linearly with height as shown in figure below. The lateral stiffness of the building is a more important consideration than its strength for multi-storied structures. Wind has become a major load for the designer of multi-storied buildings. Prediction of wind loading in precise scientific terms may not be possible, as it is influenced by many factors such as the form of terrain, the shape, slenderness, and the solidarity ratio of building and the arrangement of adjacent buildings. The appropriate design wind loads are estimated based on two approaches. Static approach is one, which assumes the building to be a fixed rigid body in the wind. This method is suitable for buildings of normal height, slenderness, or susceptible to vibration in the wind. The other approach is the dynamic approach. This is adopted for exceptionally tall, slender, or vibration prone buildings. Sometimes wind sensitive tall buildings will have to be designed for interference effects caused by the environment in which the building stands. The loading due to these interference effects is best ascertained using wind tunnel modelled structures in the laboratory. However, in the Indian context, where the tallest multi-storied building is only storey high, multi-storied buildings do not suffer wind-induced oscillation and generally do not require to be examined for the dynamic effcts.

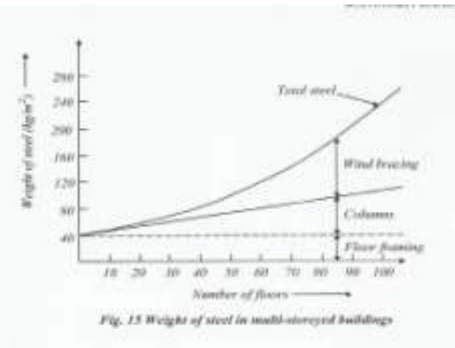


Figure 3.1: weight of steel in multi-storeyed buildings

3.2 Seismic Load

Seismic motion consists of horizontal and vertical ground motions, with the vertical motion usually having a much smaller magnitude. Further, factor of safety provided against gravity loads usually can accommodate additional forces due to vertical acceleration due to earthquakes. So, the horizontal motion of the ground causes the most significant effect on the structure by shaking the foundation back and forth. The mass of buildings resists this motion by setting up inertia forces throughout the structure. The magnitude of the horizontal shear force F shown in Fig. 16 depends on the mass of the building M, the acceleration of the ground a, and the nature of the structure.If a building and the foundation were rigid, it would have the same acceleration as the ground as given by Newton's second law of motion, i.e. F = Ma. However, in practice all buildings are flexible to some degree. For a structure that deforms slightly, thereby absorbing some energy, the force will be less than the product of mass and acceleration. But, a very flexible structure will be subject to a much larger force under repetitive ground motion [F. This shows the magnitude of the lateral force on a building is not only dependent on acceleration of the ground but it will also depend on the type of the structure. As an inertia problem, the dynamic response of the building plays a large part in influencing and in estimating the effective loading on the structure. The earthquake load is estimated by Seismic co-efficient method or Response spectrum method. The later takes account of dynamic characteristics of structure along with ground motion.

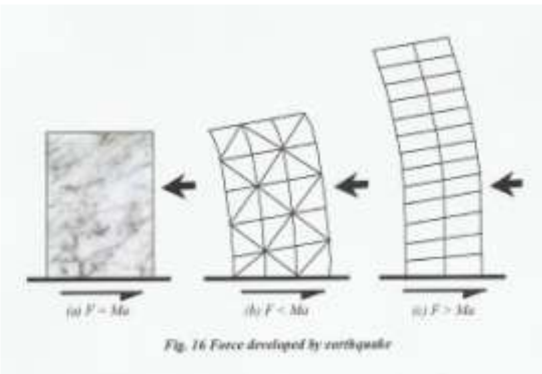


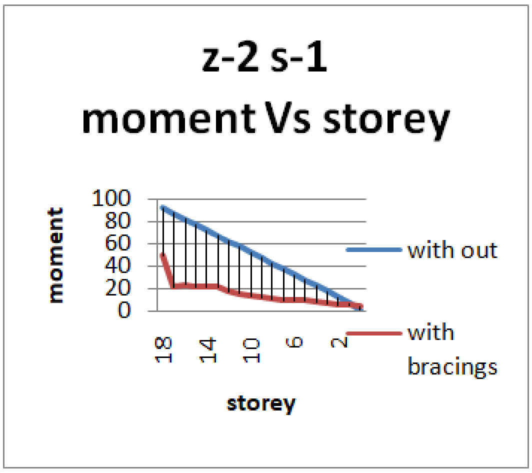
Figure 3.2: force developed by earthquake

