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A Study on Time History Analysis of High Rise Building with Infill P anels

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Abstract: Reinforced concrete frame buildings with masonry infill walls have been widely constructed for commercial, industrial and multi storey residential uses in seismic regions. The masonry infill panels are generally not considered in the design process and treated as architectural (non-structural) components. Properly designed infills increase the overall strength, lateral resistance and energy dissipation of the structure. In this study, the effects of infill walls to the response of a selected G+15 R.C framed building under earthquake loading were investigated. The present study is an effort towards analysis of the structure during the earthquake. G+15 stories residential building is considered. The El-centro time history analysis is carried out for special moment resisting frame under earthquake loading using computer software E-TAB 2016. Seismic analysis of RC frame with bare and different position of shear wall and bracings, infill wall effect in frame is carried out using dynamic analysis method as per IS 1893 (Part I): 20016by using E-TAB 2016 . The time history method had been used to find the design lateral forces along the storey in X and Z direction of the building. The main aim of the modeling is to study the change in building responses (mainly deflection and storey drift) due to various shear resisting elements as per IS 1893:2016. For this analysis different types of models will discussed in chapter are considered and comparison is carried out.
Keywords: ***Response spectrum method, E-TAB 2016, high-rise Steel building etc.***

I. INTRODUCTION

A. General

The tallness of a building is relative and can not be defined in absolute terms either in relation to height or the number of stories. But, from a structural engineer's point of view the tall building or multi-storied building can be defined as one that, by virtue of its height, is affected by lateral forces due to wind or earthquake or both to an extent that they play an important role in the structural design. Tall structures have fascinated mankind from the beginning of civilization. The Egyptian Pyramids, one among the seven wonders of world, constructed in 2600 B.C. are among such ancient tall structures. Such structures were constructed for defense and to show pride of the population in their civilization. The growth in modern multi-storied building construction, which began in late nineteenth century, is intended largely for commercial and residential purposes. The design of tall buildings essentially involves a conceptual design, approximate analysis, preliminary design and optimization, to safely carry gravity and lateral loads. The design criteria are, strength, serviceability, stability and human comfort. Earthquake have become a frequent event all over the world. It is very difficult to predict the intensity, location, and time of occurrence of earthquake. Structures adequately designed for usual loads like dead, live, wind etc may not be necessarily safe against earthquake loading. It is neither practical nor economically viable to design structures to remain within elastic limit during earthquake. The design approach adopted in the Indian Code IS 1893(Part I): 2002 'Criteria for Earthquake Resistant Design Of Structures' is to ensure that structures posses at least a minimum strength to withstand minor earthquake occurring frequently, without damage; resist moderate earthquakes without significant structural damage though some non-structural damage may occur; and aims that structures withstand major earthquake without collapse.

Structures need to have suitable earthquake resistant features to safely resist large lateral forces that are imposed on them during frequent earthquakes. Ordinary structures for houses are usually built to safely carry their own weights. Low lateral loads caused by wind and therefore, perform poorly under large lateral forces caused by even moderate size earthquake. These lateral forces can produce the critical stresses in a structure, set up undesirable vibrations and, in addition, cause lateral sway of structure, which could reach a stage of discomfort to the occupants.

1) *Shear Wall:* Shear wall is one of the most commonly used lateral load resisting element in high rise building. Shear wall (SW) has high in plane stiffness and strength which can be used simultaneously resist large horizontal load and support gravity load. The scope of present work is to study and investigate the effectiveness of RC shear wall in medium rise building. Reinforced concrete shear walls are used in Bare frame.building to resist lateral force due to wind and earthquakes. They are usually

provided between column lines, in stair wells, lift wells, in shafts that house other utilities. Shear wall provide lateral load resisting by transferring the wind or earthquake load to foundation. Besides, they impart lateral stiffness to the system and also carry gravity loads. But bare frame with shear wall still become economically unattractive. If the structural engineer consider property the non structural element in structural design along with other elements like shear wall gives better results.

