e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:05/Issue:10/October-2023 Impact Factor- 7.868 www.irjmets.com

ANALYSIS OF A UNSYMMETRICAL BUILDING FRAME CONSIDERING SEISMIC LOAD USING ETABS

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DOI : https://www.doi.org/10.56726/IRJMETS45054

ABSTRACT

This paper aims to determine the differences in seismic performance of regular and irregular structures in plan and also to identify a suitable method that can be used in an asymmetric structure to reduce the effect of seismic load.

Models of L-shaped and T-shaped G+15 storied buildings are considered for analysis in Etabs software. From dynamic analyses of these models, various parameters like storey shear, storey displacement and overturning moment have been calculated and compared. It is concluded that symmetrical structures are superior to asymmetric structures in view of resistance against seismic forces. Further, shear walls can be used in asymmetric structures to ensure safety against seismic forces.

Keywords: Plan Irregularity, Seismic Coefficient Method, Response Spectrum Method, Story Shear, Overturning Moment.

I. INTRODUCTION

Structural irregularities in plan. Irregularities in plan consist of four different types of structural irregularity. These are torsional irregularity, floor discontinuities, projections in plan, and nonparallel structural member axes. In this section, irregularities in plan are evaluated in detail with their solutions.

Now a days, the modern urban infrastructure demands uniqueness, which is often leading to irregular buildings. These irregular buildings are more often prone to earthquakes hence it is very essential to consider earthquake loads while designing these buildings. The IS 1893 (part 1) 2002 for earthquake resistant design of structures classifies the irregularities into 2 types namely:

1) Plan Irregularity: Plan Irregularity refers to asymmetrical plan shapes or discontinuities in horizontal resisting elements such as cutouts, large openings etc., resulting to torsion, diaphragm deformation and stress concentration. Plan irregularity is further classified as torsional irregularity, re-entrant corner, diaphragm discontinuity, out of plane offsets and non parallel systems.

2) Vertical Irregularity: Vertical irregularity is the vertical discontinuities in the distribution of mass, stiffness and strength. Vertical irregularity is further divided into stiffness irregularity, mass irregularity and vertical geometric irregularity.

A. Centre of Mass

The centre of mass is a portion defined relative to an objector system of objects. It is the average position of all the parts of a system weighted according to their masses. For single rigid body having uniform density the centre of mass shall be located at its centroid.

B. Centre of Rigidity

Centre of rigidity is the point where the whole body have fully resisting rotation. Hence, it is the point where the force is applied but the body does not rotate instead translates in space.

C. Torsional Irregularity

Torsional Irregularity is defined to exist where the maximum storey drift computed including accidental torsion, at one end of the transverse to an axis is more than 1.2 times the average storey drifts at the two ends of the structure. Torsional irregularity shall be considered when the floor diaphragm is rigid in their own plan in relation to the vertical structural elements that resist lateral forces.

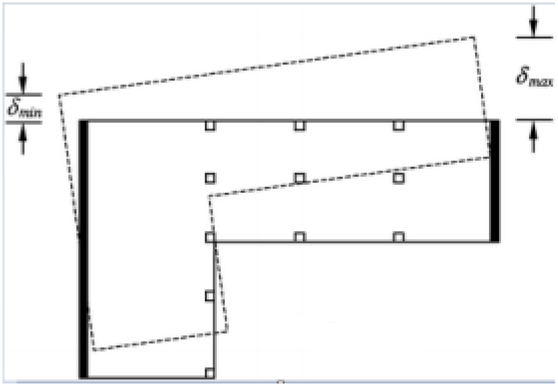

Fig 1: Torsional Irregularity

D. Re-Entrant corner Irregularity

Re-Entrant corner irrgularity is defined to exist where both plan projections of a building beyond a re-entrant corner is greater than 15 percent of the plan dimension of the building in given direction. Presence of Re-Entrant corner in a building mainly causes torsion and sterss concentration in the corners of the building.

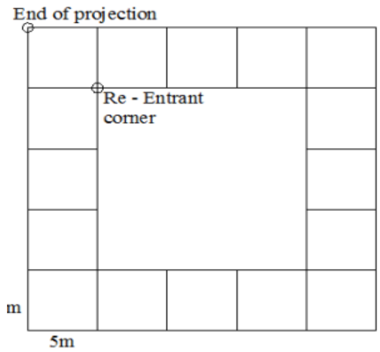

Fig 2: Plan of Regular Building

E. End of Projector

End of Projection is the external or outside corner of the structure where the two wings of the structure meets. Generally, the concentration of stress is a bit less than that of the stress at re-entrant corner. In a building, the end of projection and the re-entrant corner are considered as the most critical points.