4. Results

Comparison of moment in zone-2 & zone-5

Table 1: Showing moment values of zone-2 soil-1

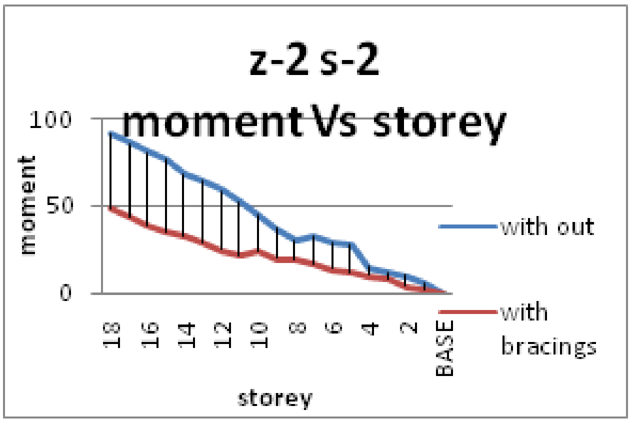
Storey	With out	With bracings
18	92	49
17	87	21
16	82	23
15	77	21
14	72	21
13	67	21
12	62	17
11	57	15
10	52	13.23
9	47	11.343
8	42	10.345
7	37	9.4
6	32	9.12
5	27	8.99
4	22	7.23
3	17	6.123
2	12	5.324
1	7	4.525
Base	0	3.726



Graph 1: Showing moment variations in z-2 s-1

Table 2: Showing moment values of zone-2 soil-2

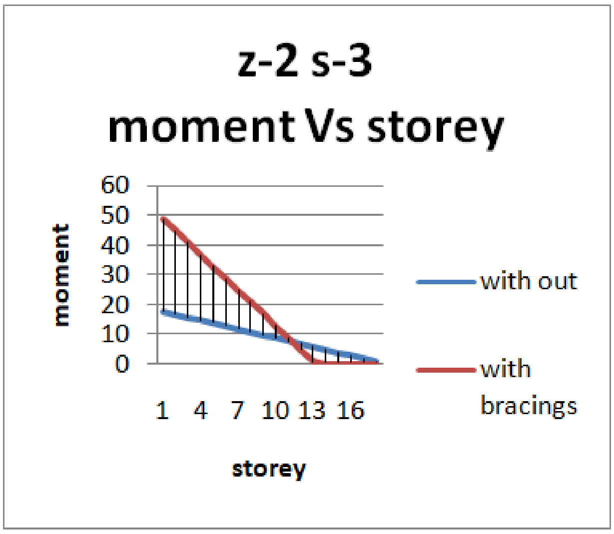
Storey	With out	With bracings
18	91	49
17	86	44
16	81	39
15	77	35
14	68	33
13	64	29
12	59	25
11	52	22
10	45	24
9	37	20
8	30	19
7	33	17
6	29	14
5	28	12
4	15	10
3	12	8
2	10	4
1	6	2
Base	0	0



Graph 2: Showing moment variations in z-2 s-1

Table 3: Showing moment values of zone-2 soil-3

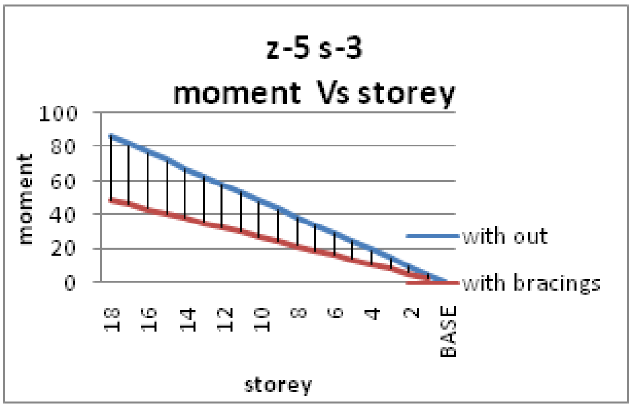
Storey	With out	With bracings
18	97	49
17	91.61111	45
16	86.22222	41
15	80.83333	37
14	75.44444	33
13	70.05556	29
12	64.66667	25
11	59.27778	21
10	53.88889	17
9	48.5	13
8	43.11111	9
7	37.72222	5
6	32.33333	1
5	26.94444	0
4	21.55556	0
3	16.16667	0
2	10.77778	0
1	5.388889	0
Base	0	0



