IARJSET ISSN (O) 2393-8021, ISSN (P) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

Impact Factor 7.105 ⫹ Vol. 9, Issue 4, April 2022

DOI: 10.17148/IARJSET.2022.94119

A REVIEW ON HIGH RISE BUILDINGS USING STEEL AS CONSTRUCTION MATERIAL

Anjum Taj[1], Sushma C K[2]

Department of Structural Engineering, Dayananda Sagar College of Engineering, Bengaluru, Karnataka, India[1&2]

Abstract: Tall building developments are rapidly increasing worldwide. In past years, developed countries have emerged as centers for brand spanking new highrise buildings. The land is scarce and expensive, particularly in big cities like Japan, where tall buildings represent the simplest solution for solving the matter. Steel-frame structures of relatively lightweight, high strength, and high ductility became mainstream for the earthquake-resistant construction of high-rise buildings. Taller buildings also face higher wind loads hence steel is flexible, allowing the building to maneuver and deflect with the wind forces, instead of making it rigid like concrete. High-rise buildings, built completely in steel or primarily with steel are limited in India. This paper reviews the performance of the high-rise buildings with steel as the construction material and therefore the parameters that are considered during the development and its behavior.

Keywords: High rise building, steel structure, ductility, analysis, seismic design.

I. INTRODUCTION

The tallest building within the world, as of 2022 is Burj Khalifa. The title of "world's tallest building" has been borne by various buildings, like the 3rd-century Jetavanaramaya stupa, Lincoln Cathedral, the New York Building and therefore the original World Trade Centre.

Before the trendy skyscraper era, between c. 1311 and 1884, the tallest buildings and structures were mostly Christian churches and cathedrals.

(Mir and Kyoung 2011) Tall buildings emerged in the late nineteenth century in the US of America. They constituted a so-called “American Building Type,” meaning that almost all important tall buildings were in-built by the U.S.A. Many tall buildings are built worldwide, especially in Asian countries, such as China, Korea, Japan, and Malaysia.

Traditionally the function of tall buildings has been as commercial office buildings. Other usages like residential, mixed-use, and hotel tower developments have rapidly increased. Tall building development involves various complex factors like economics, aesthetics, technology, municipal regulations, and politics. Among these, economics has been the first governing factor.

In the late nineteenth century, early tall building developments were based on economic equations – increasing rentable area by stacking office spaces vertically and maximizing the rents of these offices by introducing as much natural light as possible. In order to serve this economic driver, new technologies were pursued that improved upon the conventional loadbearing masonry walls that had relatively small punched openings. The result was the iron/steel frame structure which minimized the depth and width of the structural members at building perimeters.

(Nazri and Ken 2014) Most of the construction in Malaysia concentrates only on the use of reinforced concrete as the choice for the structural system. In the past few years the industry has been experiencing shortage of cement for concrete construction. With all these considerations, steel structures may provide a better choice for the construction industry present needs.

(Ibrahim 2007) Steel is highly durable metal. Due to its strength and load bearing capacity to weight ratio, steel is the undisputed material of choice for high-rise building structures. It can withstand a considerable amount of external pressure and hence steel structures are earthquake resistant. Steel structures can have a variety of structural forms like braced frames and moment resistant frames suitable to meet the specific requirements of higher buildings.

II. NUMBER OF STORIES

(IŞIK, SAYIN, and ULU 2020) Number of stories occupy an important place among the factors affecting the behavior of buildings under earthquake effects. There is a direct relationship between the number of stories and earthquake damages.

(Seyed Morteza Kia and Mahmood Yahyai 2004) A typical 3-bay frame with stories 3, 6, 9, 12 and 15 have been adopted to study ductility demand that includes the seismic behavior and inelastic response of steel moment resisting frames.

Whereas (Moghaddam and Mohammadi 2001) along with SDOF models, the shear building models of 5, 10 and 15 storey structures with identical storey heights with total mass uniformly distributed over the height have been used to introduce a modification factor for dynamic analysis of MDOF structures to account for inelastic nonlinear behavior of structures under earthquakes.

(IŞIK, SAYIN, and ULU 2020) As the number of story decreases, the period value and seismic capacity increases and the stiffness value decrease. The increase in the footprint area and number of story caused the structure to be less rigid.

(Moghaddam and Mohammadi 2001) A nominal elastic base shear was introduced for evaluating the demand seismic elastic forces of an MDOF shear-building structure. It was illustrated that this is generally greater than the theoretical elastic base shear of both MDOF and SDOF systems.

(Seyed Morteza Kia and Mahmood Yahyai 2004) The ductility demand of the critical story in most cases occurs in the lower stories (first or second) of the structure and the amount is significantly high in tall structures especially under severe earthquakes. The results indicate that the ductility demand of the lower stories under variation of peak acceleration and type of record do not significantly vary.

