Comparative Study on Seismic Behaviour of G+41 Storey Frame with X, K and V Bracings

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1 Introduction

Construction materials, machines, technology and knowledge as well as the lifestyle of people are improving and so is the need of the hour to construct high rise buildings. However, construction of tall structures has its own challenges and problems. Vertical loading increases as height of the building increases. Also there is a large effect from horizontal wind load on the building. Unexpected seismic load also can affect the building stability [1, 2]. Structures designed to resist earthquakes must have excellent stiffness and strength to control deflection and hence prevent any possible damage or collapse [3].

One of the main challenges while designing tall structures is its ability to absorb the horizontal forces and to transfer the resulting moment into the foundation. Bracings play an important role in seismic resistance of structures [2, 4–6]. They contribute much to the resistance of lateral loads acting on high rise buildings. Seismic analysis of these buildings are mainly done to obtain various parameters like storey shear, storey displacement, base shear, joint displacement and so on, that defines the seismic behaviour of buildings. In this study we analysed braced steel frame with concrete slab for base shear and storey displacement by using equivalent static and response spectrum method of analysis.

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2 Bracing System

The seismic performance depends upon the lateral force resisting system provided in the structures. Incorporating bracings into the system can give high seismic resistance to the structure. As per studies, braced structures have less drift compared to unbraced structures which shows that the performance of structures can be increased by providing different bracings [7]. On the basis of the reaction mechanism or structural behaviour for resisting the lateral loads, there are various structural systems for steel structures. There are different arrangements in bracing a structure in which the mainly used as well as the conventional method is placing the braces in a vertical line, in story height and bay width dimensions. The other arrangements have been found by tests and optimizations. Researches are still going on in the field [8].

Braced frames have excellent stiffness due to limited ductility. There are several ways of providing braces to increase the seismic resistance of buildings [6]. They are mainly classified as:

1. Vertical bracing system: Bracing in vertical planes (between lines to ground level and provide lateral stability of columns) provides load paths to transfer horizontal forces.
2. Horizontal bracing system: The bracing at each floor provides load paths for the transference of horizontal forces to the planes of vertical bracing. Horizontal bracing is needed at each floor level; however, the floor system itself may provide sufficient resistance.

Different types of bracings used in buildings are given below:

- Single diagonal bracing
- X bracing or cross bracing
- K Bracing
- V Bracing
- Inverted V Bracing
- Eccentric bracing

Bracings are usually provided all throughout the height of the building and it forms a vertical truss structure. These structures hence increase the strength of the building and hence provide resistance to the effect of lateral loads like wind and seismic loads and this in turn increases the stability of the whole building [9]. The performance of bracings vary according to its type and load acting on them.

Steel bracings are also used in retrofitting of RC and steel structures affected by earthquake. The ease of construction and the relatively low cost make steel bracings more effective in comparison to other conventional upgrading techniques such as adding concrete or masonry shear walls or base isolation systems. Adding bracings enhances the global capacity of the buildings with respect to strength, deformation and ductility compared to the case with no bracings [10]. In case of high rise buildings, stiffness plays an important role. Moment resisting frames and braced frames have been commonly used as lateral load resisting structural elements in steel buildings.

Moment resisting frames provide ductility through yielding, but due to their flexibility they do not satisfy the criteria for stiffness. However, excellent stiffness is provided by concentric braced frames due to their limited ductility [11].

A braced frame is an earthquake-resistant design system of steel-frame structures, and due to its high rigidity, strength and cost effectiveness, it is widely used in areas where frequent earthquakes occur [12]. Braces of concentrically braced frames (CBFs) are subjected to deformations caused by repeated tension and compression after buckling, and through this behaviour, seismic energy is dissipated. Sufficient stiffness and strength should be there for structures constructed in seismically active regions to minimize deflections. In an economically effective design, we cannot permit the structure to remain in elastic region under severe earthquakes. The inherent damping of yielding structural elements provides ductility against sudden failure, and this can be utilized to lower the strength requirement, leading to a more economical design. Always it is desirable to design a structural system that combines stiffness and ductility, in cost effective manner [3].

3 Problem Statement

G+41 frame is chosen for the work. It is a steel frame with concrete slab. Three building models are considered with X, K and V bracings at right end, left end and mid portion of the building. Both response spectrum and equivalent static methods are taken into account for the seismic analyses.