Graph 3: Showing moment variations in z-2 s-3

Table 4: Showing moment values of zone-5 soil-1

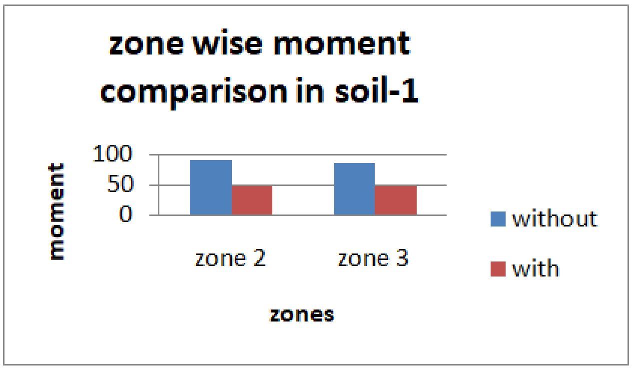
Storey	With out	With bracings
18	86	48.89
17	81.2222	46.17389
16	76.4444	43.45778
15	71.6667	40.74167
14	66.8889	38.02556
13	62.1111	35.30944
12	57.3333	32.59333
11	52.5556	29.87722
10	47.7778	27.16111
9	43	24.445
8	38.2222	21.72889
7	33.4444	19.01278
6	28.6667	16.29667
5	23.8889	13.58056
4	19.1111	10.86444
3	14.3333	8.148333
2	9.55556	5.432222
1	4.77778	2.716111
Base	0	0



Graph 4: Showing moment variations in z-5 s-1

Table 5: Showing moment comparison values of soil-1 in z-2 & z-5

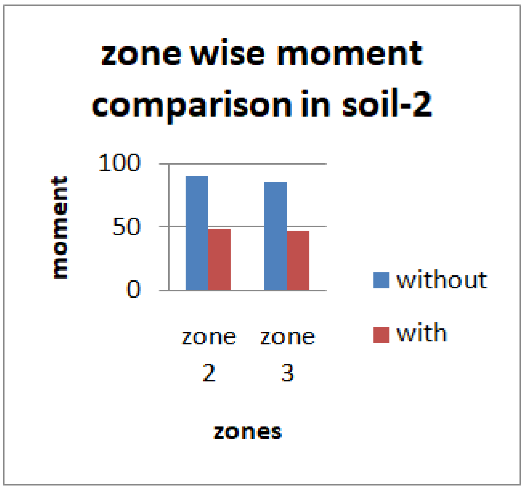
Zones	Soil-1	
	Without	With
Zone 2	92	49
Zone 3	86	48.89



Graph 5: Showing shear variations of soil-1 in z-5 s-2

Table 6: Showing moment comparison values of soil-2 in z-2 & z-5

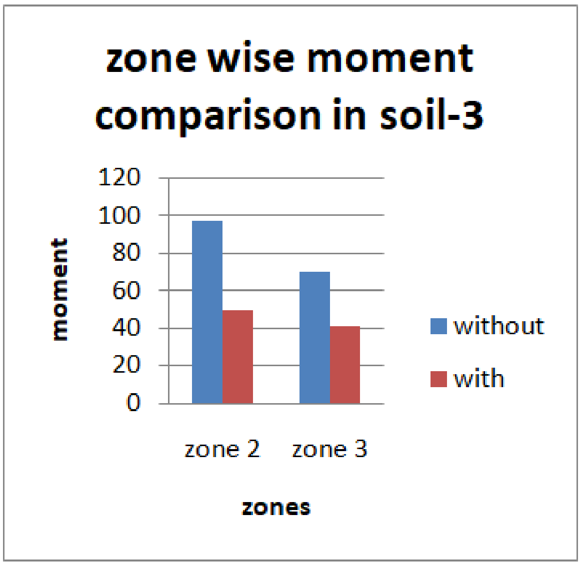
Zones	Soil-2	
	Without	With
Zone 2	91	49
Zone 3	86	48



