Structural Analysis of Building Using ETABS For Different Plan Configuration

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Abstract- *ETABS use for analysis of concrete as well as steel structure. Extended Three-dimensional Analysis of Building System means ETABS also used for analysis and design of high rise building and also skyscrapers. In this study we are going to observe the effect of different plan configurations on performers of building. We will observe the maximum shear force, maximum bending moment, maximum story displacement and story drift for different plan configuration for skyscrapers.*

Keywords- Structural analysis, Skyscrapers, ETABS, Plan irregularities.

I. INTRODUCTION

ETABS is very useful software to analyse the structure. World tallest building “Buraj Khalifa” was analyse and design using this software. It will provide us nearly actual behaviour of structure.

In this study Rectangular, L, C, I and E shape buildings will analyse using ETABS. For these we will take 40m X 24m size of building and G + 15 + Terrace and G + 30 + Terrace, having storey height3m each. Total height of building 45.45m& 90.45m respectively. Live, earthquake and wind load are applied to structure accordance with IS 875 part II, IS 1893: 2016, IS 875 part II respectively. Wall load are applied accordingly with storey height.

Spectrum analysis will be carried out for the structure. Initially we assume site located in Pune i.e., Earthquake zone III, Soil type II and basic wind speed 39 m/s., terrain category II and class B.

Because of the nature of earthquakes, a dual design philosophy has been adopted for the design of buildings in earthquake prone regions. The first design criterion is to ensure that little or no damage is suffered during an earthquake that can reasonably be expected to occur during the life-time of the structure. The second is that the building does not collapse during the most severe probable earthquake that could occur at that site. The corollary of this is that if the building is to remain cost effective the second criterion will make it necessary to design the building in elastically.

It is for this reason that all buildings designed in regions where earthquakes pose a serious threat to infrastructure are in some way designed in elastically. At present three main methods are used to analyse buildings subjected to earthquakes. These are:

1. Response history analysis.
2. Response spectrum analysis.
3. Quasi-static method.

Response history analysis is potentially the most accurate but there are two problems associated with it. The first is that it can be difficult to choose an appropriate earthquake to use as the loading, while the second is that it is generally too computer-intensive to be practical especially if inelastic analysis is considered. The computer resources required to perform a response history analysis on a detailed inelastic finite element model are generally considered prohibitive.

The most commonly employed method is the quasistatic method, as it is the simplest, requires only static analysis, and estimates the response of the structure foran ensemble of earthquakes.

The response spectrum method is identical to the quasistatic method except that it considers more than just the fundamental mode of vibration. Most codes require that enough modes of vibration are considered to account for90% of the modal mass.

For the quasi-static method and the response spectrum method the earthquake forces are divided by a behaviour factor (also known as a structural response factor or response modification coefficient). This factor accounts for the reserve strength of the building after the formation of the first plastic hinge and allows a pseudo inelastic design to be achieved without complicating the analysis. The only extra requirement to account for inelastic behaviour is for the designer to choose an appropriate building behaviour factor. Typically, this is done by choosing a value from a table in a relevant earthquake code. This is simple and reasonably effective but it is overly conservative. The various ductility factors have been arrived at empirically based on past experience of structural behaviour during earthquakes and based on generalised analysis of simple models of various building types.

A recent improvement to this technique, known as modal push-over analysis (which accounts in an approximate way for the effects of yielding) has been developed and evaluated by Chintanapakdee and Chopra. The combination of modal responses remains problematic, and results suggest that significant errors may arise in the analysis of tall and/or reduced-strength frames. The method is evaluated by comparing results with those of(non-linear) response history analysis, which evidently remains our most reliable analytical tool. Other recent developments of the push-over technique include that of Kim et al. where the procedure is enhanced by considering more than just the fundamental mode and recalculating mode shapes whenever yielding occurs.

Tall buildings, which are usually designed for office or commercial use, are among the most distinguished space definitions in the architectural history of American urbanism in the twentieth century. They are primarily a reaction to the rapid growth of the urban population and the demand by business activities to be as close to each other as possible. Architect’s reinterpretations of the building type, the high cost of land in urban areas, the desire to prevent the disorganized expansion, the need to preserve agricultural production, the concept of skyscraper, influence of cultural significance and prestige, have all contributed to force buildings upward. Today, it is virtually impossible to imagine major city without tall buildings. The importance of tall buildings in the contemporary urban development is without doubt ever increasing despite their several undeniable negative effects on the quality of urban life.