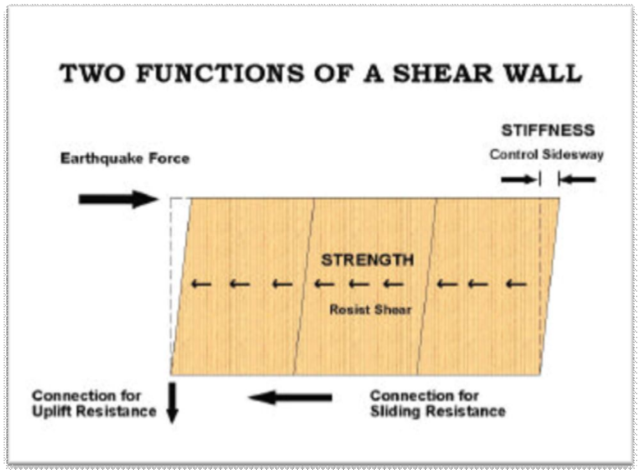

Fig. 1 Function of shear wall

Reinforced concrete (RC) buildings often have vertical plate-like RC walls called Shear Walls in addition to slabs, beams and columns. These walls generally start at foundation level and are continuous throughout the building height. Their thickness can be as low as 150mm, or as high as 400mm in high rise buildings. Shear walls are usually provided along both length and width of buildings shear walls are like vertically-oriented wide beams that carry earthquake loads downwards to the foundation. Properly designed and detailed buildings with shear walls have shown very good performance in past earthquakes. Shear walls in high seismic regions require special detailing. However, in past earthquakes, even buildings with sufficient amount of walls that were not specially detailed for seismic performance (but had enough well-distributed reinforcement) were saved from collapse. Shear wall buildings are a people choice in many earthquake prone countries, like Chile, New Zealand and USA. Shear walls are easy to construct, because reinforcement detailing of walls is relatively straight-forward and therefore easily implemented at site. Shear walls are efficient, both in terms of construction cost and effectiveness in minimizing earthquake damage in structural system.

2) *Bracing:* The most effective and practical method of enhancing the seismic resistance is to increase the energy absorption capacity of structures by combining bracing elements in the frame. The braced frame can absorb a greater degree of energy exerted by earthquakes. Bracing members are widely used in steel structures to reduce lateral displacement and dissipate energy during strong ground motions. This concept extended to concrete frames. The various aspects such as size and shape of building, location of shear wall and bracing in building, distribution of mass, distribution of stiffness greatly affect the behaviors of structures. Diagonal bracing is efficient and economical method of resisting horizontal forces in a frame structure because the diagonals work in axial stress and therefore call for minimum member sizes in providing stiffness and strength against horizontal shear.

Fig.2 Provision diagonal bracing

Bracing system improves the seismic performance of the frame by increasing its lateral stiffness and capacity. To the addition of bracing system load could be transferred out of the frame and into the braces, by passing the weak columns. Diagonal braced frames are efficient structural system for buildings subjected to seismic or wind lateral loading. Therefore, the use of diagonal bracing system for both retrofitting as well as newly constructed RC frame with adequate lateral resistance is attractive. The diagonal braces are usually placed in vertically aligned spans. This system allows obtaining a great increase of stiffness with minimum added weight, and so it is very effective for structure for which the poor lateral stiffness is the main problem. Diagonal bracing is well suited for strengthening operations. The stiffness added by the bracing system is maintained almost up to the peak strength. Stiffness is particularly important at serviceability state, where deformation are limited to prevent damage.

Fig 3. Retrofitting by diagonal bracing

B. Objectives and Scope of the Work

Tall building developments have been rapidly increasing worldwide. The growth of multistory building in the last several decades is seen as the part of necessity for vertical expansion for business as well as residence in major cities. It is observed that there is a need to study the structural systems for R.C. framed structure, which resist the lateral loads due to seismic effect. Safety and minimum damage level of a structure could be the prime requirement of tall buildings. To meet these requirements, the structure should have adequate lateral strength, lateral stiffness and sufficient ductility. Among the various structural systems, shear wall frame or braced concrete frame could be a point of choice for designer. Therefore, it attracts to review and observe the behavior of these structural systems under seismic effect. Hence, it is proposed to study the dynamic behavior of reinforced concrete frame with and without shear wall or bracings, RC frame with infill wall effect. The purpose of this study is to compare the seismic response of above structural systems. Axial forces and moments in members and floor displacements will be compared.

The most effective and practical method of enhancing the seismic resistance is to increase the energy absorption capacity of structures by combining bracing elements in the frame. The braced frame can absorb a greater degree of energy exerted by earthquakes.

