Seismic Analysis of a Tall Building with and without Open storey's : A Review

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Abstract - A common feature which we see in the modern Tall building constructions in growing urban India is Open storey. Though Tall buildings with open storeys are quite vulnerable to collapse due to earthquake but still their construction is wide spread in a developing country like India. A big need arises to provide openings such as car parking space or even basements at ground level or below and for offices with open storey's at different levels of building and this out weights the warning which is given against such buildings from engineering sector. Now, with the availability and easy usage of fast computers, use of different civil engineering software's has greatly reduced the various complexities that arise in the analysis and designing of a project. In this paper a study has been investigated which is on the seismic behavior of multistory buildings and even tall buildings with open storey's or without open storey's when seismic analysis is carried over it. It is observed that buildings without open storeys are more resistant and strong structures as compared to buildings with open storey's when undergone seismic analysis.

Keywords - Open storey, seismic analysis, investigation, Tall buildings.

I. INTRODUCTION

Tall Buildings throughout the world are becoming more popular day by day with the advancement of modern day construction technology and computers, the basic aim now is the construction of safer buildings keeping in view the complete economics of the project. In some areas tall buildings are called "high rise buildings" or even "vertical cities". Basically we can define tall building as a structure which has a height of 35 meter or more. Nowadays, the increasing population since past few years have increased the demand of construction of apartments or buildings with more car parking space and more safer designing and aesthetic beauty of the building and this is why construction of multi storey buildings with open storey's has become a common practice especially in basement and first storey. As regarding existing structures, it is necessary to evaluate and strengthen them based on evaluation criteria before an earthquake. The lateral loads which occur in Tall buildings due to earthquake are a main matter of concern.

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Seismic analysis and structural design of buildings for seismic loading is primarily concerned with structural safety during major earthquakes. In Tall Buildings, it is very important to ensure adequate lateral stiffness to resist lateral load. When buildings are tall, beam and column sizes are quite heavy and requirement of steel is very large so there are number of problems at joints and concrete is difficult to place properly at these places and displacement is quite heavy. Then arises the question of providing walls or not i.e., providing open storeys or not. The Response spectrum analysis mainly gives us many modes of response of a building which can be then taken into account. The response of a structure is a combination of many special modes that in a vibrating string corresponds to harmonics. But in cases where structures are very irregular or too tall or have a big significance to a community in disaster response, we don't use response spectrum approach then, and then in that case more complex analysis is used such as non linear dynamic analysis. Non Linear dynamic analysis mainly uses the combination of records of ground motion with a detailed structural model and so gives us the results with low uncertainty.

II. LITERATURE REVIEW

A significant amount of research work has been done on studying the seismic behavior of a tall building with and without open storey's by many investigators using different computer software's such as,

1. Varikuppala Krishna, Chandrashekar and Rajashekar^[1]

Analyzed and designed (Parking floor + 5) upper stories of a multi storied RCC Framed building under the lateral loading effect of wind and earthquake using ETABS. Concluded that Building layout and design has to follow the nature especially for sunlight and wind directions. Geotechnical engineering cannot be neglected while building the tall buildings. The geotechnical engineer needs to be consulted. The use of light weight concrete and light weight materials will reduce the dead load of structure, which then allows the structural designer to reduce the size of the columns, footings and other load bearing elements. The occurrence and spread of fire is unpredictable and uncertain. For more than 5 storey buildings it is better to provide the connecting beams in between the flats.

2. K. Shaiksha Vali and B. Ajitha^[2]

Discussed an analytical study which was carried out on a multistory building of 35 stories for different seismic zones and hard soil type. These building models are analyzed using software SAP 2000. Concluded the structural performance among three bracing systems, one infill, the variation of displacement is smaller in infill system. With the provision of bracings, infills the stiffness of structure is increasing and so the base shear is decreased with increasing height of the structure. Structural capacity is greatly influence by the concrete infills. Infill systems have lesser displacements with respect to time.

Waseem Khan, Dr. Saleem Akhtar and Aslam Hussain^[3] 3. Described the results of an extensive study on the seismic behavior of a structure with damper and without damper under different earthquake acceleration frequency like EQ Altadena, EQ Lucerne, EQ Pomona, EQ Smonica and EQ Yormo. The proposed procedure is placed the dampers on the floors of the ninth-floor and five-floor of a ninth story building frame then compare the different performance of structure with damper up to Ninth-floors, damper up to Fifthfloors and without damper of ninth-story building frame using SAP2000 V15. Concluded that Seismic performance of building can be improved by providing energy dissipating device (damper), which absorb the input energy during earthquake. The frame is safer when damper is provided up to top floor from base. With the deployment of damper in the structure, the base shear effectively reduces.