Many researches and studies have been done in order to mitigate excitations and improve the performance of tall buildings against wind loads & earthquake loads. An extremely important and effective design approach among these methods is aerodynamic modifications, including, modifications of building’s corner geometry and its cross-sectional shape. Tall buildings are gigantic projects demanding incredible logistics and management, and require enormous financial investment. A careful coordination of the structural elements and the shape of a building which minimize the lateral displacement, may offer considerable savings. Nowadays, the challenge of designing an efficient tall building has considerably changed. The conventional approach to tall building design in the past was to limit the forms of the buildings to a rectangular shape mostly, but today, much more complicated building geometries could be utilized.

The increase in population by which land deficit occurs and to overcome that, high-rise buildings are opted. These types of high-rise buildings are affected by the natural calamities. Calamities like earthquakes are the most dangerous by means of the damage and chaos caused to the structural components and they cannot be controlled. These natural calamities caused property damage and interruptions in development of the normal lifecycle. Since it’s a global concern, most of the analysis should be carried out and provided with the results to prep the structure in order to attain time period. With the technological advancement, man tried combating with these natural calamities through various ways like developing early warning systems for disasters, adopting new prevention measures, proper relief and rescue measures. But unfortunately, it is not true for all natural disasters. Hazard maps indicating seismic zones in seismic codes (IS 1893:2002) are revised from time to time which leads to additional base shear demand on existing buildings. The collapse of a structure can be minimized if the following points are taken in to consideration.

II. LITERATURE REVIEW

S. M. Wilkinson, R. A. Hiley

In this paper author study a non-liner response history model for the seismic analysis of high rise framed buildings. An efficient simplified model for the analysis of high-rise buildings has been presented. This model can analyse nominally symmetric structures using only $v + 1$ degrees of freedom per floor (where v is the number of vertical elements in a floor).The rank of the condensed stiffness matrix is only *m*. Its construction, which requires the inversion of the rotational, rank *mv*, stiffness matrix, is required only at time-steps where the pattern of yielding has altered from the previous time-step. This makes it particularly attractive for non-linear response history analysis. Three verification examples have been presented. The model was shown to be capable of analysing simple structures to within less than 1% of the results obtained by finite element analysis. The model accurately predicts higher modes of vibration and therefore can be used to consider the influence of these on the collapse of buildings. Using a simple push over analysis for structures with significant 2nd modal masses and accelerations may produce the wrong collapse sequence and therefore the incorrect collapse load. To accurately determine the collapse loads of structures, P–d effects need to be considered as does the true moment rotation relationship of the connections especially if stiffness degrades over successive cycles.

Abhay Guleria

Author studied the structural analysis of a multi stored building using ETABS for different plan configuration, such as rectangular, C shape, I shape & L shape. The analysis of the multi-storeyed building reflected that the storey overturning moment varies inversely with storey height. Moreover, L-shape, I-shape type buildings give almost similar response against the overturning moment.Storey drift displacement increased with storey height up to 6th store reaching to maximum value and then started decreasing. From dynamic analysis, mode shapes are generated and it can be concluded that asymmetrical plans undergo more deformation than symmetrical plans.

Anupam Rajmani, Prof Priyabrata Guha

Study of analysis of wind & earthquake load for different shape of high-rise building given in this paper. Effect of wind &earthquake on different shape of building for different height was studied. There is not a definite description for “tall building”, “high-rise building” and “skyscraper” in terms of height, or number of stories. Although the terms all mean the same type of building which is built extremely high, there is an implicit difference among them.For 15 storied building the most stable structure is circular shape and triangular shape for maximum earthquake and maximum wind load respectively, similarly for 30 storied building, rectangular shape is most stable for maximum earthquake and wind load and for 45 storied building circular shape & rectangular shape is most stable for maximum earthquake and windload respectively. With respect to node displacement triangular shaped building is least stable for 15 & 30 storied building whereas for 45 stories building rectangular shape is least stable. In terms of maximum Mz triangular Shape for 15 storey, rectangular shape for 30 storey and circular shape for 45 storey buildings are most stable respectively. In terms of maximum Fy Rectangular shape for 15 storey, circular shape for 30 storey and rectangular shape for 45 storey buildings are most stable respectively.

