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To Check the Seismic Response of Pyramid Shaped Building and Conical Shaped G+10 Building using ETABS

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ABSTRACT

Pyramid shape structures are one of the most applicable shapes that are used for designing of high rise buildings. Concrete braced frame is one of the structural systems used to resist earthquake loads in multistoried buildings. Many existing reinforced concrete buildings need retrofit to overcome deficiencies to resist seismic loads. The use of bracing systems for strengthening seismically inadequate reinforced concrete frames is a viable solution for enhancing earthquake resistance. Concrete bracing is economical, easy to erect, occupies less space and has flexibility to design for meeting the required strength and stiffness. In this study, the seismic analysis of reinforced concrete (RC) buildings with X bracing is studied. The bracing is provided for peripheral columns and any two parallel sides of building model. A seven-storey pyramid shaped building is analyzed for seismic zone III as per IS 1893: 2002 using ETAB software. In this paper, response spectrum analysis was executed.

INTRODUCTION

General

Pyramid shaped high rise buildings have been increasingly used in new development zones. The structural components usually consist of beams and vertical columns in middle part and inclined columns in side faces of buildings. Multistoried buildings are designed for gravity loads as well as lateral loads and their combination. Is code providing these loading combinations for which structure need to be analyzed and designed. In the analysis the internal forces in the component structures, displacements are found out. The designed structure mustbe safe for strength as well as serviceability ETABS is the present day leading design software in the market. Many design company's use this software for their project design purpose. So, this paper mainly deals with the comparative analysis of the results obtained from the analysisof a multi storied building structure when analyzed using ETABS software.

Earthquake in general had a long history of deadly devastations in the past. Earthquakes canbe measured in terms of energy release i.e. measuring amplitude, frequency, and location of seismic waves and also by evaluating intensity i.e. considering the destructive effect of shaking ground on people, structures and natural features. Basically the response of the structure due

to ground motion is an essential factor to analyze and design any earthquake resistant structure. The loads or forces which a structure subjected to earthquake motions are called upon to resist, the distortions induced by the motion of the ground on which it rests. The properties of a building are lateral stiffness, lateral strength and ductility. Lateral stiffness refers to the initial stiffness of the building, even though stiffness of the building reduces with increasing damage. Lateral strength refers to the maximum resistance that the building offers during its entire history of resistance to relative deformation.

Ductility towards lateral deformation refers the ratio of the maximum deformation and the idealized yield deformation. The effect of the vertical component of ground motion is generally considered not to be significant and is neglected except in cantilevers.

Seismic Analysis

Earthquake is a natural procedure of shaking ground due to movement of tectonic plate. The force of earthquake is random so the design engineer need to care full predict of these force and analyze the structure under these random force. Earthquake loads are to be carefully modeled so as to assess the real behavior of structure with a clear understanding that damageis expected but it should be regulated. Earthquake plays an influential role in analysis and design of structures. Seismic analysis is a branch of structural analysis that involves calculation of a building's (or non building's) earthquake response. Analysis is the process to determine the behavior of structure under specified load combinations.

LITERTURE REVIEW

General

The research papers from authors are summarized below which have investigated analysis ofcomplex structures using different analytical tools.

M Rame Gowda and Hanumesh (2022) research paper presented analysis and comparison of (G+40) high rise building subjected to combined effect of earthquake and wind load using ETAB software. Analysis was performed using equivalent static method and response spectrum method for different soil types under various earthquake zones using ETAB software. Results stated that storey shear of seismic zone V was higher than 72.2%,55.55%, and 33.33% as compared to zones II, III, and IV respectively. The storey drift of seismic zone V was higher than 3.6,2.25, and 1.5 times higher than the zones II, III and IV respectively. The storey displacement of seismic zone V is higher than3.6, 2.25, and 1.5 times higher than the zones II, III, and IV respectively. The overturning moment of seismic zone V was higher than 72.22%, 55.55%, and 33.33 % as compare to zones II, III, and V respectively.

Vinay M R et.al (2022) in the research paper, a G+3 storey building was modeled using theexisting beam and column cross sections. In addition, models with reduced cross sectional areas of 5%, 10%, and 15% were developed and static linear analysis was performed using Etabs software in accordance with IS1893 (Part-1):2016. The parameters considered for the analysis were storey displacement, storey drift, and base shear.

Results stated that storey drift and storey displacement increase with a decrease in cross-section from 0% to 10%. Despite a drop in cross-section of 0% to 15%, the base shear only decreased by 2 to 3% respectively. it was not advised to modify the specified cross-section sizes. The existing building details were adequate to satisfy the earthquake criteria as described in IS1893 (Part-1):2016.