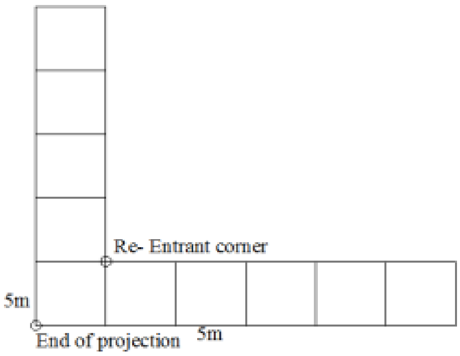

Fig 3: Plan irregular building

Objectives

- To model a symmetric structure and its equivalent asymmetric structures in Etabs and perform seismic analysis by static and dynamic methods of analysis.
- To compare the seismic response of symmetric and asymmetric structures.
- To compare the structural response from the static and dynamic methods of seismic analysis.

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- To determine a suitable method to reduce the structural response parameters in the asymmetric building.

II. LITERATURE REVIEW

B G Nareshkumar et.al (2018) research paper presented analysis of a six storey plan regular (box shape) and plan irregular (L-shape) buildings using Pushover analysis in ETABS (V15.2.2). The floor diaphragms considered were rigid and semirigid in membrane.

Results stated that the membrane with semi-rigid diaphragm and shell with semi-rigid diaphragm were performing better in the seismic area when compared to membrane rigid diaphragm and shell rigid diaphragm. It was concluded that the storey shear goes on decreases with the increase in height of the building. Similarly, the lateral displacement increases as the height of the building increases.

Divya Vishnoi (2018) research paper performed analysis on symmetric and asymmetric frame to study the behaviour of bending moments, shear forces and axial forces. The modeling and analysis works was done based on software named “Staad Pro” and “SAP: 2000”.

Results stated that symmetric model provides more Gross Leasable Area (GLA) as compared to Asymmetric model. The Load Distribution in Symmetric model is more uniform as compared to asymmetric model. The requirement of reinforcement is more in asymmetric frame than the symmetric frame. The Symmetric model is more Cost Effective with respect to Asymmetric model as the volume of material being used is more in Asymmetric model.

M R Vyas and Dr. S P Siddh (2018) research paper considered analysis of high rise structure, (27 meters) symmetric and asymmetric in shape, considering all four earthquake zones as per seismic code (Zone II, III, IV, and V) and hard, medium and soft type of soil. The modelling and analysis was done using the linear analysis approach of Equivalent Static Force method using STAAD.pro software as per IS1893-2002-Part-1.The parameters selected for comparison were deflection, storey drift, storey shear, base shear, bending moment and shear force.

The results stated that as structure was designed on the higher zone the value of SF increases by minimum 14% (for each zone) while the values for bending moment increases by around 27% (for each zone) considering all different types of soil. Maximum Storey Drift increase by 37% for zone II to III while the increment percentage reduces to 33% for higher zone. Base shear of the symmetric and asymmetric building increases by more than three times in zone V in comparison to Zone II considering all three types of soil. The value of SF and BM it is observed that for zone II to zone III, the increment is by around 37% while for zone III to zone IV and zone IV to V the percentage reduces by 33%.

Murlidhar Chourasia and Rahul Kumar Sathbhaiya (2018) author conducted a comparative study on the effect of positioning of shear wall on a un-symmetric and symmetrical, 3-dimensional structure with 2-dimensional frame to determine its positive impact to enhance resistivity and comparing the variation in forces considering seismic zone II and wind basic speed 39 m/s. Modelling and analysis is done using STAAD.PRO software. The comparison was made for the results modelled shear wall with 2-D AND 3-D models of various useful parameters such as lateral displacement, inter- storey drift, natural time period, base shear, torsion, resisting moment.

Results stated that 3-dimensional symmetric is comparatively more economical as compared to 2- dimensional, whereas in un-symmetrical case 3- dimensional shows more bending moments. Symmetric frame 2-dimensional shows more force than 3-dimensional, whereas in unsymmetrical structure result is opposite showing least in 2-dimensional and more in 3-dimensional. Axial force in 2-dimensional symmetric structure is more than 3-dimensional. Whereas 2-dimensional in unsymmetric is less than 3-dimensional.