Dr. K. Chandrasekhar Reddy, G. Lalithkumar

Seismic analysis of high-rise buildings (G+30) by using ETAB is given in this paper. Behavior of the high-rise building was shown by the graphs and lateral displacements. It is found that the lateral displacements or drifts are more in zone 5 when compared to the zones 4, 3&2.It is also found that from the base reactions of structure obtained in zone 5, the story shear is higher in zone 5 than in zone 2.

D. G. Lee, H. S. Kim

The effect of the basement on the seismic response of high-rise buildings and the effect of the lateral forces applied to the superstructure on the member forces in the basement were investigated in this study and the following conclusions could be drawn.

Lateral stiffness of a high-rise building structure may be significantly overestimated resulting in larger lateral displacements and shorter natural periods of vibration if the basement of a high-rise building is ignored in the analytical model. Especially in the case of the building structures with shear walls, the effect of the basement on the seismic response turned out to be more significant. Therefore, it is necessary to include the effect of basement in the analysis of high-rise building structure. Lateral loads affect not only the response of the super structure but also that of the basement structure. Therefore, seismic loads as well as gravity loads should be considered in the analysis of a high-rise building structure. The story shear forces in the basement may be significantly overestimated if the rigid diaphragm assumption is applied to the basement. Therefore, an efficient analysis method using partial rigid diaphragms is proposed in this study for the analysis of high-rise buildings subjected to lateral forces such as the seismic loads including the effects of basement.

Hyun-Su Kima, Dong-Guen Leea, Chee Kyeong Kimb

An efficient three-dimensional model for the analysis of building structures with shear walls was proposed in this study using super elements and substructures. The refined finite element model of a high-rise building structure with shear walls is expected to cost a significant amount of computational time and memory while it would provide the most accurate results. Thus, the refined mesh model may not be feasible for practical engineering purpose. It is desirable for the engineers in practice to be aware of the limitation in the accuracy of the results obtained by this model. The proposed method could provide static and dynamic analysis results with an accuracy comparable to that of a refined mesh model with the cost of slightly increased computational time compared to the model using equivalent beams for the lintel. The super elements are connected only through the active nodes and fictitious beams are used to enforce the compatibility at the boundary of super elements because the inactive nodes at the boundary are eliminated in the proposed method. Thus, the location of inactive nodes in the finite element mesh to be used for a super element is not required to coincide with the counterpart in a neighboring super element.

Yi Hui, Akihito Yoshida, Yukio Tamura

Experiments were carried out to investigate the interference effect on local peak pressures between two identical rectangular cross-section high-rise buildings in this paper. The interfering building does not have a significant effect on largest positive peak pressure. For most configurations of the interfering building, the interference factors for the largest positive peak pressure were in the range of 0.9–1.1.It exceeded 1.2 for only one configuration of the perpendicular arrangement. The largest interference factor was greater than 1.5, which means the absolute value of the smallest negative peak pressure coefficient is 50% higher than the design value of the isolated building situation. Wind direction is one of the most crucial parameters. For most cases, the interference effect was stronger when the interfering building was located upstream of the principal building. The unfavorable wind directions depend strongly on the configurations of the two buildings. Based on the flow visualization experiment, the flow patterns of some critical cases also showed that high negative and positive peak pressures on the downstream building were usually caused by the shear layer from the upstream building.The downstream building in some configurations also significantly affected the upstream building. Designers need to pay more attention to the edges and corners of buildings in cladding design for negative pressures considering interference effects.

Yaik-Wah Lima,Mohd Hamdan Ahmadb, Dilshan Remaz Ossena

This paper has presented the use of internal shading for efficient tropical daylighting in Malaysian contemporary high-rise open plan office. For daylight quantitative performance, DF (Daylight Factor) shall be used to evaluate the potential for daylight utilization.Therefore, internal shading shall not be overlooked or simply left to the office users to install without proper understanding in daylighting. This paper only focuses on the efficient daylighting for visual comfort. The impact of solar radiation heat gain on energy consumption was not investigated. However, justification can be made that by evading direct sunlight patches, thermal comfort and energy saving were realized.

Yasuhiro Tsuneki, Shingo Torii, Katsuhide Murakami, Toshiyuki Sueoka

Middle-story isolated structural system of high-rise building were studied in this paper. In a such structure, the building as a whole is affected by higher mode vibrations, so the vibration characteristics of the building are governed not only by the stiffness of the isolation layer and the number of dampers, but also by the stiffness of the upper structure and the lower structure, and the weight ratio of the upper and lower structures.This paper describes the characteristics and response properties of high-rise buildings with an energy and damage concentration type of vibration control system using a middle-story isolated structure, and points out its effectiveness.