Krishna Prasad Chaudhary and Ankit Mahajan (2021) in the research paper, several high rise buildings were analyzed using CSI ETABS under the influence of the response spectrumanalysis over it. Several different shaped high rise buildings such as H shaped, O shaped and C shaped buildings were taken into consideration for carrying out the research work. All three shaped buildings were of different storey, that was of 12 storey and of 16 storey.

H-shaped building showed better results as compared to the other shaped building. With the transference of heavy mass, very little effect was seen in latera sway i.e. variation in maximum displacement was negligible. Again, for 16 storey building, maximum displacement was found in the case L-Shaped 16 storey building with the value of 87.804 mm. Again, the transferenceof heavy masses had a minimal effect on total quantity and cost of the 16 Storey building. hence results concluded that bending moments and shear forces were increased from 1.17% to 1.84%. Maximum variation in B.M and S.F. was seen in O-shaped Building. L-shaped Building produces maximum displacement from all the three irregular shapes i.e. H-shape, L-shaped and O-shaped.

Minal Dnyaneshwar Jadhav and S.V.Shelar (2021) objective of the research paper was toanalyse and design the RCC tall building G+25 storied for dynamic responses as per Indiancode IS 1893 Part I and further analyze the RCC tall building for dynamic responses with different thickness of boundary elements of Special shear walls as per Indian code IS 1893 PartI and with special shear wall having different boundary elements.

Sindhu Nachiar S et.al (2021) objective of the research paper was systematic seismic analysis of a conical and pyramidal frustum shaped commercial building (G+6) at Janakpuri, Delhi using STAAD.Pro V8i. The buildings are located in seismic zone IV. The result of the analysis aidsto understand and compare the storey drift, storey displacement and stiffness of the structuressubjected to earthquake forces. For the beam, the bending moment is reduced by 0.498 %, shear force is reduced by 23.86 % and deflection is increased by 66.73 % in square pyramid frustum building when compared to conical frustum building. For the column, the bending moment is reduced by 48.47 %, shear force is increased by 48.37 % and deflection is increased by 21.66 % in square pyramid frustum building when compared to conical frustum building. The average displacement is reduced by 15.39 % in square pyramid frustum building when compared to conical frustum building. The drift is reduced by 13.92 % in square pyramid frustum building when compared to conical frustum building. The time period is reduced by 13.55 % in square pyramid frustum building when compared to conical frustum building. Hence results concluded that Square pyramid frustum building have better seismic performance.

Bin Jiang et.al (2020) in the research paper, data collection and statistics was carried out on 28 special ultra-high buildings (including some 300m~400m representative super-tall buildings) which have been built in the world. Special ultra-high-rise buildings have developed rapidly in recent years, especially in China, which accounts for an increasing proportion of the world's highest buildings. The overall building height-to-width ratio and core tube height-to- width ratio have little correlation with the structural height. The demand of core tube area is not directly proportional to the building height. Facade selection is characterized by simplicity, regularity, tapering and continuity. There are 7 main types of commonly used structural system: frame - core tube, tube in tube (including box tube - core barrel, oblique net tube - all the coretube), giant column - core barrel - cantilever truss, giant column - giant brace - core barrel, giant column - giant brace - core barrel - cantilever truss, beam tube structure, buttress core barrel. The order is according to the minimum using highly respectively. Most of the Special ultra-high-rise building's foundations use the form of "pile foundation +raft". The thickness of the bottom plate is positively correlated with the height and depth of the structure. Raft thickness can be estimated by 0.044 times the number of building floors.

Nikita kosta et.al (2020) in the research paper, a G+10 Earthquake pyramid structure was designed and analyzed using analytical application STAAD.pro. In this structure, there was adecrease in length and breadth while construction is process on one by one floor. Primary target was to investigate seismic analysis of structure in static and dynamic condition.

Structure have support on X and Z direction by its own structure member not an externalSupport.

Dr. Mahdi Hosseini and Zahra Nezhadasad (2019) research paper aimed to study the behavior of high rise structure with dual system with different type of RC Shear Walls (C, Box, E, I and Plus shapes) under different type of soil condition with seismic loading.

Estimation of structural response such as; storey displacements and Time period and frequency was carried out. In dynamic analysis; Response Spectrum method was used. Thirty story building with C Shape, Box shape, E Shape, I shape and new shape (Plus shape +) RC Shear wall at the center in Concrete Frame Structure with fixed support conditions under differenttype of soil for earthquake zone V as per IS 1893 (part 1) : 2002 in India are analyzed using software ETABS by Dynamic analysis.