Sumit Desai et.al (2018) research paper presented an overview of performance of the torsionally balanced and unbalanced buildings also called as symmetric and asymmetric buildings subjected to seismic analysis. ETABs software was used to analyse the structural behaviour of RCC building. It gives the comparative information between the symmetric structures and asymmetric structures. Etabs software was used to investigate the different structural parameters such as lateral displacement, time period. Structural analysis of different building elements like columns, beams, slab was done and there behavior in different seismic zones was determined.

Results stated that performance of Symmetrical building was better than Asymmetrical building. Maximum displacement for irregular shapes and minimum for regular shapes and column behaviour changes differently for Symmetrical and asymmetrical structure, as height of building increases. In comparison of torsional moment in beam the results stated that for asymmetrical building the torsional moment is more than symmetrical therefore it was necessary to design the beam and column for torsional moment. Structural parameters such as lateral displacement, time period for Asymmetrical structure was higher as compared to Symmetrical structure.

Md Jaweed Jilani Khan et.al (2018) research paper compared the Structural behavior of buildings constructed on plain ground and on hilly slopes, considering normal loads and thereafter by considering heavy loads. Three different types of Symmetrical and Asymmetrical Analytical Models were generated using "ETABS", and analyzed under the effect of normal and heavy loads separately by performing Pushover analysis.

As per the results, Response reduction factor was highest for Bare Frame and least for frames with infill. Bare frame models has the resistance capability even after occurrence of first yielding. Hence the practice of ignoring the infill during the analysis and design process will be detrimental to the structure. Displacement at First hinge formation is more for Asymmetrical buildings compared to the Symmetrical building models. Presence of infill have overall effect on the structural response of buildings when subjected to seismic forces. Displacement and drifts reduces considerably for building models with infill.

Yogesha AV and Dr. Jagadish G.Kori (2018) research paper was worried about the near investigation of balanced and unsymmetrical structure utilizing various dampers like Liquid thick and Visco-versatile dampers. Utilizing codal arrangements IS 1893 (Section I): 2002, the designs was broke down by Comparable static and Reaction range strategy. The demonstrating and examination is finished with utilizing programming ETAB 2016, Results that is seismic boundaries, for example, uprooting, story floats and story shear were organized and afterward near investigation of design with and without dampers and blend of Liquid thick and Visco-versatile dampers was finished.

Results expressed that near examination of even and unsymmetrical structure utilizing dampers were successful diminishing the underlying reactions of the design. Contrast with working without dampers the viability of added of liquid gooey dampers is decreased the seismic reaction up to 40 - 50 % in even and unsymmetrical structure. Contrast with working without dampers the adding of mix various dampers in even and unsymmetrical structure is decrease the seismic reaction up to 35 - 45%

Mohammad Noor Jan Ahmadi and Dr C. S. Sanghvi (2017) objective of the examination paper was to explore the impact of shear walls on delicate story and look at the reaction of unpredictable structure having shear walls with sporadic structures without shear walls. L-shape plan of G+7 story supported substantial structure was chosen and examined in two stages, in First Stage the structure was dissected without shear walls and delicate story in Ground floor and second stage a similar structure was broke down with shear walls and having delicate story in Ground floor. In the Second Stage likewise the shear walls are added to the model in two unique cases, to concentrate on the best area of shear walls in the building.The models are broke down by STAAD. Genius V8i SS6 programming utilizing IBC-2012(9) code (Global construction law 2012), by Straight Static Strategy. As the IBC-2012 Draft Code (Afghanistan Building regulation 2012) is utilized for structures in Afghanistan, so the IBC-2012 code was chosen for examination.

Results expressed that dislodging, story float, minutes and shear powers in radiates, minutes in sections and backing responses decline of the structure with shear walls and having delicate story in Ground floor when contrasted with the structures without shear walls and having delicate story in Ground floor. By adding shear walls to sporadic structure, for the most part the impact anomalies like delicate story float, removal and minutes and shear powers in shafts and minutes in segments of delicate story decline essentially when contrasted with different stories.

Muhammed Sabith K and Dr.Sabeena M. V (2017) in the research paper, a 10-storeyed composite structure with shear connector having irregular plan such as bilateral symmetrical and asymmetrical was compared with symmetrical structure and its variations for considered parameters with respect to RCC structure in Seismic Zone V. The parameters considered are storey displacement, base shear, storey drift, stiffness, axial force in

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columns, shear force in beams and mass of the structure. The provisions of IS-11384 1985 is considered. The seismic behavior of these structures is evaluated by Response spectrum analysis with the help ETABS V 16.