The details of the structure are given below:

- G+41 steel frame with concrete slab is considered for the work.
- Number of bays = 9 × 7 (5 m each)
- Plan dimension = 45 × 35 m
- Height of storey = 3.5 m, height of elevated portion above lift and stair area = 2.5 m
- Thickness of slab = 150 mm
- Column ISMB550
- Beam ISMB500
- Zone V
- Response Reduction Factor = 4
- Damping = 5%
- Soil type = Medium soil

As per IS 1893, the following combinations were used:

- 1.7 (D.L + L.L)
- 1.7 (D.L + EX
- 1.7 (D.L + EZ)
- 1.7 (D.L – EX)
- 1.7 (D.L – EZ)

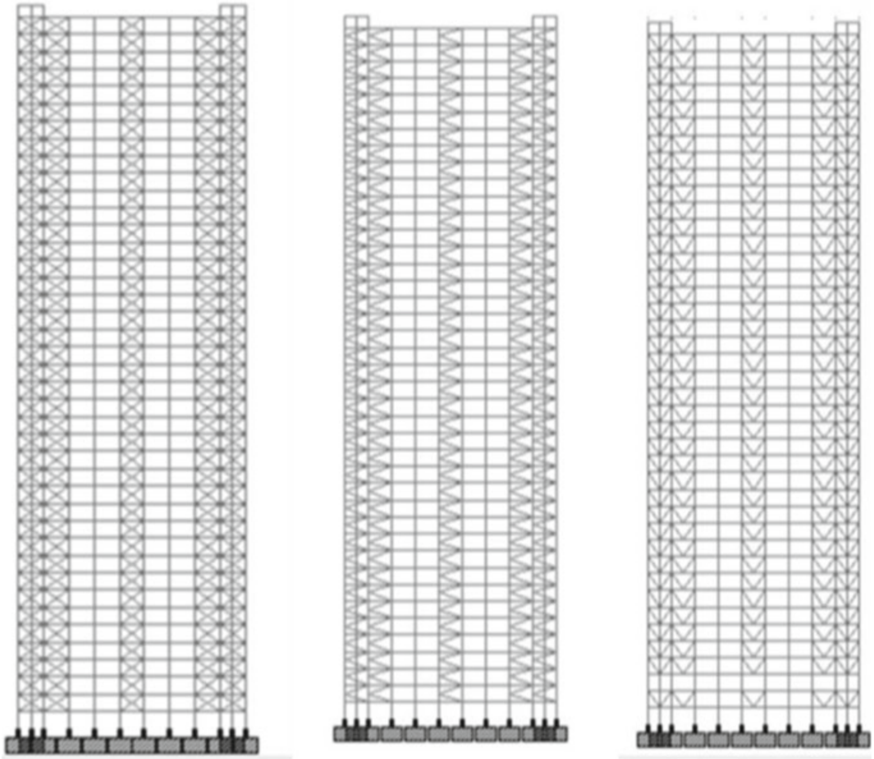

Fig. 1 X, K and V braced frames

- 1.3 (D.L + L.L + EX)
- 1.3 (D.L + L.L + EZ)
- 1.3 (D.L + L.L – EX)
- 1.3 (D.L + L.L – EZ)

Modelling and analysis of structures were done in STAAD pro V8i software. The building models with X, K and V bracing are shown in the following Fig. 1.

4 Results and Discussions

All the structures were modelled and analysed in Staad Pro V8i software by equivalent static and response spectrum methods. Following graphs represent the comparison of seismic behaviour of different bracing systems after equivalent static and response spectrum analysis. Figures 2 and 3 represent the storey displacement for frames with the three bracing systems. Storey displacement increased from storey 1–42 for all three cases. The highest displacement was for X bracing in case of both equivalent