It was found that the behavior of new shape (plus shape) of the RC shear wall was not more different with I and box shape and also there is no more difference between 1.5 (DL + EL) and 1.2 (DL + IL ± EL) combination load. It was evident that shear walls which are provided from the foundation to the rooftop, are one among important means for executing quake resistantmultistory building with different type of soil. For severe lateral loads caused by wind load and or earthquake load, the reinforced shear wall is obvious. Because it produces less deflection and less bending moment in connecting beams under lateral loads than all others structural systems.

Giuseppe Nitti et.al (2019) objective of the research paper was to analyse the Piedmont Region Headquarters Tower, using an analytical formulation which enables the calculation of structural displacements and stresses. The analytical formulation used in the static and dynamic analysis of the structure was implemented using Mat lab computation code. A computational model was also created using a commercial Finite Element Code to validate the results. The results obtained with the analytical model were compared with those obtained with the FEM model.

The transversal displacements, bending, torsional, and axial stresses in the vertical bracings were calculated, along with the principal natural frequencies of the structure. Conclusion proved that analytical calculation codes are a good tool for the preliminary designof a high-rise building. In particular, the proposed formulation, which has only three degreesof freedom per floor, provided results similar to those obtained using a FEM model.

The greatadvantage of this analytical code is to speed up the computation time, which is proportional tothe square of the degrees of freedom. In a FEM model, these have orders of magnitude greater than in the analytical model. Moreover, the proposed formulation allows the load distributionbetween the structural elements to be determined.

Hanna Golasz-Szolomicka and Jerzy Szolomicki (2019) research paper presented presents an architectural and structural analysis of seven selected tall buildings with a twisted form, of which three have a residential function (the Cayan Tower, the Absolute World Tower, the Agora Garden Tower), three office function (the Al Bidda Tower, the EvolutionTower, the Shanghai Tower) and one educational (the Mode Gakuen Spiral Towers). Buildings are characterized by different bodies and plans that are not related to the function of the object.

J. Singh and A K Roy (2019) research paper demonstrated the pressure variation due to wind load on a two storey building with a square plan and a pyramidal roof through CFD simulation. ANSYS Fluent was used for the simulation and ANSYS CFD-Post was used for observing the wind pressure on building roofs. The simulation was performed using the realizable k-ε turbulent model by considering grid sensitive analysis and validation with previously published wind tunnel experimental measurements. The research included wind behaviour around the building model with different roof slopes. Comparisons of pressure coefficients was shown for five wind incidence angles to study the effect of wind on the building. Double storey square plan pyramidal roof building models have been investigated in the present study with roofslopes of 20°, 25°, 30°, 35° and 40°, for 0° wind incidence angle to determine the wind pressure coefficients.

Jibi Abraham and Reshma C (2018) objective of the research paper was to analyze pyramid shaped building using E-tabs on the parameters of story drift, displacement, shear and story stiffness on different floor.

Result stated that the displacement is decreased in pyramid shaped building with x bracing as compared to pyramid shaped building without bracing. The story stiffness is more in pyramidbuilding with x bracing than the pyramid building without bracing. The story drift is decreased in pyramid building with x bracing than the pyramid shaped building without bracing. The pyramid shaped building was suitable in earthquake prone area due to its higher stiffness andless displacement. The inclined columns of pyramid shaped building resist the lateral displacement effectively. So the % reduction of lateral displacement by the use of x bracing is 5% to 10%. Results suggested that building with inclined column is excellentseismic control for high-rise Buildings.

S .Vijaya Bhaskar Reddy and M. Eadukondalu (2018) in the research paper, a Plain frame system, a Shear wall system and framed tube system were considered for 30,40,50,60 storeystructures. The analysis has been carried out using software STAAD Pro-2005. The roof displacements, internal forces (Support Reaction, Bending Moments and Shear Forces) of members and joint displacements were studied and compared.

Shear wall system was very much effective in resisting lateral loads for the structures up to 30stories and for structures beyond 30 stories the Framed tube system is very much effective than Shear wall system in resisting lateral loads. For the structure with framed tube, the maximumsupport reactions for outer periphery Supports are much less compared to that of the Shear wall structure as the columns are very close to each other.

Maximum Base shear for the 30 storey structure is observed for structure with Shear wall system. Maximum Base Shear for 40, 50 and 60 storey structures is observed for structure with framed tube system.