The present study is an effort towards analysis of the structure during the earthquake. G+15 stories residential building is considered. Time history method is carried out. For all the models mentioned above the base shear result are compared.

II. LITERATURE REVIEW

In Paper [1] carried out study of G + 5 storey building in zone IV is presented with some preliminary investigation which is analyzed by changing various position of shear wall with different shapes for determine parameters like axial load and moments. The project describe the analysis of structure with effect of shear wall. In Structural engineering, a shear wall is a wall composed of braced panels (also known as shear panels) to counter the effects of lateral load acting on a structure. Wind and earthquake loads are the most common loads braced wall lines are designed to counteract [11].

Paper [2] highlights the error invoived in the modeling of building as complete bare frame, neglecting the presence of infill in the upper storey are brought out through the study of an example building. Nine different models of buildings are studied and a comparative study is done. Two different analyses are performed on the model of the building considered in the study, namely, the equivalent static analysis and the multi modal dynamic analysis. They concluded that open first story is a typical feature in modern multistory constructions in Urban India. Such features are highly undesirable in buildings built in seismically active areas. They suggested some measures as increasing the size of column in the open first storey and introduction of concrete core, to reduce the stiffness irregularity and to provide adequate lateral strength. In [12] addition to this, they observed that the soil flexibility in the modeling of buildings with shear wall, failing which the drift and strength demand in the first storey column can be under estimated, resulting in an incorrect design of building. Hence under flexible soil conditions, the analytical model of building with shear walls should include the foundation flexibility.

In this Paper [4] Nonlinear structural analysis is the method for determining the earthquake response of the structural systems. Guidelines clearly point out about various methodologies as nonlinear static pushover and nonlinear dynamic time history analysis. Nonlinear dynamic time history analysis is one of the most reliable structural nonlinear analyses, however it is very complex and time consuming. Due to this kind of difficulties, FEMA 356 concluded that nonlinear static pushover analysis becomes more efficient and common. The standard commercial software is used for structural non linear analysis. Nonlinear static pushover procedure is based on the axial force –displacement relationship which shows capacity of structure under axial forces, regarding with materially and geometrically nonlinear structural theory.

Paper [5] studied steel braced frame is one of the structural systems used to resist earthquake loads in multi-storied buildings. Many existing reinforced concrete(RC) buildings can be retrofitted to overcome deficiencies, to resist seismic loads at the same time steel bracings can be incorporated with RC frames which in combine can be called as dual system to resist lateral force in the new buildings. Steel bracing is economical, easy to erect, occupies less space and has flexibility to design for meeting the required strength and stiffness. It investigate, the seismic performance of reinforced concrete buildings using concentric steel bracing. The bracings are provided at peripheral columns. A six, twelve and eighteen storied buildings are analyzed for seismic zone V as per IS 1893: 2002. Response spectrum analysis is performed for the buildings. For getting eigen values and eigen vectors the MathCAD Prime software is used. And hence storey shear and base shear are computed. The seismic performance of the building is evaluated in terms of storey drifts [14].

Paper [6] presented multistory building in high seismic areas may be susceptible to the sever damage. Along with gravity load structure has to withstand to lateral load which can develop high stresses. The shear wall is one of the best lateral load resisting systems which is widely used in construction world but use of steel bracing will be the viable solution for enhancing earthquake resistance. In this paper R.C.C. building is modeled and analyzed in three Parts I) Model without bracing and shear wall II) Model with different shear wall system III) Model [15] with Different bracing system The computer aided analysis is done by using E-TABS to find out the effective lateral load system during earthquake in high seismic areas. The performance of the building is evaluated in terms of Lateral Displacement, Storey Shear and Storey Drifts, Base shear and Demand Capacity (Performance point). It is found that the X type of steel bracing system significantly contributes to the structural stiffness and reduces the maximum inter story drift, lateral displacement and demand capacity (Performance Point) of R.C.C building than the shear wall system.