III. DUCTILITY

Ductility plays a central role in seismic analysis and design of steel buildings. In severe and most of moderate earthquakes, the structures pass the elastic limit and reach the inelastic state. The ductility under such earthquakes becomes very important. Ductility values significantly may vary with the strong motion, ductility definition, structural element, story number, type of analysis and model.

(Llanes-Tizoc et al. 2019) To evaluate the ductility parameter for steel buildings with typical welded moment-resisting frames different types of local ductility as well as story and global ductility are calculated according to both nonlinear dynamic analysis and nonlinear static analysis (pushover).

A. GLOBAL DUCTILITY

Global ductility is the mean value of story ductilities (μGs) and is the ratio of the utmost inelastic top displacement to the highest displacement when yielding occurs for the primary time (μGt).

μGS for dynamic analysis give reasonable values, but μGt doesn't.

B. LOCAL DUCTILITY

The local ductility of a tensile member ($\mu_{L\delta}$) is the ratio of the utmost inelastic axial deformation that the member undergoes during the total time of excitation (δ_{max}) to the axial deformation of the member when it yields for the primary time (δ_y).

Bending local ductility (μLφ) is far larger for beams than for columns. Although the demands of Tension local ductility (μLδ) are considered an important issue they're less relevant than μLφ.

C. STORY DUCTILITY

The ductility of a story (μ_s) is the ratio of the maximum inelastic drift of the story during the total time of excitation (Δ_{max}) to the drift of the story when any of its members yields for the primary time (Δ_y).

μLφ, μS, and μGS obtained from pushover are larger than those obtained from dynamic analysis, and in contrast to the case of dynamic analysis, μLφ tends to extend with the story number showing an opposite trend. Considering that μGt for dynamic analysis leads to unreasonable values, pushover analysis doesn't consider energy dissipation, the strong column–weak beam (SCWB) concept was followed within the model designs, and μLδ isn't relevant in framed steel buildings. Thus, if bending local ductility capacity is stated as basis for the design, the global ductility capacity may be easily estimated.

IV. METHOD OF ANALYSIS

(Reyes-Salazar et al. 2018) Investigations regarding nonlinear analysis of buildings under the action of earthquakes, following different objectives are conducted by many researchers during the last decades.

(Zubritskiy et al. 2021) proposes a way for taking into consideration the upper vibration modes under seismic resistance estimation of multi-story steel frames by nonlinear static method and is verified with timehistory analysis. Such calculations require an oversized time resource, complex software and special qualifications of the engineer.

The average error value within the results obtained by the time history analysis with the results supported the multimodal nonlinear static method for all structural response criteria doesn't exceed 15%, while providing a margin for assessing seismic resistance. Proposed technique allows one to significantly reduce the calculation time, while excluding the deficit of seismic resistance.

(Nazri and Ken 2014) Static and dynamic assessments of the steel structures by Pushover analysis (POA) and incremental dynamic analysis (IDA) were run on moment-resisting steel frames of three, 6, and 9 stories.
Steel frames are subjected to nonlinear inelastic time history analysis for 14 different scaled ground motions, 7 near field and seven far-field.
The results obtained from POA show consistent results for both uniform and triangular lateral loading. Uniform loading shows that the steel frames exhibit higher base shear than the triangular loading.
The IDA results show that the far-field ground motions have caused all-steel frame design within the research to collapse while near-field ground motion only caused some steel frames to collapse.
The POA is often wont to estimate the performancebased-seismic-design (PBSD) limit states of the steel frames with consistency while the IDA seems to be quite inconsistent.
(Nazri and Ken 2014) It is concluded that the POA is often consistently accustomed estimate the limit states of steel frames while limiting state estimations from IDA requires carefully selected ground motions with considerations of important parameters.

V. CONNECTIONS

Extensive studies show that the behaviors of beam-to-column connections of steel frames are between the fully rigid and pinned ones greatly influenced the behaviors of structure.
(Nader and Astaneh 1991) The single-story steel structures having these flexible , semi-rigid, and rigid connections were subjected to base excitation, simulating several major past earthquakes using the shaking table.
As the stiffness of the connection increased, the bottom shear resulting from the identical ground motion increased, while the corresponding lateral drift didn't decrease in an exceedingly similar manner. In this case of a one-story structure, having a hard and fast connection isn't the optimal solution.
A well-proportioned semi-rigid and even a versatile connection designed to permit active participation in nonlinear deformation may enhance the dynamic performance of steel frames in low-rise buildings.
Flexible and semi-rigid structures behaved well in most of the dynamic tests. That is, these structures didn't have large base shear forces and yet they failed to undergo large lateral drifts. the instant capacity of the semi-rigid connections was more than expected.