Reihane Tavakoli, Reza Kamgar, Reza Rahgozar

In this paper, the seismic performance of 2-D braced buildings is studied considering SSI effects to obtain the optimal location of the BRB outrigger system. The following results are obtained. Considering SSI (Soil Structure Interaction) has a significant effect on the fundamental period of the structures. Therefore, it can affect seismic demand considerably, and ignoring it, is not logical. Adding a fixed BRB outrigger at the top of the buildings reduces the first period and makes the structure stiffer. Placing the second BRB outrigger at 0.4 to 0.6 of 2-D braced buildings height (H), increases the structure's stiffness more than any other locations. The flexibility of the foundation causes the increment of top displacement and inter-story drift ratio; this can be interpreted as a reduction in the overall stiffness of outrigger buildings due to foundation movements and the effects of the soil-structure interaction. In this paper, the additional damping parameter is also studied as one of the most important goals of using BRB outrigger systems. The BRB outrigger system is enhancing the capacity of energy dissipation. According to this criterion, the optimal location of BRB outrigger, which maximizes the additional damping, is calculated 0.45H to 0.65H.

B. Blocken, J. Carmeliet

Pedestrian wind conditions at outdoor platforms in a high-rise apartment building: generic sub-configuration validation, wind comfort assessment and uncertainty issues studied in this paper. CFD (Computational Fluid Dynamics) has been applied to evaluate pedestrian wind comfort at outdoor platforms in a high-rise apartment building. Model validation has focused on generic building configurations that are obtained by decomposition of the actual complex building geometry. This methodology of generic sub-configuration validation evidently does not provide full confidence, but in absence of wind tunnel measurements for the actual geometry or for very similar complex geometries, it is often the only option. An important source of uncertainty in the wind comfort assessment procedure, as outlined in this paper, is the calculation of the terrain related contribution of the total wind amplification factor. In particular, the resulting discomfort probabilities can be very sensitive to the value of the upstream aerodynamic roughness length, which is estimated from a roughness classification. This might change the outcome of such studies and lead to wrong decisions. This problem is present in both wind tunnel and CFD wind comfort studies. Improved roughness mapping is required for increased accuracy.

PotnuruAvinash, Shaik Yajdani

Comparative study of different plan configuration buildings using wind analysis done in this paper. From the results and graphs it is inferred that the lateral displacement for all load combinations is increasing with the increase in asymmetry of plan. For example the lateral displacement for all the load combinations in L shaped plan is obtained maximum when compared to the other plans.It was also inferred that Base shear and Torsion remains unchanged irrespective to the plans.From the results it was interpreted that the Overturning moment is less for rectangular shape and very high for L Shape plans.Maximum Shear force in a beam is changing drastically between rectangular and L Shape. It was found that the maximum shear force has been increased to 23.41% in case of L shaped plan when compared to the rectangular plan. Maximum Bending moment in a beam for different load combinations is differ by 17.2% to Rectangular and L shape building. Shear force in columns for different load combinations, it is interpreted that is differ by 30.477%.
It is inferred that the moment in columns are doubled when compare with rectangle and L shape building. Lateral displacement in L Shape building is decreased by nearly 55% for all combinations by providing Shear wall.

Prof. S.S. Patil, Miss. S.A. Ghadge, Prof. C.G. Konapure, Prof. Mrs.C.A. Ghadge

The study of seismic analysis of high-rise building by response spectrum method done in this paper. It is seen that a significant amount of decrease in story drift has been observed in case 2 and 3 i.e. lateral stiffness system is centrally located at exterior frame of X direction throughout height and lateral stiffness system is centrally located at exterior frame of X & Z direction throughout height in both brace frame and shear wall frame compared to other models. Also shear wall models in case 3 gives less storey deflection and storey drift than bare frame and brace frame. A significant amount of decrease in time period of model in case 2 and 3 i.e. lateral stiffness system is centrally located at exterior frame of X direction throughout height and lateral stiffness system is centrally located at exterior frame of X & Z direction throughout height in both brace frame and shear wall frame compared to other models, therefore displacements in the structure are minimized. Building with short time period tends to suffer higher accelerations but smaller displacement. Comparing the top storey drift in the longitudinal direction, it can be seen that it decreases by 52.59%, 52.08% & 41.63% in case 2, 3 and 4 of brace frame as compared to bare frame and it decreases by 52.59%, 52.94 & 48.38% in case 2, 3 and 4 of shear wall frame as compared to bare frame. The models with shear wall located at exterior frame of X & Z direction throughout height is found most effective in resisting lateral loads because it shows least deflection as compare with other models.

