International Journal of Technical Innovation in Modern Engineering & Science (IJTIMES)
Impact Factor: 5.22 (SJIF-2017), e-ISSN: 2455-2585
Volume 5, Issue 02, February-2019

ANALYSIS AND DESIGN OF MULTI-STOREY R.C.C. FRAME STRUCTURES USING COMPUTER MODELLING TOOLS: A REVIEW

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Abstract*— Every individual wish to live in a safety, serviceability and healthy environment building. Therefore, every engineer should design a building with the most efficient planning and also be economical. In multi-storey frame structures there are many members that are monolithically connected to each other and if yielding takes place in any one of them, then a redistribution of forces takes place. Therefore, great attention should be taken whenever multi-storey buildings are to design, most especially in areas that are prone to earthquake. This paper presents a detailed review of the analysis and design of multi-storey frame structures by using various computer modelling tools. Various Parameter such as story displacement, overturning moment, story drift and story shear are discussed in this paper.

Keywords*— Multi-storey, Story displacement, Overturning Moment, Story drift, Story Shear.

1. INTRODUCTION

A multi-storey building is a self-contained housing unit that occupies only part of the building. Such a building may be called a multi-storey building. As the population of our country is growing faster, the need for shelter in highly populated cities is more and more demanding which lead to an increase of land cost. Also, the further horizontal expansion will not be possible due to unavailability of space. So the only solution is the vertical expansion. The construction of multi-storeyed buildings depends on the availability of materials, the level of construction technology and the availability of services such as elevators necessary for the use in the building. There are various construction material available such as RCC, steel and composite. However, the most common practice in construction is the RCC because the material used is easily available and skilled labour can be approached easily. An RCC framed structure is an assembly of slabs, beams, columns, and foundation inter-related to every different as a unit. The load transfer, in this kind of structure, takes place from the slabs to the beams, from the beams to the columns, from columns to the foundation and then finally transfers it to the soil.

2. LITERATURE

2.1 STORY DISPLACEMENT

Mahmoud *et al.* (2016) perform a time history analysis of reinforced concrete frame buildings. A set of different building models is considered to perform the analysis. The building consider were a bare frame (without infill walls), frame with fully infill walls and a frame models with infill panels and soft storey located at base level, 3rd storey level, 6th storey level, 9th storey level and 12th story level.. Dynamic time history, using El Centro and Loma Prieta ground motion records, has been used to perform the seismic analysis of the considered model configurations. ETABS has been used in developing the building models and performing the simulation analysis. They found that there is a sudden change of displacement after passing the soft storey level which has lead to an increase in storey displacement especially under El Centro record. However the bare frame model produces higher peak displacements as compare to the masonry infill building frame models with and without soft storey under both the El Centro and Loma Prieta earthquake which can be due to infill frame building system with and without soft storey having higher stiffness than the bare frame building model under the applied dynamic lateral load.

Mosleh *et al.* (2016) investigate the seismic behaviour of RC building structures designed according to FEMA-356 and ATC-40. Two six-story irregular RC buildings were considered. The building consists of 6 floors high and 3 underground floors. The finite element structural analysis program SAP2000 was used to develop the non-linear analyses. The displacement profiles resulting from each non-linear analysis are compared to the response of the push-over analysis. The building models in two directions have been pushed until the response resulting from the structure becomes equal to roof displacement from the time history analysis. The target displacements of the buildings are more flexible in a longitudinal direction, while in transverse direction it is stiffer. Building 2 shows poor performance in terms of strength, tangent stiffness and deformation as compared with building 1.

Arslan *et al.* (2016) perform an evaluation of in-plan irregular RC frame buildings based on Turkish seismic code. Eight different, five and seven storey RC frame buildings with and without beam discontinuity in plan and with different

