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Design & Modelling Different Bracing System to The Building

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A B S T R A C T

In recent years, India has witnessed a significant rise in the construction of steel-framed buildings, offering much-needed architectural diversity in urban areas dominated by reinforced concrete (RC) structures. This shift toward steel construction can be attributed to several key advantages: faster erection times, lighter weight allowing easier handling and reduced transportation costs, and generally lower material costs. However, due to the inherently flexible nature of steel, unbraced steel frames tend to exhibit greater storey displacements compared to RC buildings. For mid-rise and high-rise structures, incorporating bracing systems is essential to control storey drifts and displacements within acceptable limits. While bracing increases the overall stiffness of the structure—leading to higher base shears and bending moments—the effects on structural response, including storey drifts and fundamental time periods, can vary depending on the location of the braces, even when using similar bracing sections. This paper investigates these variations to assist designers in optimizing brace placement for steel-framed buildings.

Keywords: Steel building, Bracing, Seismic design, Storey drift, Base shear, Fundamental time period.

1. Introduction

The construction of steel-framed buildings has seen significant growth in urban India, offering an alternative to the traditionally dominant reinforced concrete (RC) structures. This shift is driven by advantages such as faster construction, lighter weight for easier handling and transportation, and potentially lower material costs. These benefits are particularly valuable in fast-developing cities like Mumbai, Delhi, and Bengaluru.

However, the flexible nature of steel makes unbraced frames more prone to lateral displacements under wind or seismic loads compared to RC frames. In mid-rise and high-rise buildings, this necessitates the use of bracing systems to control storey drift and improve stability. While bracing increases stiffness and alters structural responses—such as base shear, bending moments, and natural period—the effectiveness of these responses depends significantly on the position of the braces.

This study investigates how different bracing configurations affect the seismic performance of steel-framed buildings, with the goal of helping designers identify optimal bracing arrangements that balance stiffness, material efficiency, and safety.

2. Structural Configuration & Design Approach-

2.1 Building Specifications

Analyzed two high rise steel buildings having 10 story height 30 m. One structure has no bracings and one have X type bracings at all four faces of structure. Building has 5 bays on each side. Spacing of bay is 4 m.

2.1.1 Bracing System-

Bracing is an effective and economical method of resisting horizontal forces in a framed structure. Braced frame systems are utilized both in RC as well as in steel buildings. Normally, the structure comprises of column and beams whose basic purpose is to transfer gravity load. When bracings are fixed to it, the total set of members forms a vertical cantilever truss like structure to resist the horizontal forces. Bracing members are utilized in the building as a horizontal load resisting system to improve the stiffness of the frame for seismic forces. Braces can be connected with fixed-ended or pin ended connection. In the case of pin ended connection, it will be subjected to axial forces and it normally fails under compressive load by global buckling. Once the buckling occurs, its strength gets reduced in the succeeding cycles. But there will not be many changes in maximum tensile strength in subsequent cycles. The main advantage of using braces is that they dissipate the energy without damaging the building and also it can be replaced without any difficulty when it gets damaged. Building Specifications

2.2 Types of Bracing System-

2.2.1 Diagonal Bracing-

Diagonal bracing is the simplest and most commonly used type. It connects diagonally between columns and beams, forming a triangulated system that efficiently transfers lateral loads to the foundation. It offers high stiffness and strength but may interfere with openings such as windows or doors.

2.2.2 X-Bracing (Cross Bracing)

In X-bracing, two diagonal members cross each other within a single bay. Both members can resist tension and compression, providing high resistance to lateral forces. However, under seismic loading, one brace may buckle, leaving the other to carry the load in tension.

2.2.3 V-Bracing (Chevron Bracing)

V-bracing consists of two diagonal braces meeting at a single point on the beam, forming a 'V' shape. It leaves the center of the bay open, allowing architectural flexibility. However, under lateral loading, it can induce additional vertical forces (unbalanced loading) on the beam.