Results stated that storey shear reduced by 43% to 67% with respect to RCC structure shows composite structure is suitable for earthquake resistant constructions. Axial force in the column reduced by 14% to 42% shows that the usable floor area can be increased, due to reduction in column size. The self-mass of the composite structure is reduced by 27% to 43%. Hence the stiffness and base shear is reduced and made the structure more flexible and economical. The effect of shear connector in composite structure made composite structure more advantageous than RCC structure. Hence it was clear that the composite construction is an alternative method for the construction industry and it has a bright future in India.

B K Raghuprasad et.al (2016) research paper examined the inelastic seismic way of behaving of symmetric and uneven single and multi-celebrated structures thinking about the impacts of twist on structures. A mathematical report was accounted for on a solitary story building having 6 sections and inflexible stomach. Time history examination and steady unique investigation was performed. A 11 story working with unpredictability same on every one of the floors (uniform unconventionality) and the other with erraticism changing over the floors have been exposed to EL-Centro 1940 N-S part ground movement input and the reactions like phantom dislodging, unearthly speed increase, ghostly speed are gotten is there impressive contrast between the two.

Results expressed that regular frequencies of an uneven spring model was more noteworthy than those of symmetric spring model while the turns about the upward pivot through the mass focal point of a hilter kilter model are lesser than those of symmetric model. Most extreme removal of deviated segment model because of a tremor ground movement (unusualness 17%) was more prominent than that of symmetric section model. Likewise, most extreme dislodging of a lopsided spring model because of a seismic tremor is more prominent than that of symmetric spring model. The base shear of a hilter kilter 11 story building (erraticism 11%) is bigger than that of an even 11 story building.

III. METHODOLOGY

Initially, an architectural plan is considered that contains unsymmetrical design in L shape and T shaped modelled using ETABS software considering structural plan of the building with assumed or appropriate dimensions, Loads are put on the structure as per IS 875, factors like zone factor, importance factor, response reduction factor play a major role to determine the value of Base Shear of the structure, Design check is performed on the structure for the given value of structural member dimensions.

Geometrical Specification of the Structure

Building configuration for conventional structure	
Building configuration	G+15
Structure Type	Residential Apartment
Plan Dimension	25mx25m
Number of Bay in X-direction	5
Number of Bay in Y-direction	5
Depth of Foundation	2.5m
Bearing capacity of soil	200 KN/m2
Slab Thickness	150mm
Storey Height	3m
Wall Thickness	150mm

IRJMETS
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Parapet Wall	150mm
Section of Beam	500mmx350mm
Section of Column	450mmx450mm

IV. ANALYSIS RESULTS

The results were compared on parameters for storey drift, storey displacement, shear force, base shear and time period.