torsional irregularity were designed. Three performance evaluation method was used: Linear elastic method (LEM), Nonlinear static procedure (NSP) and Nonlinear time history analysis (NTA). The result shows that the inelastic displacement demand of some members by LEM and NSP were in damage state whereas using NTA all the members were ok. They conclude that the difference of results of NSP and LEM than those of NTA may be the reason of conservative limits of LEM and NSP. Thus LEM and NSP give more vulnerable seismic performance level.
Joshi *et al.* (2010) perform a linear and nonlinear static analysis for assessment of progressive collapse potential of the multistoried building. Four and ten storey frame structures having four bays of 5 m in the longitudinal direction and three bays of 5 m in the transverse direction are taken in this study and are evaluated as per GSA guidelines. The linear static and nonlinear static analysis are carried out using SAP2000. They found that the first hinge form at a location where DCR is maximum and continues through the location having higher DCR in various displacement level. They conclude that the location where the DCR exceeds the permissible values, there is a high possibility that the member components exceeded its elastic limits during column a failure scenario.
Chintanapakdee *et al.* (2004) perform the seismic demands for vertically irregular frames by nonlinear response history analysis. 48 irregular frames, all 12 stories high with strong columns and week beams, were designed with three types of irregularities-stiffness, strength and combined stiffness and strength introduced in eight different locations along the height with a modification factors=2. They conclude that as long as the irregularity is in the mid or upper stories, all the three types of irregularities have very little influence on floor and roof displacements. In contrast, irregularity in the base story or lower half of the building significantly influences the height wise variation of floor displacement.

2.2 Overturning Moment

Mahmoud *et al.* (2016) perform a time history analysis of reinforced concrete frame buildings. A set of different building models is considered to perform the analysis. The building consider were a bare frame (without infill walls), frame with fully infill walls and a frame models with infill panels and soft storey located at the base level, 3rd storey level, 6th storey level, 9th storey level and 12th story level. Dynamic time history, using El Centro and Loma Prieta ground motion records, has been used to perform the seismic analysis of the considered model configurations. ETABS has been used in developing the building models and performing the simulation analysis. They found that the peak storey moments under the Loma Prieta earthquake vary significantly as the level of the soft storey changes, especially at lower storeys. However, under El Centro earthquake records, the variation in the peak storey moment seems to be insignificant and shows slight change with the variation of the soft storey level. Under both excitation records and irrespective of the loading direction, the bare frame building model induces the lower storey moments. Contrary to the bare frame model, the full masonry infill building model induces the higher storey moments as compared to the other models. The reason behind the higher storey moments in case of fully infilled models can be due to the increase in stiffness of the full infill model which is assumed to be the summation of the bare frame model stiffness and the infill wall stiffness.
Mosleh *et al.* (2016) investigate a seismic behaviour of RC building structures designed according to FEMA-356 and ATC-40. Two six-storey irregular RC buildings were considered. The building consists of 6 floors high and 3 underground floors. The finite element structural analysis program SAP2000 was used to develop the non-linear analyses. Non-linear time history analysis with 12 artificially seismic records with PGA levels from 0.09 g to 0.44 g was used. They found that there is an abrupt change in inter-storey rotation of building 1 in the transverse direction between 0.29g-0.33g which shows the large rotation in the 6th storey. This is because of the non-linear behaviour of the structure.
Hu *et al.* (2012) perform a study on high-rise structure with oblique columns by ETABS, SAP2000, MIDAS/GEN and SATWE. The structure is a 29 storey building with 3 floors underground and 26 floors above ground. Response spectrum method was executed and ETABS, SAP200 and SATWE are the software used for finding the overturning moment and comparison is made between them. Result found that the overturning moment (ratio) of the column in X and Y direction respectively are 32.10% and 24.80% by ETABS, 52.86% and 54.77% by SAP2000 and 57.91% and 51.80% by SATWE which is a big difference of columns' overturning moment ratio between ETABS and other tools. They conclude that may be ETABS may miss the statistic of oblique columns, which need to be paid attention to in future design.

2.3 Story Drift

Mahmoud *et al.* (2016) perform a time history analysis of reinforced concrete frame buildings. A set of different building models is considered to perform the analysis. The building consider were a bare frame (without infill walls), frame with fully infill walls and a frame models with infill panels and soft storey located at the base level, 3rd storey level, 6th storey level, 9th storey level and 12th story level. Dynamic time history, using El Centro and Loma Prieta ground motion records, has been used to perform the seismic analysis of the considered model configurations. ETABS has been used in developing the building models and performing the simulation analysis. The result shows that the bare frame building model has drift ratios of higher values than those associated with the considered fully infill frame building model under both El Centro and Loma Prieta records. However, the drift ratio at the specified soft storey of the infill frame building models exceed those values obtained considering the building structure modelled as a bare frame under the applied two ground motions. This sudden increase of storey drift at the specified soft storey level may be due to the building frame models with soft storeys suffer from strength and stiffness discontinuities of those above and below the storey.
Mosleh *et al.* (2016) investigate a seismic behaviour of RC building structures designed according to FEMA-356 and ATC-40. Two six-storey irregular RC buildings were considered. The building consists of 6 floors high and 3