Sayyed Javad and Hamane Ajay A. (2018) research paper intended to compare the seismicanalysis of various shapes of high rise buildings with different International Codes namely Indian Standard and American Standard. In R.C. buildings, frames were considered as main structural elements, which resist shear, moment and torsion effectively. These frames be subjected to a variety of loads, where lateral loads was always predominant. Seismic Analysis of Square-Type and C-Type shape of G+10 buildings by IS 1893(Part-I):2002 Criteria for Earthquake Resistant Design of Structures was done. Multi-storied Reinforced concrete, moment resisting space frame have been analyzed using professional software. Square-Typeand C-Type shape of G+10 buildings frame with six bays in horizontal and six bays in lateraldirection is analyzed by Equivalent Static Method and Response Spectrum Method.

Ahmed Abdelraheem Farghaly (2016) research paper dictated the behavior of shear wall under a seismic event in slender high rise buildings, and studies the effect of height, locationand distribution of shear wall in slender high rise building with and without boundary elements induced by the effect of an earthquake. Shear walls were located at the sides of the building, to counter the earthquake forces. This study was carried out in a 12 storeysbuilding using SAP2000 software.

Mirghaderi et.al (2007) in the research paper, three type buildings; symmetric pyramid, asymmetric pyramid and regular structures which in 8-Storey & 16-Storey were employed. Symmetric variants of the buildings were designed according to AISC seismic provision of steel structure pre-standards. Symmetric pyramid 8-storey and 16-

storey structureswith different slope faces which change from 200% to 900% at side faces are selected andcompare lateral stiffness of test structures with regular structures with same storey and shape. Results demonstrated that symmetric and asymmetric pyramid structures especially withextreme slope such as 200% and 300%, due to seismic forces has not equal variation of lateralstiffness in each storey's as same as regular buildings and need precise analysis such as modalresponse spectrum, non-linear static analysis or Time-history analysis to design it in safemanner.

METHODOLOGY

General

In present study, two models of three dimensional R. C. Frame conical shaped and pyramid shaped are modeled for G+11 Floor building with symmetrical plan. The R.C. frame structures are designed and analyzed according to IS 456:2000 and IS 1893:2016 by using ETABS software.

Steps involved in the Modelling and Analysis

Step 1- the research papers from different authors were summarized to understand the behaviour of connected towers and the research done till date.
Step 2: In order to initiate the modelling of the case study, firstly their's need to initialize the model on the basis of defining display units on metric SI on region India as ETABS supportsthe building codes of different nations. The steel code was considered as per IS 800:2007 andconcrete design code as per IS 456:2000.
Step 3: ETABS provides the option of modelling the structure with an easy option of Quick Template where the grids can be defined in X, Y and Z direction. Here in this case, 5 bays in considered in both X and Y direction with a constant spacing of 4m making the model symmetrical in nature. G+10 storey structure is considered with typical storey height of 3.2 m.
Step 4: Next step is to define material properties for concrete and steel. Here in this case study, M30 concrete and rebar HYSD 415 is considered and its predefined properties are available in the ETABS application.
Step 5: Defining section properties for Beam, Column. Beam size of 400x300mm, Column sizeof 500x300mm and Slab size of 150 mm is considered in the study.
Step 6: Assigning Fixed Support at bottom of the structure in X, Y and Z direction in both theconsidered cases.
Step 7: Defining Load cases for dead load, live load and seismic analysis for X and Y Direction.
Step 8 Defining Seismic Loading as per IS 1893: 2016 Part I.
Step 9: Conducting the model check for both the cases in ETABS
Step 10: Analyzing the structure for dead load, stress analysis and displacement.

PROBLEM IDENTIFICATION

General

In the study the behaviour of conical building and pyramid shaped structure under seismic loads was investigated. An analysis of buildings with 11 storeys has been carried out. The buildings were assumed to be located in seismic zone III. The analysis of the building has been carried out by Seismic Coefficient Method Approach using Etabs. The seismic responseof various buildings was compared in terms of Storey drift and Average displacements Four RC framed regular buildings with different heights and with four different locations of shear walls situated in seismic zone V have been taken for the purpose of the study. The other features of the buildings are as follow.

Methods of Seismic Analysis of Structure

Various methods of differing complexity have been developed for the seismic analysis ofstructures. The two main techniques currently used for this analysis are:

a) Static Analysis
b) Dynamic analysis.
c) Linear Dynamic Analysis.
d) Non-Linear Dynamic Analysis.
e) Push Over Analysis

Dynamic Analysis

When subjected to loads or displacements, any true physical structure exhibits dynamic behaviour. Newton's second law states that the inertia force is equal to the mass times the acceleration. A static load analysis can be justified if the loads or displacements are appliedextremely gradually since the inertia forces can be ignored. So, dynamic analysis is just a straightforward extension of static analysis.