4. Rupali Kavilkar and Shweta Patil^[4]

Investigated a study of Pune city's housing needs, demands, market and type of structures being built, reveal that tall buildings of 11 floor are being developed on the city's urban fringe. Concluded that high rise structures are not preferred due to user perception of insecurity in case of fire and high cost of the building. Studied the availability and use of fly ash in various proportions, which can be used in Indian high rise residential buildings. The paper indicates and also concludes that fly ash concrete can be used to reduce the cost of construction and has the potential to minimize the damage caused due to high temperature.

5. Mohit Sharma and Dr. Savita Maru^[5]

Analysis is done on a G + 30 storied regular building. The static and dynamic analysis has been done by using STADD Pro software and using the parameters for the design as per IS 1893 - 2002 - Part 1 for zones II and III. The performance of RCC Framed Structure is then analyzed for zone II and III and the results are tabulated. Concluded that the results as obtained for the Dynamic analysis are higher than the results as obtained by Static analysis for the same points and conditions.

6. Baldev D. Prajapati and D. R. Panchal^[6]

Discussed the analysis & design procedure adopted for the evaluation of symmetric high rise multi-storey building (G+30) under effect of Wind and EQ forces. This study examines a G+30 storey building and is analyzed and designed under effect of wind and earthquake using ETABS. Concluded that S.F and B.M is more in RCC, Steel and S+B building but when we use the composite beam the forces are reduced due to the reduced section. Displacement is within the limits for all buildings. Wind forces are more compared to earthquake. Keeping span and loading unaltered, smaller structural steel sections are required in composite construction compared to non-composite construction. This reduction in overall weight of the composite structure compared to other structure results in less cost of structure and foundation. Comparison of all models buildings shows that composite buildings are more economic for all other buildings structure. From 21 models of various buildings in which RCC building subjected to the wind is most critical case.

7. Satpute S G and D B Kulkarni^[7]

Discussed a study on seismic responses of the 10 storey Reinforced Concrete shear wall building with and without opening. Analyzed the reinforced concrete shear wall building by using different nonlinear methods basically time history and pushover method and developed mathematical model too. Analysis is carried out by using SAP2000. Different parameters of these models like displacement, storey drift and base shear have been compared. Concluded that the results of seismic responses namely base shear, storey displacement and storey drift for both methods are found out to be in increasing order. The percentage of opening increases with increasing displacements. Plastic hinges occurred in the structure remains stable.

8. P. P. Chandurkar and Dr. P. S. Pajgade^[8]

Investigated a study to determine the solution for shear wall location in multi-storey building. Effectiveness of shear wall has been studied with the help of 4 different models. Model 1 is bare frame structural system and other 3 models are dual type structural system. An earthquake load is applied to a building of 10 stories located in zone II, zone III, zone IV and zone V. Concluded that in 10 storey building, constructing building with shear wall in short span at corner (model 4) is economical as compared with other models. Large dimension of shear wall is not effective in building with 10 stories or below. Shear wall is economical and effective in high rise buildings. Also observed that changing the position of shear wall affects the attraction of forces, so that wall must be in proper position. Providing shear walls at proper locations reduces the displacements due to earthquake.

9. Prof. S. S. Patil, Miss S. A. Ghadge, Prof. C.G Konapure and Prof. Mrs. C. A. Ghadge^[9]

Discussed a study on seismic analysis of high rise building using STADD Pro with various conditions of lateral stiffness system. Some models which are prepared are bare frame, brace frame and shear wall frame. Analysis is done using response spectrum method. Results including base shear, storey drift and storey deflections are shown. Concluded that some amount of decrease in storey drift and time period is there in case 2 and 3 i.e., lateral stiffness system is located centrally at exterior frame of X direction throughout height and lateral stiffness system is located centrally at exterior frame of X and Z direction throughout height in both brace and shear wall frames compared to other models. Building with short time period suffers more acceleration but smaller displacement. The models with shear wall located at exterior frame of X and Z direction throughout height is found most effective in resisting lateral loads because least deflection is there as compared to other models. Some amount of increase is observed in lateral stiffness in all models of brace and shear wall frames as compared to bare frame.

10. Deepak Murlidhar Sundrani^[10]

Discussed a study on finding out the perception of home buyers towards tall buildings. Construction of tall buildings is a recent trend in most Indian cities nowadays. Many people are unwilling to stay in tall buildings due to the risk involved in evacuation in case of fire and earthquake. And some people are willing to stay in tall buildings as the view is larger, noise and smoke pollution is less as go up. Concluded that 95% buyers are unwilling to stay in tall buildings as they are unsure about the fire fighting measures and even about evacuation in case of earthquake. Only 5% are willing to stay in tall buildings as for them the occurrence of events like fire and earthquake is low. Before making tall buildings the builders should convince the buyers about the fool proof arrangements for firefighting measures and the building is earthquake resistant.

