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Comprehensive Study of Seismic Analysis of Steel Frame Buildings and Structures

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ABSTRACT

Seismic Analysis is a subset of structural analysis and is the calculation of the response of a structure to earthquakes. Nowadays High Rise Steel frame building is well establishing in metro cities. For construction of high rise building bracing are constructed for stiffness and lateral load resistance purpose. Steel frame usually refers to a building technique with a “skeleton frame” of vertical steel columns and horizontal I-beams, constructed in a rectangular grid to support the floors, roof and walls of a building which are all attached to the frame. Steel moment resisting frames without bracing, inelastic response failure generally occurs at beam and column connections. They resist lateral forces by flexure and shear in beams and columns i.e. by frame action. Under severe earthquake loading ductile fracture at beams and columns connections are common. Moment resisting frames have low elastic stiffness. P-∆ effect is another problem associated with such structures in high rise buildings.

Keywords: Steel, frame, building, bracings, structure.

INTRODUCTION

Steel structure plays an important role in the construction industry. Previous earthquakes in India show that not only non-engineered structures but engineered structures need to be designed in such a way that they perform well under seismic loading. Structural response can be increased in Steel moment resisting frames by introducing steel bracings in the structural system. Bracing can be applied as concentric bracing or eccentric bracing. In the present time, Steel structure plays an important role in the construction industry. Previous earthquakes in India show that not only non-engineered structures but engineered structures need to be designed in such a way that they perform well under seismic loading. Structural response can be increased in Steel moment resisting frames by introducing steel bracings in the structural system. Bracing can be applied as concentric bracing or eccentric bracing. There is “n” number of possibilities to arrange steel bracings, such as cross bracing “X”, “K” bracing, and Inverted “V” type bracing. Steel moment resisting frames without bracing, inelastic response failure generally occurs at beam and column connections.

They resist lateral forces by flexure and shear in beams and columns i.e. by frame action. Under severe earthquake loading ductile fracture at beams and columns connections are common. Moment resisting frames have low elastic stiffness. P-∆ effect is another problem associated with such structures in high rise buildings. So, to increase the structure response to lateral loading and good ductility properties to perform well under seismic loading concentric bracings can be provided. Beams, columns and bracings are arranged to form a vertical truss and then lateral loading is resisted by truss action. Bracings allow the system to obtain a great increase in lateral stiffness with minimal added weight. Thus, they increase the natural frequency and usually decrease the lateral drift. They develop ductility through inelastic action in braces. Failure occurs because of yielding of truss under tension or buckling of truss under compression. These failures can be compensated by use of Buckling Reinforced Braced frame (BRBs) or Self Centering Energy Dissipating frames (SCEDs).

When a tall building is subjected to lateral or torsional deflections under the action of fluctuating wind loads, the resulting oscillatory movement can induce a wide range of responses in the building’s occupants from mild discomfort to acute nausea.

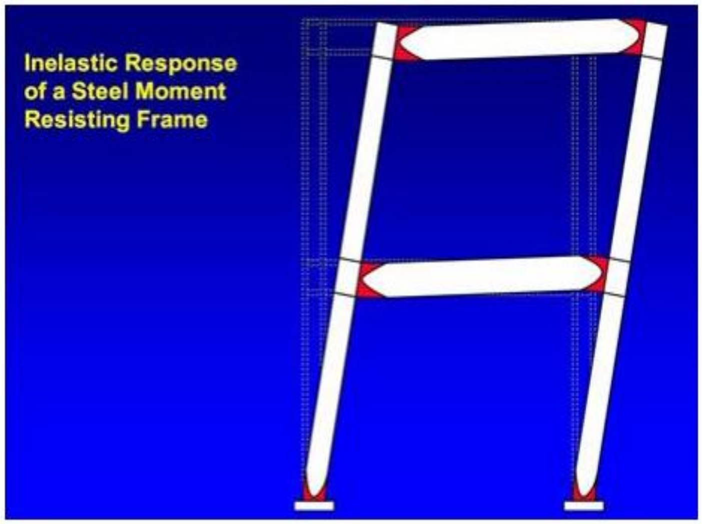

Fig. 1: Inelastic Response of steel Moment Resisting Frame

As far as the ultimate limit state is concerned, lateral deflections must be limited to prevent second-order p-delta effect due to gravity loading being of such a magnitude which may be sufficient to precipitate collapse. In terms of serviceability limit states deflection is required to be maintained at a sufficient low level for following reasons;

- To allow proper functioning of non-structural components such as elevators and doors.
- To avoid the distress in the structure, to prevent excessive cracking and consequent loss of stiffness and to avoid any redistribution of the load to non- load-bearing partitions, infill, cladding or glazing.