Graph 6: Showing shear variations of soil-2 in z-5 s-2

Table 7: Showing moment comparison values of soil-3 in z-2 & z-5

Zones	Soil-2	
	Without	With
Zone 2	97	49
Zone 3	70	41



Graph 7: Showing shear variations of soil-2 in z-5 s-3

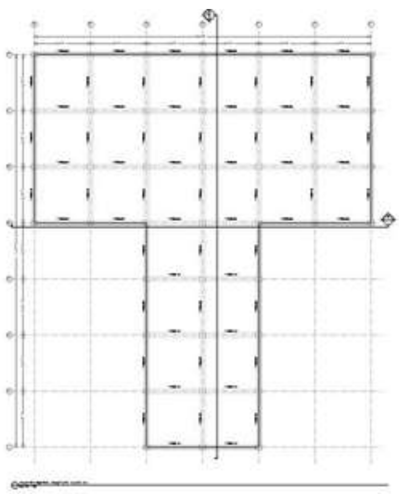


Figure 4.1: Sectional view of T Shape building

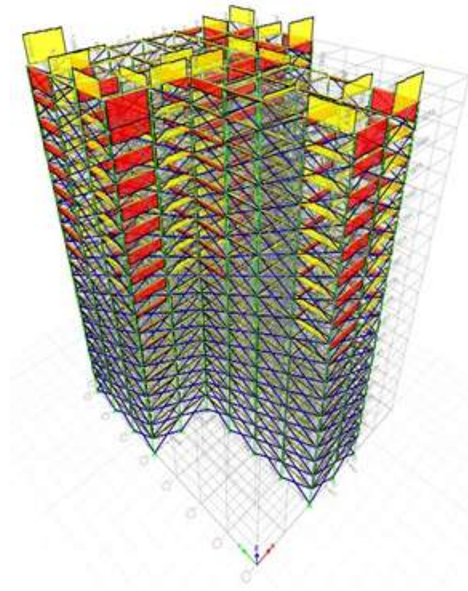


Figure 4.2: showing torsion diagram for T Shape building in 3D view

5. Conclusion

Based on the analysis;

1. The structural performance is analyzed in two different models i.e. Without bracings, With steel Bracing of X Shape, the displacement of 50% is reduced when lateral systems are provided.
2. Shear is also analyzed for both the models, Shear of 40% is reduced when the lateral systems i.e,, X steel bracings are provided.
3. Moment is also compared for both the models, moment of 60% is reduced when X steel bracings are provided.
4. Zone wise comparison in made for each soil and it is observed that average of 50% is reduced in displacement, shear, moment.
5. By providing the bracings the stiffness of the structure is increased and storey shear is decreased with increase in height of structure.
6. Time History analysis is performed for all the models i.e. without bracings & with bracings. Base Shear is decreased with respect to time for the models.
7. Time History analysis is performed for all the models i.e. without bracings & with bracings. Moment is decreased with respect to time for the models with bracings.
8. By providing lateral systems in the framed structures the reduction in the displacement, shear, moment thereby increasing the stiffness of the structure for resisting lateral loads due to earth quakes.
9. Zone wise comparison is made in dynamic analysis for base shear in each soil a base shear of 50 % is reduced when x bracings are provided.
10. Zone wise comparison is made for base moment in dynamic analysis at each soil and it is observed that a base moment of 40 % is reduced when X bracings are provided.

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Author Profile

B Narendra Presently persuing his M.Tech (structural engg) in CIVIL**,** SVR Engineering College, Nandyala AndhraPradesh, India.

M. S. Anantha Venkatesh M.Tech (structural engg) Presently working as HOD in Dept of CIVIL Engineering, SVR Engineering College, Nandyala AndhraPradesh, India.