11. Haroon Rasheed Tamboli and Umesh N. Karadi^[11]

Discussed a study in which seismic analysis has been performed using Equivalent Lateral Force Method for different reinforced concrete (RC) frame building models that include bare frame, infilled frame and open first storey frame. In modeling the masonry infill panels the Equivalent diagonal strut method is used and software ETABS is used for the analysis of all the frame models. Concluded that infill wall can affect the seismic behavior of frame structure largely and the infill wall increases the strength and stiffness of the structure. In case of open first storey in a frame structure, the storey drift is very large than the upper storey's, which may cause the collapsing of structure during strong earthquakes. Therefore the infilled frame structures will be the better option in the seismic regions.

12. Greeshma S, Jaya K P and Annilet Sheeja $L^{[12]}$

Discussed the various possibilities of modeling and reinforcement detailing of reinforced concrete models. For carrying out the analytical investigations, the structure is modeled in a Finite Element software ANSYS. The consequences of small changes in modeling are discussed and results are obtained from the two models. Concluded that the smeared model exhibited 10% increase higher ultimate strength compared to that of discrete model. Smeared model has higher average ductility than discrete model. The enhancement in deformation capacity for smeared model is 2.5% than that of discrete model. Spindle shaped hysteretic loops are observed with large energy dissipation capacity for smeared model compared to discrete model. The ultimate shear capacities of both the models were observed to be matching with the empirical relation as per ACI 318.

13. Romy Mohan and C. Prabha^[13]

Discussed a study in which 2 multi storey buildings, one of six and other of eleven storeys have been modeled using SAP 2000 for earthquake zone V in India. Different types of shear walls with various shapes are considered for studying their effectiveness in resisting lateral forces. This paper mainly focuses on the accuracy and exactness of Time History analysis in comparison with the Response Spectrum Analysis and equivalent static analysis. Concluded that the equivalent static method can be used for symmetric buildings up to 25m height. Response spectrum method should be used for higher and unsymmetrical buildings. Time history analysis should be used for very important structures as it predicts the structural response much more accurately as compared with other two methods.

14. Nilupa Herath, Priyan Mendis, Tuan Ngo and Nicholas Haritos^[14]

Discussed about a study in which general concepts, current methods of analysis and seismic performance of super tall buildings are reviewed. And also discussed the effect of higher modes on performance of super tall buildings. Concluded that widely used seismic analysis methods such as displacement based method, N2 method, Capacity Spectrum method may not be directly applicable to super tall buildings due to higher mode effects. The higher mode lengthening phenomenon is shown through nonlinear dynamic analysis of a 300m tall building.

15. Andreas J. Kappos and Georgios Panagopoulos^[15]

Discussed about a performance based design procedure for realistic 3D RC buildings are presented, that involves the use of advanced analytical tools. The proposed method is then applied to a regular multi storey reinforced concrete 3D frame building and is found to lead to better seismic performance than the standard code (Euro code 8) procedure, and in addition leads to a more economic design of transverse reinforcement in the members that develop very little inelastic behavior even for very strong earthquakes.

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Concluded that the proposed design framework can readily be applied to realistic 3D buildings. The validity of the procedure has currently been verified only for the case of regular buildings. In particular those based on the displacement based design (DBD) approach, the method suggested herein is generally more involved in the case that time history analysis is utilized but almost equally demanding in the case of pushover analysis The time history version of the proposed method is clearly the most appropriate option for complex and/or higher mode dominated structures.

III. CONCLUSION

Normally RC Frame Tall buildings with open storey's are known to perform poorly under strong earthquake shaking because the stiffness at lower floors is lesser than stiffness at storey's above as majority of open storey's are tend to provide at basement or first storey. For a building where there is no lateral load resistance component provided such as shear wall or bracing i.e., with open storey's, the strength is considered very weak and it can fail very easily during an earthquake as when compared to a building with some lateral resistance provided, these buildings without open storey are more stronger. In such a situation, an investigation has been made to study the seismic behavior of such buildings considered with and without open storey's subjected to earthquake loading so that we can find out some solution or guideline to minimize the risk involved in buildings with open storey's and on the other hand we can promote more and more construction of buildings without open storey's. Investigators analysis numerically and by using various computer programs such as STADD Pro, ETABS, SAP 2000, etc. Their various calculations shows that when buildings having brick masonry infill on majority of floors especially bottom floors are more resistant, safe, strong and dependable as compared to buildings which don't have brick masonry infill when undergone seismic analysis.

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