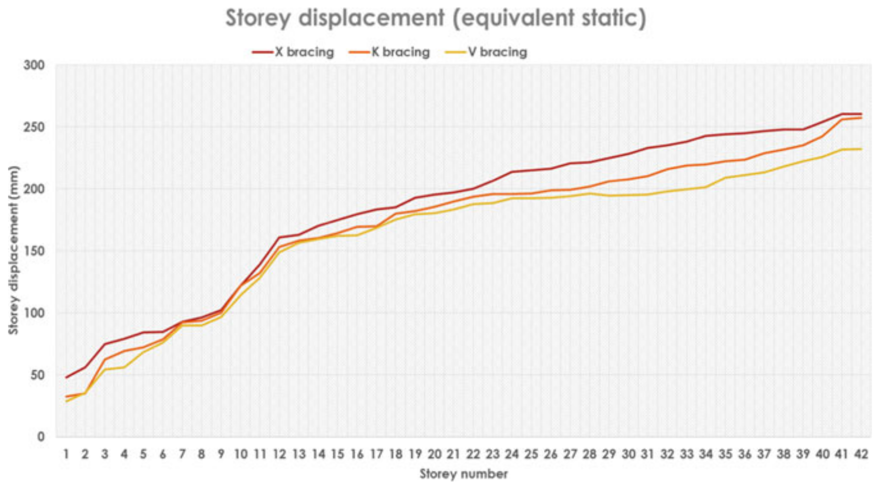

Fig. 2 Storey displacement after equivalent static analysis

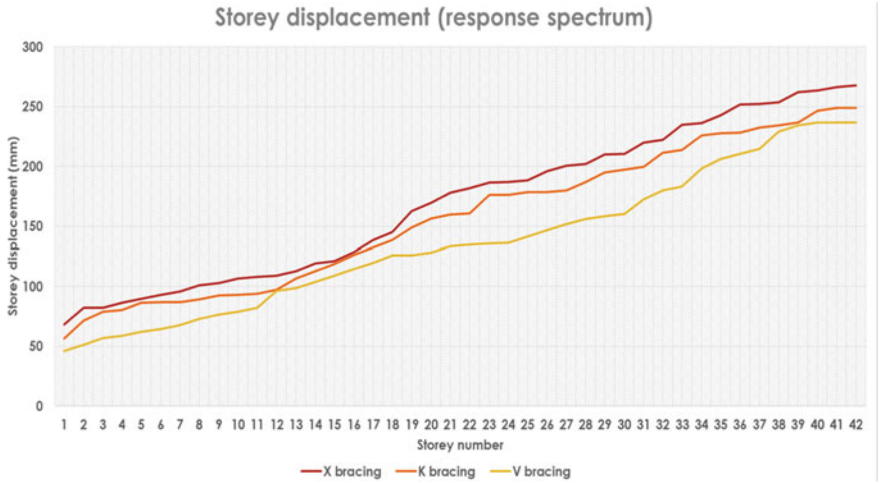

Fig. 3 Storey displacement after response spectrum analysis

static and from response spectrum analysis. The lowest was for V braced frame in both the analyses.

Figures 4 and 5 represent the base shear for different braced systems from equivalent static and response analysis. V bracing showed highest base shear while K bracing showed the lowest in both the methods.

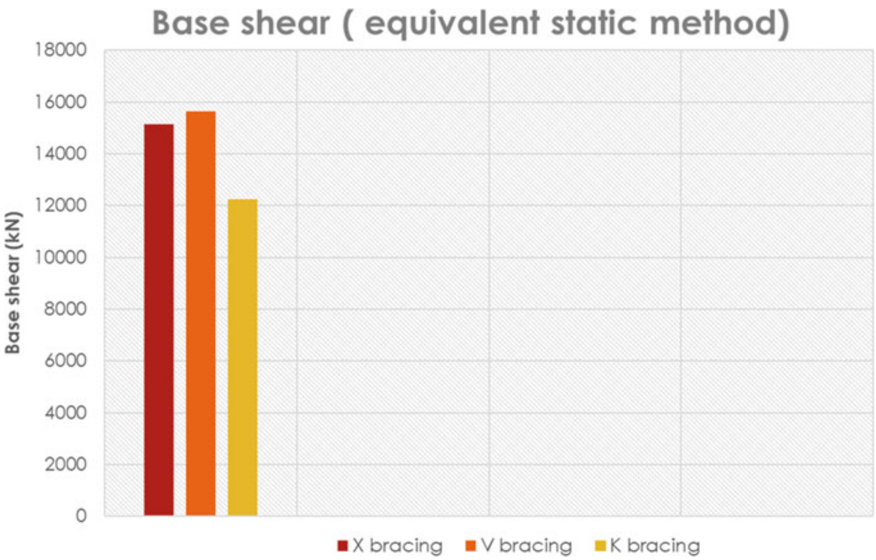

Fig. 4 Base shear after equivalent static analysis

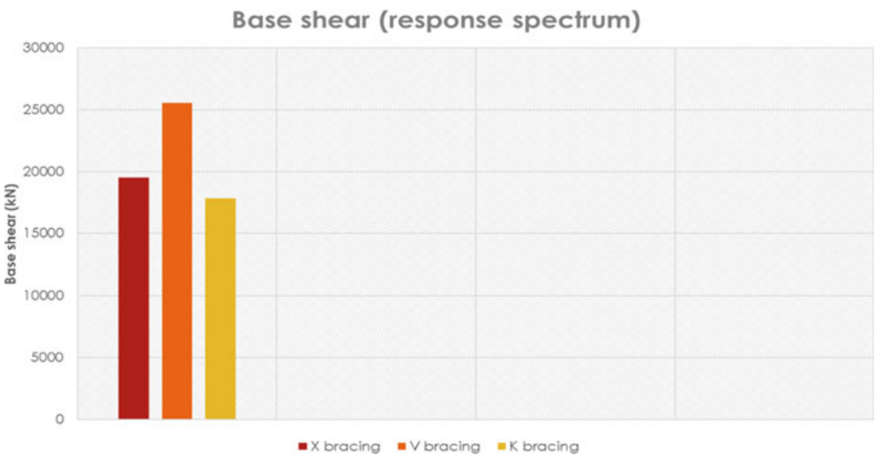

Fig. 5 Base shear after response spectrum analysis

5 Conclusions

Response spectrum and equivalent static analysis were done for frames with X, K and V bracing and compared for base shear and storey displacement. The followings were observed.

- Storey displacement for X braced frame was 4.9% higher than the lower value of V braced frame in equivalent static method and 16.5% higher in response spectrum method.
- Base shear was higher for V braced frame, around 42.3% higher in equivalent static analysis and 49.6% higher in case of response spectrum analysis than the K braced frame which exhibited low base shear.
- As per the analyses done, the seismic behaviour of V braced frame was more efficient with respect to the other bracing types used for the G+41 steel frame in zone V considered in this study.
- K braced framed frame performed second best in terms of displacement when compared to X braced frame.

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