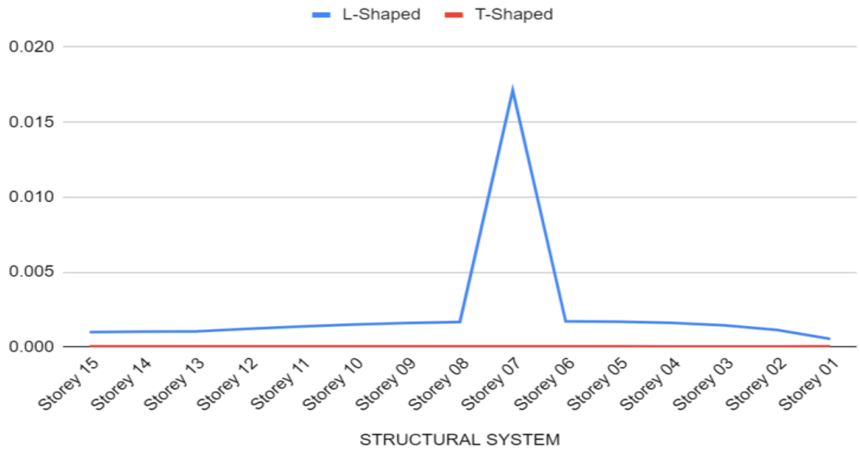

Fig 4: Storey Drift in X-direction

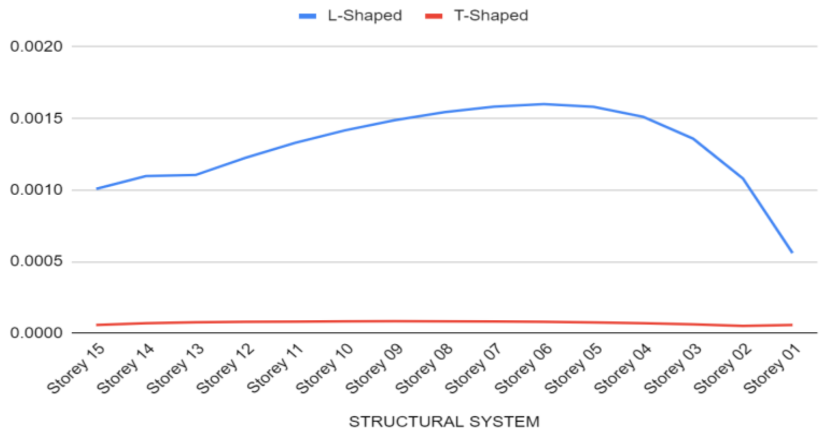

Fig 5: Storey Drift in Y Direction

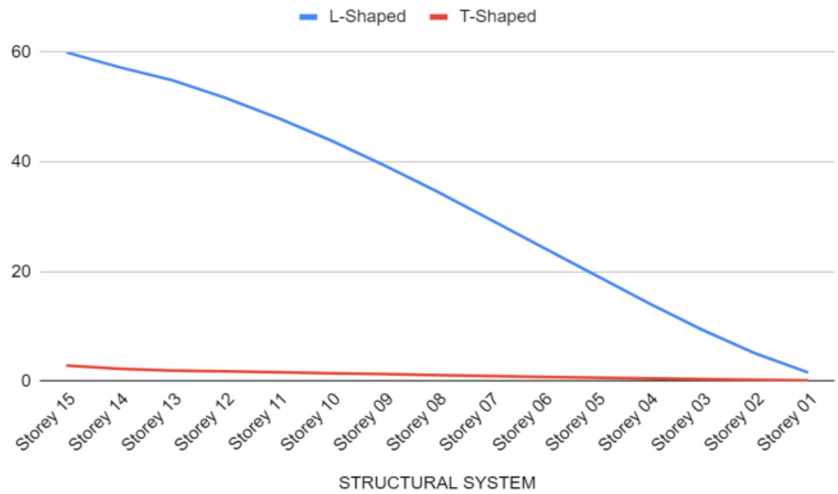

Fig 6: Storey Displacement in X-direction

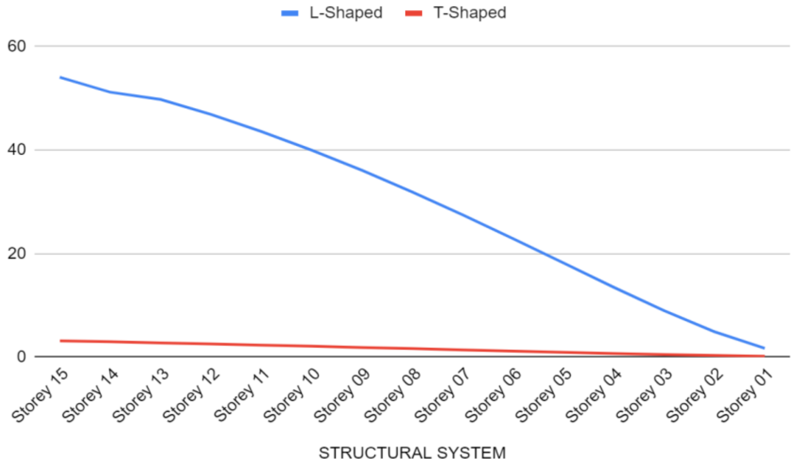

Fig 7: Storey Displacement in Y Direction

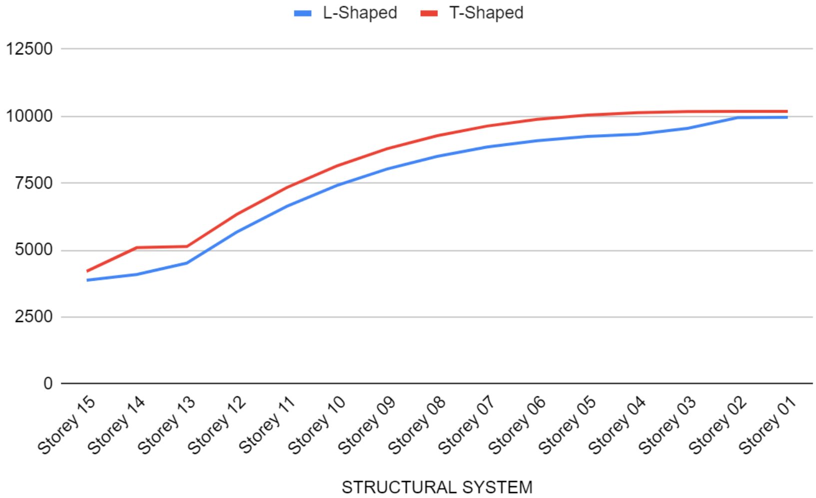

Fig 8: Lateral Load

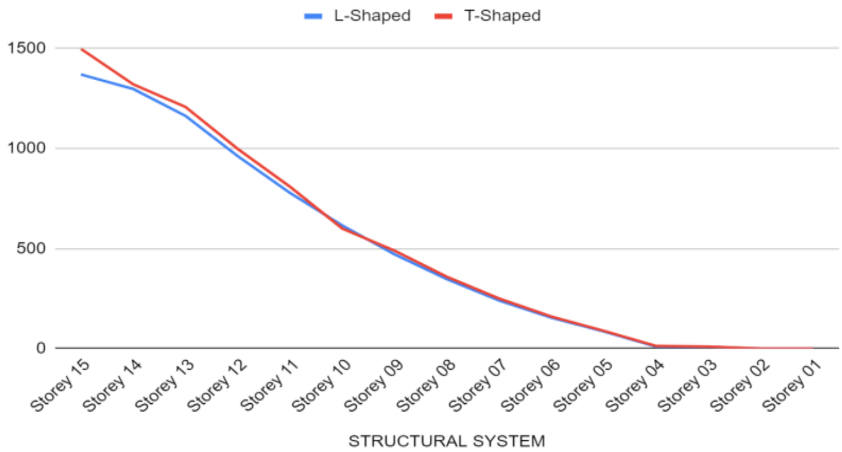

Fig 9: Storey Shear in KN

V. CONCLUSION

When building is constructed with unique asymmetrical system than the displacement is less as compared to building constructed with conventional system in X direction and Y-direction. The decrease in displacement is due to increase in stiffness. There is not abrupt change in the stiffness at various storeys and the storey drift is very less. For G+15 storey building story drift is less in both direction for T-shaped system as compared to L-shaped system. Even though lateral loads are higher in case of T-shaped structure there is decrease in displacement in both directions. Time Period value decreases and base shear value increases for T-shaped structure as compared to L-shaped structure system. Cost for construction for T-shaped structure is 20% more as compared to that of L-shaped structure.

1. Storey Drift

Storey drift is the lateral displacement of a floor relative to the floor below, and the storey drift ratio is the storey drift divided by the storey height. Storey drift was found maximum at seventh storey in case of L shaped structure in both X and Y direction with a variation of 3% was seen in comparison to T-shaped structure.

2. Storey Displacement

Story displacement is the lateral displacement of the story relative to the base. The lateral force-resisting system can limit the excessive lateral displacement of the building. Storey Displacement increase with rise in storey with a increase of 3.1% variation was seen in X direction in between L shaped structure and T-shaped structure and 1.9% variation was seen in Y direction.