Paper [7] evaluate the performance of the framed structures under future expected earthquakes. Need was felt to evaluate the performance the of structure after Boumerdes (2003) earthquake which devastated a large part of Algeria. It is stated that pushover analysis is a viable method to assess the damage vulnerability of buildings. The paper explains pushover analysis of three framed building with 5, 8, and 12 stories representing low, medium and high rising building respectively. The study is carried out using general finite element . The result [16] show that capacity spectrum intersect the demand spectrum near elastic range of the response which shows that margin of safety against collapse is high and sufficient strength and displacement are in reserved. The paper finally concludes that behavior of properly designed reinforced concrete framed structures is adequate for design ground motion.

In this paper [8] the structural analysis is basically done by three approaches. i. Mechanics of material approach- Applied to very simple structural elements under relatively simple loading condition. ii. Elasticity theory approach- Applied to general geometry under general loading condition. iii. Finite element approach- Applied at highly complex geometry and loading conditions. Regardless of approach [17] formulation is based on the same three fundamental relations i.e. equilibrium, constitutive and compatibility. The solutions are approximate when any of these relations are only approximately satisfied. To design safe structures structural engineers must fully understand the structural behavior of these structures [9]. In [18] the long past, the structural engineers gained the knowledge into the structural behaviors by carrying out experimentations using a physical model of the real structure in the laboratory. Based on the test results, the behavior of the prototype structure can be understood and generalized. However physical modeling has its limitations, as it is expensive and time consuming. Thus mathematical modeling has been a viable alternative. Earthquake analysis of building is required to know how the building is going to behave at the time of earthquake. There are two methods of earthquake analysis static analysis and dynamic analysis. Static analysis does not give us clear idea of how the structure is going to behave during earthquake but gives approximate forces and displacements. Dynamic analysis gives

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somewhat accurate results. This method [19] requires large amount of computational work. Moreover, to carry out this analysis ground motion data is required. Author concluded that When compared with bare frames, it is found that axial force attracted by column segment at all levels remains almost same, shear force increases and bending moment reduces substantially. All frames exhibit a continuous rise in the axial force as the depth of beam increases. Shear force reduces as the depth of beam increases. This reduction was found to be 2.06 to 2.5% for 600mm beam depth for 3 bay and 4 bay structures respectively. Braces are subject prominently to axial compression and carry negligibly small shear and bending moment. Paper [9] describes the seismic retrofitting of an existing fourteen storied reinforced concrete building frame located in the seismic zone IV. The study include evolution and retrofitting of reinforced concrete frame building by using steel bracing and infill masonry walls. Seismic evolution is carried out on the basis of 2D, linear elastic dynamic analysis using response spectrum method. The study is concludes that the building design as per provision of IS:456-1978 using limit state method of design, and analyzed as per existing seismic code IS : 1893-1978, inadequate for the provision of revised code (IS :1893-2000) the seismic performance of two retrofitting techniques such as steel bracing (V, diamond and cross pattern) and infill wall are relatively compared. Among three pattern of steel bracing, cross pattern, shows better performance than V and diamond bracing pattern. The infill masonry wall in the adjacent middle bays give better performance than that are provided in the end bays [20]. Paper [10] investigate that comparison of shear wall frame versus braced concrete frame. It is observed that there is a need the study of structural systems for R.C.C framed structure, which resist the lateral loads due to seismic effect. Safety and minimum damage level of a structure could be the prime requirement of tall buildings. To meet these requirements, the structure should have adequate lateral strength, lateral stiffness and sufficient ductility. Among the various structural systems, shear wall frame or braced concrete frame could be a point of choice for designer. Therefore, it attracts to review and observe the behavior of these structural systems under seismic effect. Hence, it is proposed [21] to study the dynamic behavior of reinforced concrete frame with and without shear wall and concrete braced frame. The purpose of this study is to compare the seismic response of above structural systems. Axial forces and moments in members and floor displacements will be compared. Seismic response of braced concrete frames is compared with that of shear frames. The parameters studied [22] are width of shear wall and bracing patterns-namely X, K and inverted V(IV) shaped. It observed that location of shear wall and brace elements have significant effect on performance of frame and there appear some advantages in using reinforced concrete braced frames over shear wall frames as former results in lesser member moments and floor displacements. The code IS: 1893-2002 provides both static (seismic coefficient method) and dynamic (response spectrum method) procedures for the determination of seismic design forces for buildings. The code generally requires that the design for horizontal seismic forces be considered only in any one direction at a time. In [23] both the seismic coefficient and the response spectrum methods, consideration is given to the seismic zone where the structure is located (The building is assumed to be located in seismic zone 'III'), importance of the structure, soil-foundation system ductility of construction, flexibility of the structure, and weight of the building. Paper [13] Framed reinforced concrete structures are most commonly types of structures constructed all over the world due to ease of construction and rapid progress of work. Generally brick or block work masonry is done in these frames which act as an infill panels in the framed structure. Infill walls provide the lateral stiffness to the structure. Its behaviour is very different from the bare frame structure [24].