underground floors. The finite element structural analysis program SAP2000 was used to develop the non-linear analyses. Non-linear time history analysis with 12 artificially seismic records with PGA levels from 0.09 g to 0.44 g was used. The drift ratio of building 1 is vulnerable in the longitudinal direction according to FEMA-356, however, it would be stable in order to ATC-40. Building 2 is stable based on both guidelines.

Arslan *et al.* (2016) perform a study on performance evaluation of in-plan irregular RC frame buildings based on Turkish seismic code. Eight different, five and seven storey RC frame buildings with and without beam discontinuity in plan and with different torsional irregularity were design. Three performance evaluation method was used: Linear elastic method (LEM), Nonlinear static procedure (NSP) and Nonlinear time history analysis (NTA). The result shows that the drift ratio by all the above mention methods was found to be under the limits for life safety performance level given by TSC 2007.

Hu *et al.* (2012) perform a study on high-rise structure with oblique columns by ETABS, SAP2000, MIDAS/GEN and SATWE. The structure is a 29 storey building with 3 floors underground and 26 floors above ground. ETABS and MIDAS were used to examine the structural performance by both the response spectrum and elastic time history analysis. They conclude that the inter-story displacement angles under X and Y direction frequent earthquakes both meet the code limited values.

Chintanapakdee *et al.* (2004) perform the seismic demands for vertically irregular frames by response history and modal pushover analysis. 48 irregular frames, all 12 storey high with strong columns and week beams, were designed with three types of irregularities-stiffness, strength and combined stiffness and strength introduced in eight different locations along the height with a modification factors=2. Using nonlinear response history, they conclude that by introducing a soft or weak story, the story drifts demand increases in the modified and neighbouring stories and decreases the drift in other stories while a stiff or strong story decreases the drift demand in the modified and neighboring stories and increases the drift demands in the other stories. On the other hand, using MPA the drift demand for the irregular frame is similar to a regular frame, except in the lower stories of the frame with stiff or strong first or lower half, for which the bias is large.

2.4 STORY SHEAR

Mahmoud *et al.* (2016) perform a time history analysis of reinforced concrete frame buildings. A set of different building models is considered to perform the analysis. The building consider were a bare frame (without infill walls), frame with fully infill walls and a frame models with infill panels and soft storey located at the base level, 3rd storey level, 6th storey level, 9th storey level and 12th story level. Dynamic time history, using El Centro and Loma Prieta ground motion records, has been used to perform the seismic analysis of the considered model configurations. ETABS has been used in developing the building models and performing the simulation analysis. The result shows that the storey shear of bare frame model shows the lowest values among all other consideration. Therefore, ignorance of masonry infill action underestimate the values of shear at the bases and may lead to unsafe design especially for earthquake resistant design. Masonry infill action magnifies the storey shear values with about 2.5 and 1.5 times as compared to bare frame case under El Centro and Loma Prieta earthquake motions, respectively. The difference between the two earthquake considered is due to El Centro records are characterized as near-fault records, while the Loma Prieta records are of far-fault characteristics. An easy way to comply with the conference paper formatting requirements is to use this document as a template and simply type your text into it.

3. CONCLUSION

Following are some of the conclusion made based on the present work study:

- By considering an infill frame building, the storey displacement of a building will be less due to higher stiffness. However, introducing a soft or weak storey at the base or lower half, there is an abrupt change in displacement at the specified and adjacent stories.
- Also, the overturning moment is higher in case of infill frame building due to higher stiffness. However, in the case of a non-linear structure, there is an abrupt change in the overturning moment.
- The story drifts demand increases in the modified and neighbouring stories and decreases the drift in other stories by introducing a soft or weak story while in a stiff or strong story the drift demand in the modified and neighbouring stories decreases and the drift demands in the other stories increases.
- The storey shear values may vary by 1 to 1.5 times by considering near-fault and far-fault records.

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