The structure must be sufficiently stiff to prevent dynamic motions becoming large enough to cause discomfort to occupants or affect sensitive equipment. To satisfy strength and serviceability limit stares, lateral stiffness is a major consideration in the design of tall buildings. The simple parameter that is used to estimate the lateral stiffness of a building is the drift index defined as the ratio of the maximum deflections at the top of the building to the total height. With the increase in trend of constructing tall buildings, there is need to find cost effective structural forms of bracing system to be used in tall buildings against lateral loads. This research study aims to find the most suitable bracing system out of five investigated bracing systems in terms of lesser weight of the structure and smaller value of lateral displacement. For this purpose, a regular shape tall building has been selected and analyzed for wind loads acting along the minor axis of bending of column and then acting along the major axis of bending of column.

LITERATURE REVIEW

This Paper deals with a brief review of the past and recent study performed by researchers on seismic analysis of braced steel frames. A detailed review of each literature would be difficult to address in this chapter. The literature review focuses on concentrically braced frames, failure mode generally observed in moment resisting frames and bracings brace to frame connections, local buckling and plastic hinge formation. The recent study of use of buckling reinforced bracing (BRBs) and Self cantered energy dissipating frames (SCEDs) is also mentioned.

Tremblay et al. performs an experimental study on the seismic performance of concentrically braced steel frames with cold-formed rectangular tubular bracing system. Analysis is performed on X bracing and single diagonal bracing system. One of the loading sequence used is a displacement history obtained from non-linear dynamic analysis of typical braced steel frames. Results were obtained for different cyclic loading and were used to characterize the hysteretic response, including energy dissipation capabilities of the frame. The ductile behaviour of the braces under different earthquake ground loading are studied and used for design applying the codal procedures. Simplified models were obtained to predict plastic hinge failure and local buckling failure of bracing as a ductility failure mode. Finally, Inelastic deformation capabilities are obtained before failure of moment resisting frame and bracing members.

Khatib et al. (1988) The failure mode generally observed in special moment resisting frames with bracing system is fracture of bracings at the locations of local buckling or plastic hinges. Significant story drift can occur at a single story and this research shows how the failure mode occurs and how the failure is concentrated entirely on single floor. So, this is one of the limitations of using moment resisting frames with bracing system.

E.M. Hines and C.C. Jacob [2009] presented a paper on Eccentric braced frame system performance. The seismic performance of low-ductility steel systems designed for moderate seismic regions have generated new interest in the cost-effective design of ductile systems for such regions. Although eccentrically braced frames (EBFs) have a well-established reputation as high-ductility systems and have the potential to offer cost-effective solutions in moderate seismic regions, their system performance has not been widely discussed. Eccentrically Braced Frames (EBFs) are known for their attractive combination of high elastic stiffness and superior inelastic performance characteristics (AISC 2005).

The University of California, Berkeley (UCB) under the direction of Professors Popov and Bertero conducted a test of two separate 0.3 scale shake table tests of Concentrically Braced Frame (CBF) and EBF dual systems (Uang and Bertero 1986, Whittaker et al. 1987, Whittaker et al. 1990). The design of shear links for the tower of the San Francisco-Oakland Bay Bridge East Bay self- anchored suspension span (McDaniel et al. 2003).

Hanson and Martin (1987); Kelly et al. (2000) The typical failure mode experienced by special moment resisting frames with bracing i.de. Damage to braces, brace to frame connections, columns and with base plates was studied.

Ghobarah A. et al., (1997) is described that the inter story drift can also be considered as a means to provide uniform ductility over the stories of the building. A story drift may result in the occurrence of a weak story that may cause catastrophic building collapse in a seismic event. Uniform story ductility over all stories for a building is usually desired in seismic design.

Christopoulus et al. (2008) An advanced cross bracing system has been used in University of Toronto called (SCEDs) Self centering energy dissipating frames. Alike, Special moment resisting frames and Buckling reinforced braced frames, they also dissipate energy, but they have self-centering capabilities which reduce residual building deformation after major seismic events.

Tremblay et al. (2008) An extensive analytical study is performed to compare the Buckling restrained braced frames with self-centering energy dissipating frames. According to the results, the residual deformation of SCED brace frame systems is negligible under low and moderate hazard levels and is reduced significantly under MCE or maximum considered earthquake level.

S.H. Chao and M.R. Bayat et.al [2008] studied on performance based plastic design of steel concentric braced frames for enhanced confidence level in China. Concentrically braced frames (CBFs) are generally considered less ductile seismic resistant structures than other systems due to the brace buckling or fracture when subjected to large cyclic displacements. This is attributed to simpler design and high efficiency of CBFs compared to other systems such as moment frames, especially after the 1994 Northridge Earthquake.

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The adverse effect of the unbalanced vertical force at the beam-to-brace connections can be mitigated by adding zipper elements, as proposed by **Khatib et al. (1988).** If the compression brace in the first story buckles while all other braces remain elastic, a vertical unbalanced force is then applied at the middle span of the first story beam. The zipper elements mobilize the stiffness of all beams and remaining braces to resist this unbalance. The unbalanced force transmitted through the zipper elements increases the compression of the second story compression brace, eventually causing it to buckle.