III. MODELING

A. Problem statement

The building is analyzed is G+15 R.C framed building of symmetrical rectangular plan configuration. Complete analysis is carried out for dead load, live load & seismic load using ETAB 2015. Time history analysis is used. All combinations are considered as per IS 1893:2016.

Typical plan of building is shown in Fig.4.1

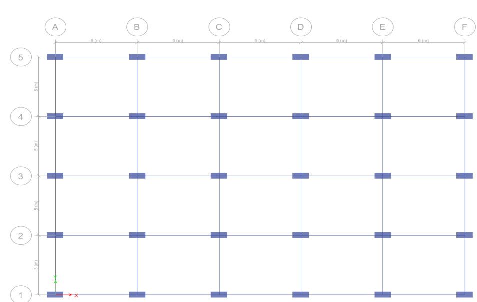

Fig.4. Plan of G+15 RCC frame building

B. Building properties

1) Site Properties

Details of building:: G+15

Plan Dimension:: 30m x 20m , 5m span in each direction.

Outer wall thickness:: 230mm

Inner wall thickness:: 230mm

Floor height ::3 m

Parking floor height :: 3m

2) Seismic Properties

Seismic zone:: IV

Zone factor:: 0.24

Importance factor:: 1.2

Response Reduction factor R:: 5

Soil Type:: medium

3) Material Properties

Material grades of M35 & Fe500 is used for the design.

4) Loading On Structure

Dead load :: self-weight of structure

Live load :: Floor :: 2.5 kN/m²

Roof:: 1.5 kN/m²

Seismic load:: Seismic Zone IV

5) Preliminary Sizes of members

Column::850mm x 350mm

Beam:: 300mm x 600mm

Slab thickness:: 125mm

Shear wall thickness:: 250mm

Steel bracing section::ISMB 350

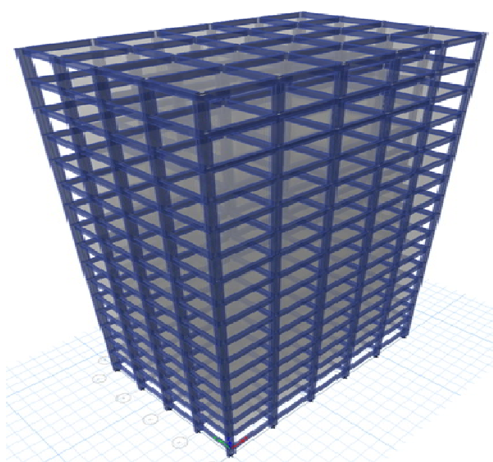

Fig.5. 3D view of G+15 RC frame building

IV. RESULTS AND DISCUSSION

A 15 storied RCC building in zone IV is modeled using ETAB 2016 software and the results are computed. The configurations of all the models are discussed in previous chapter. Eight models were prepared based on different configuration, Model 1 is Bare Frame, Model 2 Frame with Infill wall, Model 3 is Frame with outer shear wall, Model 4 is Frame with inner shear wall, Model 5 is Frame with outer diagonal steel bracing, Model 6 is Frame with inner diagonal steel bracing, Model 7 is Frame with outer X type steel bracing, Model 8 is Frame with inner X type steel bracing. These models are analyzed and designed as per the specifications of Indian Standard codes IS 1893:2016 IS and IS 456: 2000. The time history method had been used to find the design lateral forces along the storey in X and Z direction of the building.

A. Base Shear

The time history method had been adopted for seismic analysis in ETAB 2016. The Table No. 5.2.1 shows maximum base shear in X direction for Bare Frame, Frame with Infill wall, Frame with outer shear wall, Frame with inner shear wall, Frame with outer diagonal steel bracing, Frame with inner diagonal steel bracing, Frame with outer X type steel bracing, Frame with inner X type steel bracing.