3. Lateral Loads

Lateral Loads were on a marginally higher side in T shaped structure in comparison to L-shaped structure. Lateral loading is the continuous and repeated application of a load on an object or structural component in a horizontal direction or parallel to the x-axis. Lateral loading can cause a material to shear or bend in the direction of the force and ultimately lead to the failure of the material .maximum variation was seen at 15th storey.

4. Storey Shear

Story shear is the graph showing how much lateral (read: horizontal) load, be it wind or seismic, is acting per story. The lower you go, the greater the shear becomes. Story drift on the other hand is the plot of the resulting drifts per floor. Storey shear increases with increase in height which rises from 4th storey and scales to 1208.738kN. The maximum variation of 8% was seen in the results at the top storey.

5. Natural Period

Natural Period Tn of a building is the time taken by it to undergo one complete cycle of oscillation. It is an inherent property of a building controlled by its mass m and stiffness k. These three quantities are related by its units are seconds (s). The TIme period was minimal for podim structure with 0.309 sec in comparison to conventional structure to 1.801 sec.

6. Base Shear

Natural Period Tn of a building is the time taken by it to undergo one complete cycle of oscillation. It is an inherent property of a building controlled by its mass m and stiffness k. These three quantities are related by its units are seconds (s). The Time period was minimal for T Shaped structure with 0.309 sec in comparison to L-shaped structure to 1.801 sec.

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