Response Spectrum Analysis
The response spectrum technique is really a simplified special case of modal analysis. The modes of vibration are determined in period and shape in the usual way and the maximum response magnitudes corresponding to each mode are found by reference to a response spectrum. The response spectrum method has the great virtues of speed and cheapness. Thefundamental mode superposition technique, which is limited to linearly elastic analysis, yields the full time history response of joint displacements and member forces in response to a particular ground motion loading. There are two major disadvantages of using this approach. First, the method produces a large amount of output information that can require an enormousamount of computational effort to conduct all possible design checks as a function of time.

Second, since a response spectrum for a single earthquake in a particular direction is not a smooth function, the analysis must be performed multiple times for various earthquake movements in order to ensure that all relevant modes are activated.

The response spectra approach of seismic analysis offers significant computing benefits for predicting displacements and member forces in structural systems. The process entails employing smooth design spectra—the average of numerous earthquake motions—to calculate only the maximum values of the displacements and member forces in each mode.

Nonlinear Dynamic Analysis
Nonlinear Dynamic analysis can be done by direct integration of the equations of motion bystep by step procedures. Direct integration provides the most powerful and informative analysis for any given earthquake motion. The earthquake response history of the structure is computed after the application of a time-dependent forcing function (seismic accelerogram). That is, the moment and force diagrams at each of a series of prescribed intervals throughout the applied motion can be found. Computer programs have been written for both linear elastic and non-linear inelastic material behavior using step-by-step integration procedures.

Push Over Analysis
The push over analysis, also known as the non-linear static process, is a straightforward method for calculating the strength capacity in the post-elastic range. This process entails applying alateral load pattern that is predetermined and dispersed along the building height. Then, until a certain degree of deformation is attained, the lateral forces are monotonically increased in constant proportion with the building's displacement control node.

The applied base shear and the associated lateral displacement at each load increment are plotted. Based on the capacity curve, a target displacement which is an estimate of the displacement that the design earthquake will produce on the building is determined. The magnitude of the building's damage at this target displacement is thought to be typical of thebuilding's damage when subjected to design-level ground shaking.

RESULTS AND DISCUSSION

General
The two cases were evaluated for comparative analysis of conical and pyramid structure modelled and analyzed using analytical application ETABS. The analytical results were computed on grounds of displacement, moment, axial force, shear force, mode of period in sec.

CONCLUSION

The two cases were evaluated for comparative analysis of conical and pyramid structure modelled and analyzed using analytical application ETABS. The analytical results were computed on grounds of displacement, moment, axial force, shear force, mode of period insec. The design of complex building subjected to seismic effects cannot be based on analytical results obtained from general multistoried structure. As seen in results, the displacement values for conical structure and pyramid structure cases for X direction gradually decrease.

Maximum Displacement
The pre-peak displacement, or 75% of peak load, and post-peak displacement, or 80% of peakload, are used to define the yield displacement and maximum displacement, respectively. The displacement was higher by 8.2% for conical structure in comparison to other case of pyramidstructure.

Storey Drift

The distance between two consecutive storeys divided by the height of that level is known as "storey drift." Additionally, story displacement is the magnitude of the storey's movement as a result of lateral forces. When designing partitions and curtain walls, story drift is crucial. Storey drift was higher at the centre where storey drift was 1.9% higher in case of conical structure in comparison to pyramid structure.

Storey Stiffness

The ability of structure to resist lateral deflection when a lateral force is applied. This is alsocalled Storey Stiffness, wherein the lateral deflection is storey drift and lateral force is storeyshear. Storey stiffness was 4.9% less in case of pyramid structure in comparison to conical structure.

Base Shear

Base shear is a measurement of the greatest predicted lateral force from seismic activity on the base of the structure. It is determined using the lateral force formulae for the seismic zone, soil type, and building code. Base shear was 7.1% higher in case of conical structure in comparison to pyramid structure.

Time Period

A building's natural period is simply how long it takes for an oscillation to complete. One of abuilding's characteristics that is governed by mass and stiffness is its natural period. The Timeperiod was determined for the fundamental period from stage one to stage tenth. Time periodwas found maximum in both the cases in the first stage and reduced drastically from the fourth stage in both the cases and a gap of 2.1% was seen in comparison of both the cases.

Storey Shear

The ratio of the story shear force at the time of story collapse to the story shear force at the time of entire collapse is known as the storey shear factor. Simple formulae are tentatively provided to calculate the necessary story shear safety factor that can be utilised to prevent story collapse through a series of dynamic assessments. In each of the comparison scenarios, there was a minor difference of 1.29%.

Axial Force

Axial force refers to a load whose line of action runs along the length of a structure or perpendicular to the structure's cross-section. Axial force was found maximum in case of conical structure by 3.9% in comparison to pyramid structure.

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