Table I: Base shear (kN) in X-direction

Type of Model	Base shear (kN)
Bare Frame	1866.8742
Infill wall	3025.2636
Outer shear wall	3086.5404
Inner shear wall	3346.859
outer Diagonal Brace	2408.6223
Inner Diagonal Brace	2513.5323
outer X Brace	2599.6609
Inner X Brace	2742.4868

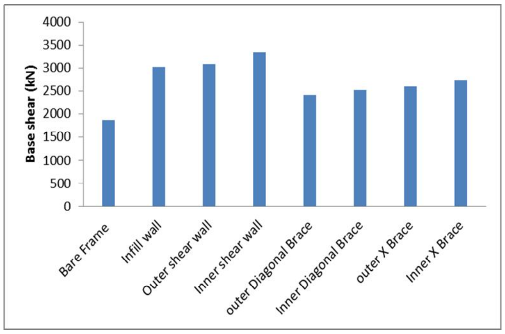

Fig. 6. Base shear (kN) in X-direction

Fig 6 shows graph of maximum base shear in X direction for Bare Frame, Frame with Infill wall, Frame with outer shear wall, Frame with inner shear wall, Frame with outer diagonal steel bracing, Frame with inner diagonal steel bracing, Frame with outer X type steel bracing, Frame with inner X type steel bracing. It shows that base shear values is maximum for frame with inner shear wall and minimum for frame with outer diagonal brace.

The Table II shows maximum base shear in Z vertical direction for Bare Frame, Frame with Infill wall, Frame with outer shear wall, Frame with inner shear wall, Frame with outer diagonal steel bracing, Frame with inner diagonal steel bracing, Frame with outer X type steel bracing, Frame with inner X type steel bracing.

Table II: Base shear (kN) in Z-vertical-direction

Type of Model	Base shear (kN)
Bare Frame	1365.433
Infill wall	2423.777
Outer shear wall	2531.7671
Inner shear wall	6907.1655
outer Diagonal Brace	1362.4756
Inner Diagonal Brace	1495.4267
outer X Brace	1474.6588
Inner X Brace	2680.0387

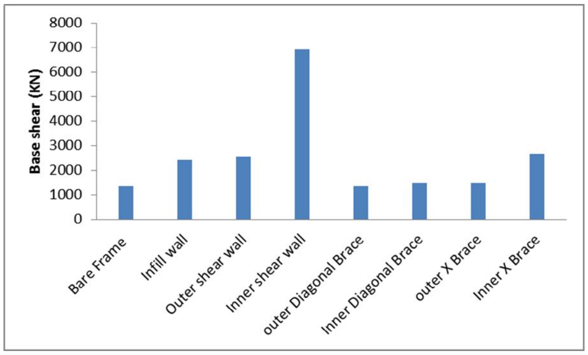

Fig. 7 Base shear (kN) in Z vertical-direction

Fig. 7 shows graph of maximum base shear in Z vertical direction for Bare Frame, Frame with Infill wall, Frame with outer shear wall, Frame with inner shear wall, Frame with outer diagonal steel bracing, Frame with inner diagonal steel bracing, Frame with outer X type steel bracing, Frame with inner X type steel bracing. It shows that base shear values is maximum for frame with inner shear wall and minimum for frame with outer diagonal brace.

B. Maximum Lateral Displacement

The time history method had been adopted for seismic analysis in ETAB 2016.The Table III shows maximum lateral displacement in X direction for Bare Frame, Frame with Infill wall, Frame with outer shear wall, Frame with inner shear wall, Frame with outer diagonal steel bracing, Frame with inner diagonal steel bracing, Frame with outer X type steel bracing, Frame with inner X type steel bracing.

Table III: Maximum Lateral Displacement (mm) in X-direction

Type of Model	Ux (mm)
Bare Frame	38.072
Infill wall	18.263
Outer shear wall	17.811
Inner shear wall	26
outer Diagonal Brace	28.898
Inner Diagonal Brace	25.58
outer X Brace	26.256
Inner X Brace	23.656

Fig. 8 shows graph of maximum lateral displacement in X direction for Bare Frame, Frame with Infill wall, Frame with outer shear wall, Frame with inner shear wall, Frame with outer diagonal steel bracing, Frame with inner diagonal steel bracing, Frame with outer X type steel bracing, Frame with inner X type steel bracing. It shows that base shear values is maximum for bare frame and minimum for frame with outer shear wall.