Xiaotao Zhang, Guihong Pei, Lei Zhu, Yue Ren

In this paper, vertical flow mechanism of fire smoke in high-rise buildings with internal corridor were studied. Bench numerous CFD (Computational Fluid Dynamics) simulations using FDS were carried out to study the vertical flow mechanism of fire smoke in high-rise buildings with internal corridor.HRR of fire source can dramatically impact on the airflow velocity.With the HRR growing, the airflow velocity increases significantly. However, the HRR has no prominent influence on the flow structure. The range of smoke spreading is increase not remarkable with HRR growing. Neutral plane can represent the range of smoke spreading. The height of neutral plane just increases 4.2% when the HRR increase from 2MW to 10MW, which indicate the dependence of height of neutral plane on HRR is weak. The area affected by smoke containing CO is not significantly increase with the HRR growing. However, in the affected area, the CO concentration increases significantly. Therefore, rapid evacuation is crucial for the people on higher floor.

REFERENCES

[1] S.M. Wilkinson, R.A. Hiley, “A non-linear response history model for the seismic analysisof high-rise framed buildings,” Elsevier publication, 29Sep 2005.

[2] Abhay Guleria, “Structural analysis of a multi-storeyed building using etabs for different plan configurations,” International Journal of Engineering Research & Technology, Vol. 3 Issue 5, May 2014.

[3] Anupam Rajmani, Prof Priyabrata Guha, “Analysis of wind & earthquake load for different shapes of high-rise building,” International Journal of Civil Engineering and Technology, Vol. 6 Issue 2, Feb 2015.

[4] Dr. K. Chandrasekhar Reddy, G. Lalith Kumar, “Seismic analysis of high-rise buildings (g+30) by using Etabs,” International Journal of Technical Innovation in ModernEngineering & Science, Vol. 5 Issue 3, March 2019.

[5] D. G. Lee & H. S. Kim, “Efficient seismic analysis of high-rise buildings considering the basements,” New Zealand Society for Earthquake Engineering Conference, 2001.

[6] Hyun-Su Kima, Dong-Guen Leea, Chee Kyeong Kimb, "Efficient three-dimensional seismic analysis of a high-rise buildingstructure with shear walls," Elsevier Publication, 2005.

[7] Yi Hui, Akihito Yoshida, Yukio Tamura, "Interference effects between two rectangular-sectionhigh-rise buildings on local peak pressure coefficients," Elsevier Publication, 2013.

[8] Yaik-Wah Lima, Mohd Hamdan Ahmadb, Dilshan RemazOssena, "Internal shading for efficient tropical daylighting in Malaysian contemporary high-riseopen plan office," Indoor Built Environment, 22;6:932-951, 2013.

[9] Yasuhiro Tsuneki, Shingo Torii, Katsuhide Murakami, Toshiyuki Sueoka, "Middle-story isolated structural system of high-rise building," World Conference on Earthquake Engineering, 17 Oct 2008.

[10] ReihaneTavakoli, Reza Kamgar, Reza Rahgozar, "Optimal location of energy dissipation outrigger in high-rise building considering nonlinear soil-structure interaction effects," PeriodicaPolytechnica Civil Engineering, 64(3), pp. 887–903, 2020.

[11] B. Blocken, J. Carmeliet, "Pedestrian wind conditions at outdoor platforms in a high-rise apartment building: generic sub-configuration validation, wind comfort assessment and uncertainty issues," 11(1): 51-70, 2008.

[12] PotnuruAvinash, Shaik Yajdani, "Comparative study of different plan configuration buildings using wind analysis,"International Journal of Science Technology & Engineering, Vol. 4 Issue 2, Aug 2017.

[13] Prof. S.S. Patil,Miss. S.A. Ghadge,Prof. C.G. Konapure, Prof. Mrs. C.A. Ghadge, "Seismic analysis of high-rise building by response spectrum method," International Journal of Computational Engineering Research, Vol. 3 Issue 3, Mar 2013.

[14] Xiaotao Zhang, Guihong Pei, Lei Zhu, Yue Ren, "Vertical flow mechanism of fire smoke in high-rise buildings with internal corridor," IOP Conference Series: Materials Science and Engineering, 10.1088/1757-899X/392/6/062019.