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R. Leon & R. DesRoches (2006) A research work on Behaviour of Braced Steel Frames with Innovative Bracing Schemes. Conventional bracing systems include typical diagonal and chevron bracing configurations, as well as innovative concepts such as strut-to-ground and zipper braced frames (Khatib et al. 1988, Bruneau et al. 1998). Seismic regulations and guidelines for the seismic design of CBFs can be found in the Structural Engineers Association of California (SEAOC) Recommended Lateral Force Requirements (SEAOC 1996), the International Building Code (IBC 2000), the NEHRP Recommended Provisions for the Development of Seismic Regulations for New Buildings (BSSC 2000), and the AISC Seismic Provisions for Structural Steel Buildings (AISC 2002). Diagonal and chevron systems can provide large lateral strength and rigidity but do not provide great ductility as buckling of the diagonals leads to rapid loss of strength without much force redistribution (Goel 1992).

STEEL DESIGN & STRUCTURES

Results of Code Checking and Member Selection are presented in the output file. The output is clearly marked for the selected specification (ASIC 360). The following details are presented on Code Checking of any member:

- Result of Code Checking (Pass / Fail) for the member Number.
- Critical Condition which governed the design and the corresponding Ratio and Location.
- Loads corresponding to the Critical Condition at the Critical Location.
- Section Classification
- Slenderness check report
- Section Capacities in Axial Tension, Axial Compression, Bending and Shear in both the directions.

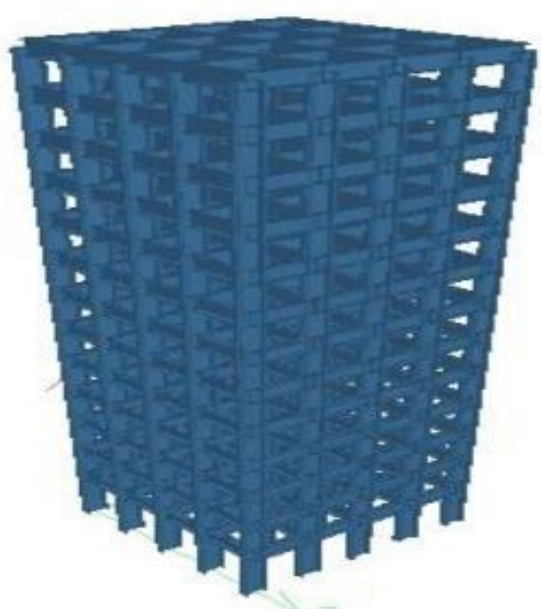

Fig. 2: dimensional view of Steel building frame

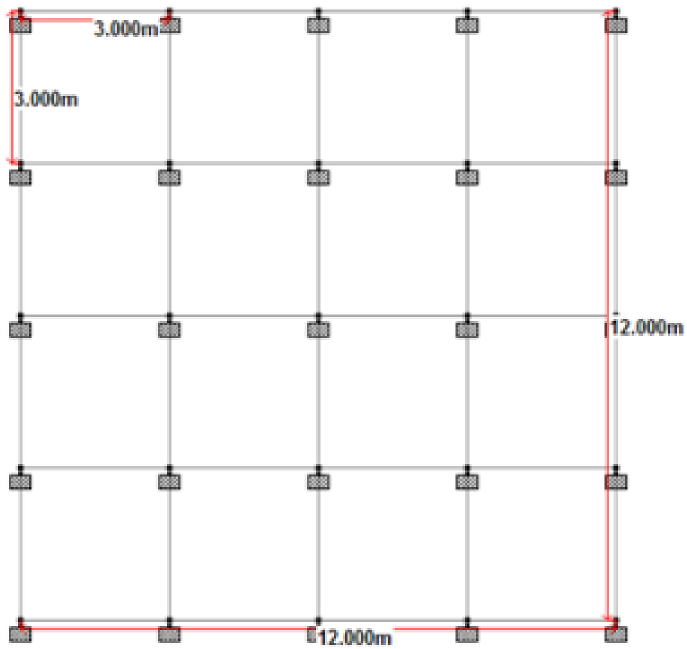

Fig. 3: Plan of building

CONCLUSIONS

In this paper, the author has studied in details about the Steel bracings and steel frame structures. Steel braced frame is one of the structural systems used to resist earthquake loads in multi-storeyed buildings. Many existing reinforced concrete buildings need retrofi to overcome deficiencies to resist seismic loads. The use of steel bracing systems for strengthening or retrofitting seismically inadequate reinforced concrete frames is a viable solution for enhancing earthquake resistance. Steel bracing is economical, easy to erect, occupies less space and has flexibility to design for meeting the required strength and stiffness Bracings also increase the shear force and bending moment capacity of the columns. In a laterally stiffer frame, the columns are subjected to less shear force and bending moment and an increased axial force at their ends. A larger height model was stiffer as compared to smaller one and hence had baser shear.

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