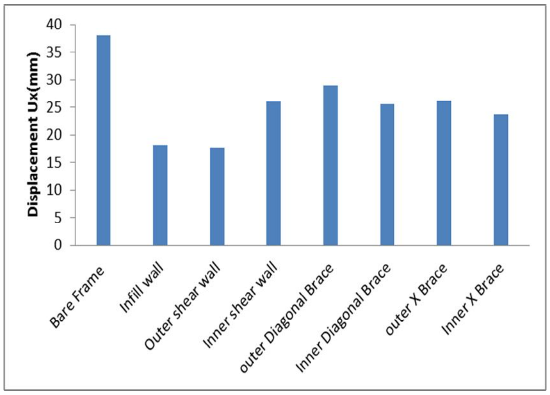

Fig. 8.Maximum Lateral Displacement (mm) in X-direction

Table IV shows maximum lateral displacement in Z direction for Bare Frame, Frame with Infill wall, Frame with outer shear wall, Frame with inner shear wall, Frame with outer diagonal steel bracing, Frame with inner diagonal steel bracing, Frame with outer X type steel bracing, Frame with inner X type steel bracing.

Table IV Maximum Lateral Displacement (mm) in Z-direction

Type of Model	Uz (mm)
Bare Frame	11.032
Infill wall	10.126
Outer shear wall	10.866
Inner shear wall	6.957
outer Diagonal Brace	11.017
Inner Diagonal Brace	10.793
outer X Brace	11.013
Inner X Brace	10.572

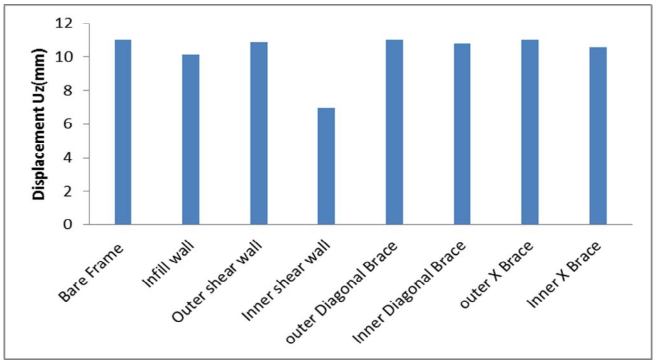

Fig.9. Maximum Lateral Displacement (mm) in Z-direction

Figure 5.6 shows graph of maximum lateral displacement in Z direction for Bare Frame, Frame with Infill wall, Frame with outer shear wall, Frame with inner shear wall, Frame with outer diagonal steel bracing, Frame with inner diagonal steel bracing, Frame with outer X type steel bracing, Frame with inner X type steel bracing. It shows that base shear values is maximum for bare frame and minimum for frame with inner shear wall.

V. CONCLUSION

Modeling and analysis is carried out for Steel frame structure, Steel frame with diagonal bracing-1, Steel frame with diagonal bracing-2,Steel frame with X type bracing-1,Steel frame with X type bracing-2, Steel frame with V type bracing-1, Steel frame with V type bracing-2, Steel frame with knee diagonal bracing-1,Steel frame with knee diagonal bracing-2,Steel frame with knee X type bracing-1,Steel frame with knee X type bracing-2, Steel frame with knee V type bracing-1,Steel frame with knee V type bracing-2in ETAB 2016. Some discussions are put here from results are as follows:

1) Modal period is maximum for normal steel frame structure.

2) Modal frequency is maximum for steel frame with X type bracing -1.

3) Bar diagram shows base shear is high for steel frame with X type bracing and least for normal steel frame structure.

4) Maximum lateral displacement is maximum for normal steel frame structure. Frame with X type bracings reduces lateral displacement upto 40% whereas frame with X type knee bracings reduces lateral displacement more than 20%. Hence response of structure is increased by combination of X type bracings.

5) Axial force in columns is maximum for steel frame with X type bracing 2 and minimum for steel frame structure.

6) Shear force in columns is maximum for steel frame with knee V type bracing 2 and minimum for steel frame with X type knee bracing 2.