VI. STRENGTH REDUCTION FACTOR

(Qu, Zhang, and Zhao 2011) The strength reduction factor (R or Rμ) is the ratio of the elastic strength demand to the particular yield strength. it's also called ductility reduction factor to focus on the effect of structural ductility, as reductions in forces are essentially produced by the nonlinear hysteretic behaviour of structures.
(Qu, Zhang, and Zhao 2011) In the previous few decades, the concept of response modification factor R has been introduced and developed to account for the inelastic nonlinear behavior of structures under earthquakes. an effort has been made to regulate and extend this idea by introducing a modifying factor, Rμ. This factor is employed for the dynamic analysis of MDOF structures, including the calculation of inelastic response spectra.
(Zhai et al. 2015) Investigating the strength reduction factor of single degree of freedom system with constant ductility performance subjected to the mainshock– aftershock sequence type ground motions. The results indicate that the strong after- shock ground motion has more obvious influences on strength reduction factors in short period region than on those in long period region.
(Qu, Zhang, and Zhao 2011) As the ductility factor increases, the estimated R-value error and standard deviation also increase. For ductility factors of μ=2, 4, and 8, the standard deviations are around 0.2, 0.4, and 0.6 for rock and soil sites, but the estimated errors at soil sites are larger than at rock sites, particularly at short periods. The results show that the approximate R-μ-T relationships are more suitable for structures built on rock sites than on soil sites. Note that for soil sites, because the standard deviation reduces as the period increases, these approximate R-μ-T relationships may provide more accurate estimates for structures with long periods.

VII. STRUCTURAL CHARATERISTICS

(Behnoud and Hong 2012)It is believed that structural characteristics in terms of stiffness and strength distributions have a key role in the seismic response of structures. The study shows that depending on the level of inelasticity, soil flexibility and number of degrees of freedom (DOFs), structural characteristics distribution can significantly affect the strength demand and ductility reduction factor of MDOF systems. It is also found that at high levels of inelasticity, the ductility reduction factor of low-rise MDOF soil-structure systems could be significantly less than that of fixed-base structures and the reduction is less as the number of stories increases.

VIII. SEISMIC DESIGN

(Nassar, Aladdin Aly 2002)Earthquake resistant design has the objective of providing structural capacities that exceed the demands imposed by severe earthquakes by a sufficient margin of safety.

(Zahrai and Jalali 2014) Structures designed to resist moderate and frequently occurring earthquakes must have sufficient stiffness and strength to control deflection and to prevent any possible damage. However, it is inappropriate to design a structure to remain in the elastic region under severe earthquakes, because of the economic constraints. The inherent damping of yielding structural elements can be advantageously utilized to lower the strength requirement, leading to a more economical design.

(Hassanien Serror, Adel Diab, and Ahmed Mourad 2014) Damping is one of the parameters that control the performance of structures when they are subjected to seismic, wind, blast or other transient shock and vibration disturbances. The viscous dampers are more effective for elastic structures than inelastic ones.

(Arroyo-Espinoza and Teran-Gilmore 2003) In recent years, current seismic codes started contemplating the design of structures with passive energy dissipating devices. Various energy dissipating structural devices have been developed and even implemented in earthquake-resisting structures. It is important to formulate expressions to accurately estimate the value of strength reduction factor for ductile structures having passive energy dissipating devices.

IX. CONCLUSION

High-rise buildings are sometimes solutions to urban problems, but if we've to try and do them we must always agree that we face an excellent challenge to reduce the risks because of the impacts and consequences of the design if not well taken into consideration.

High rise buildings or multi-story buildings, built completely in steel or primarily with steel are reasonably limited in India, and will even be viewed as some “new concept within the construction industry".

Pre-engineered steel systems, which are our specialty, allow further optimization and further efficiency in multi-story steel building design. Delving into the mechanics of high-rise building construction, we see that the introduction of hot rolled steel sections, and using higher grade steel add more strength to the building. Better steel decking as a construction material led to a revolution within the steel building space. Composite steel decking laid on each floor adds the ability to transfer lateral loads more effectively through the structure aiding the structure to be stronger than conventional rigid materials. This added strength per floor allows the general core steel structure to be lighter and even more efficient. Cross bracing or shear walls are accustomed to providing a structural frame with greater lateral rigidity to resist wind stresses. The steel frame in comparison with the R.C. frame ends up in sufficient extra space to accommodate all service conduits without significant loss in headroom. In comparison with concrete construction, steel frames are significantly lighter. This ends up in much-reduced loads on foundations. to not forget, the muse of highrise buildings usually consists of concrete piers, piles, or caissons that are sunk into the bottom. Subsequent alterations or strengthening of floors are relatively easy in steel frames compared with concrete frames. The framework isn't prone to delays thanks to slow strength gain, as in concrete construction.