7) Moment in columns is maximum for steel frame structure and minimum for steel frame with X type bracing 2.

A. Future Scope

1) The study can be further extended to analysis of irregular building.
2) Analysis can be done by using software SAP 2000, STAAD- pro etc.
3) Analysis can be carried out using Time history method.
4) Comparison of Time history method and response spectrum method can be done.
5) Analysis can be doing with different soil conditions.
6) Analysis can be done with different ground slope.

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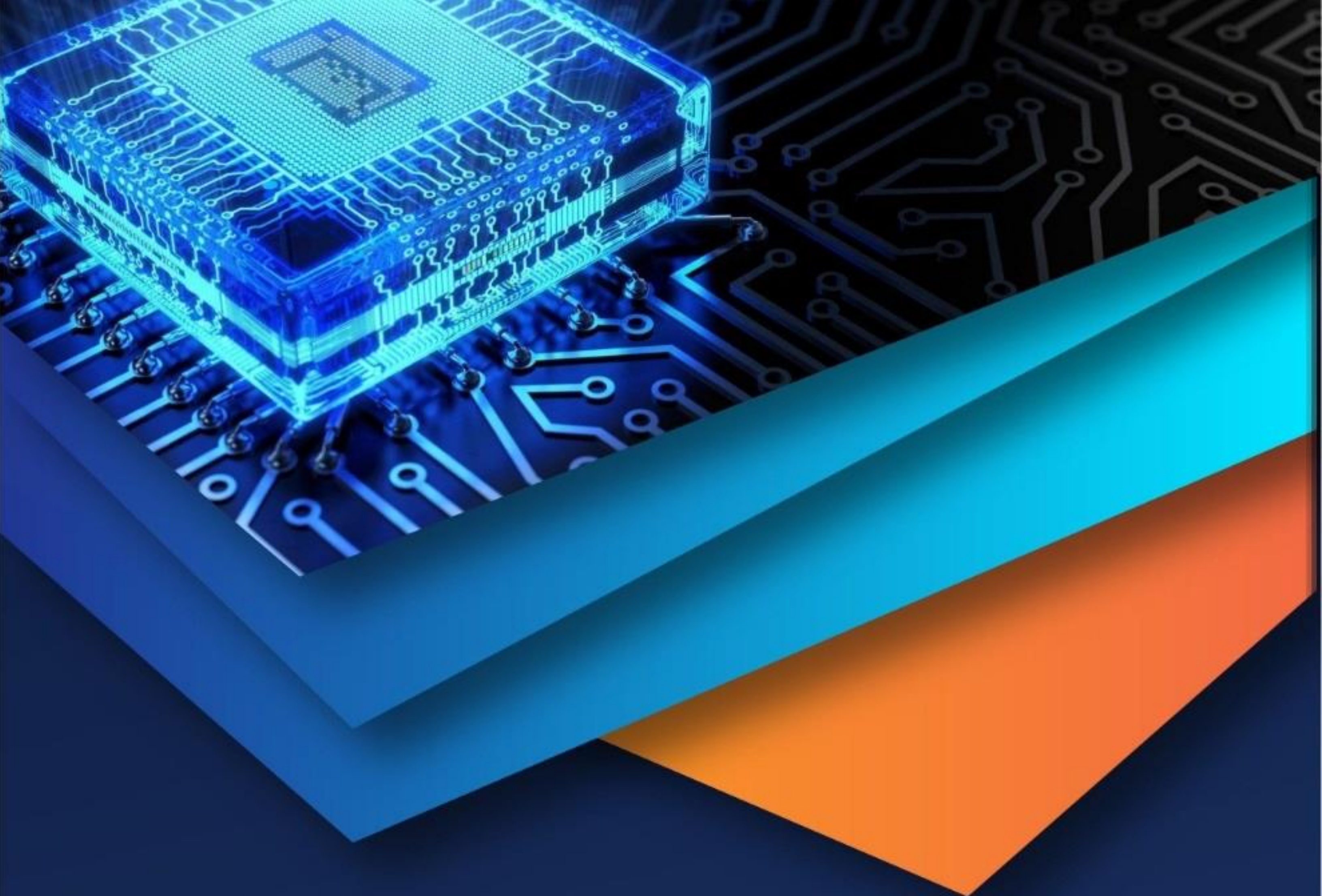

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