REFERENCES

[1] Arroyo-Espinoza, Danny, and Amador Teran-Gilmore. 2003. “Strength Reduction Factors for Ductile Structures with Passive Energy Dissipating Devices.” *Journal of Earthquake Engineering* 7(2): 297–325.

[2] Behnoud, Ganjavi, and Hao Hong. 2012. “Effect of Structural Characteristics Distribution on Strength Demand and Ductility Reduction Factor of MDOF Systems Considering Soil-Structure Interaction.” *Journal of Earthquake Engineering and Engineering Vibration* 11(2): 205–20.

[3] Hassanien Serror, M., R. Adel Diab, and S. Ahmed Mourad. 2014. “Seismic Force Reduction Factor for Steel Moment Resisting Frames with Supplemental Viscous Dampers.” *Earthquake and Structures* 7(6): 1171–86.

[4] Ibrahim, Eldemery. 2007. “High-Rise Buildings – Needs & Impacts.” *CIB World Building Congress 2017* CIB2007(269): 1998–2008. http://www.irbnet.de/daten/iconda/CIB5047.pdf.

[5] IŞIK, Ercan, Nursima SAYIN, and Ali Emre ULU. 2020. “The Effects of Changing Story Number and Structural Footprint Area on Building Performance in Reinforced-Concrete Buildings.” *Bitlis Eren University Journal of Science and Technology* 10(1): 30–34.

[6] Llanes-Tizoc, Mario D. et al. 2019. “Local, Story, and Global Ductility Evaluation for Complex 2D Steel Buildings: Pushover and Dynamic Analysis.” *Applied Sciences (Switzerland)* 9(1): 1–21.

[7] Mir, M. Ali, and Sun Moon Kyoung. 2011. “Structural Developments in Tall Buildings: Current Trends and Future Prospects.” *Architectural Science Review* 50(3): 37–41. https://www.tandfonline.com/doi/abs/10.3763/asre.2007.5027.

[8] Moghaddam, H., and R. K. Mohammadi. 2001. “Ductility Reduction Factor of Mdof Shear-Building Structures.”

DOI: 10.17148/IARJSET.2022.94119

Journal of Earthquake Engineering 5(3): 425–40.
[9] Nader, M. N., and A. Astaneh. 1991. “Dynamic Behavior of Flexible, Semirigid and Rigid Steel Frames.” *Journal of Constructional Steel Research* 18(3): 179–92.
[10] Nassar, Aladdin Aly, Ph.D. 2002. “Seismic Demand For SDOF and MDOF Systems.” *UMI*: 274.
[11] Nazri, Fadzli M., and Pang Yew Ken. 2014. “Seismic Performance of Moment Resisting Steel Frame Subjected to Earthquake Excitations.” *Frontiers of Structural and Civil Engineering* 8(1): 19–25.
[12] Qu, Honglue, Jianjing Zhang, and J. X. Zhao. 2011. “Strength Reduction Factors for Seismic Analyses of Buildings Exposed to Near-Fault Ground Motions.” *Earthquake Engineering and Engineering Vibration* 10(2): 195–209.
[13] Reyes-Salazar, Alfredo et al. 2018. “Energy Dissipation and Local, Story, and Global Ductility Reduction Factors in Steel Frames under Vibrations Produced by Earthquakes.” *Shock and Vibration* 2018.
[14] Seyed Morteza Kia, and Mahmood Yahyai. 2004. “Relationship between Local and Global Ductility Demand in Steel Moment Resisting Frames.” (3072).
[15] Zahrai, Seyed Mehdi, and Meysam Jalali. 2014. “Experimental and Analytical Investigations on Seismic Behavior of Ductile Steel Knee Braced Frames.” *Steel and Composite Structures* 16(1): 1–21.
[16] Zhai, Chang Hai, Wei Ping Wen, Shuang Li, and Li Li Xie. 2015. “The Ductility-Based Strength Reduction Factor for the Mainshock–Aftershock Sequence-Type Ground Motions.” *Bulletin of Earthquake Engineering* 13(10): 2893–2914.
[17] Zubritskiy, Maksim, Oleg Ushakov, Linar Sabitov, and Karina Nabiullina. 2021. “Seismic Resistance Estimation of Multi-Story Steel Frames under Ductility Level Earthquake Impact by Nonlinear Static Method.” *E3S Web of Conferences* 263.