2.2.4 Inverted V-Bracing

Also known as inverted chevron bracing, this configuration is similar to V-bracing but inverted, with the braces connected at the top and diverging downward. Like V-bracing, it provides architectural openness but poses challenges under unbalanced loading due to brace buckling.

2.2.5 K-Bracing

In K-bracing, diagonal members are connected from the column to mid-span of the beam, forming a 'K' shape. This system helps maintain open bays for doors and windows. However, it may lead to instability or premature beam failure under heavy lateral loads, as it induces significant axial forces in the beams.

2.2.6 Eccentric Bracing

Eccentric bracing combines the stiffness of braced frames with the ductility of moment frames. It includes an intentional offset or link between the brace and beam, which deforms inelastically during seismic activity, absorbing energy and preventing brittle failure. It is especially effective in seismic-prone regions and complies well with Indian seismic codes like IS 1893.

3. Literature Review-

3.1 Ketan Chaudhary (2019) [1]-

Explains the effect of Bracing & Unbracing Structure over lateral deflection, seismic effects like base shear, time period etc. This study emphasized the importance of lateral load resistance and found that braced frames perform better under seismic and wind loads compared to unbraced frames. Bracing enhances stiffness and load-carrying capacity.

3.2 Jagdish J.S. (2013) [2]-

Detailed study on high rise structure with seismic activity. Factors studied like seismic weight, story drift, deflection, base shear. They demonstrated that computer-aided modelling and analysis (e.g., ETABS) are useful in evaluating the structural behaviour of both braced and unbraced systems. Their results revealed that bracing systems significantly reduce story drift and displacement

3.3 Kumar Vanshaj (2022) [3]-

In this research paper, comparative study was done on structure which has bracing and structure having no bracing. They discussed different types of loads (dead, live, wind, seismic) and the response of buildings to such loads. Their findings highlighted that structural bracing plays a critical role in resisting lateral forces.

4. Methodology-

4.1 Structure Specification-

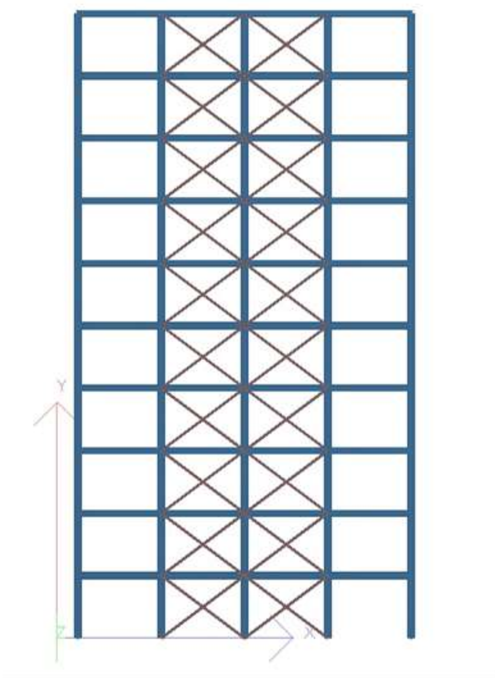
In the present study, a G+10 storey steel-framed building is analysed with and without the inclusion of bracing systems to evaluate the structural response under seismic loading. The building plan consists of four bays spaced at 4 meters centre-to-centre in both the X and Y directions. Each storey has a uniform floor height of 3 meters, and the layout remains consistent across all levels.

The seismic performance of the structure is assessed using the **Equivalent Static Method** as per IS 1893 (Part 1): 2016. The structural modelling and analysis are performed using **STAAD.Pro.** Bracing configurations is applied to the same building model to ensure a controlled comparison of their effectiveness. Wind load is also applied and evaluated with same for with and without bracing structure.

Design Data for analysis of structures	**DESIGN VALUES**
Column	ISMB 300
Beam	ISMB 300
Floor to Floor height	3m
Foundation depth	3m
length	16m
Width	16m
Height	30m
Type of bracing	X
Seismic zone	3
Bracing	PIP1016H
Type of soil	Medium

4.2 Loading Details-

Loading Details	**DESIGN VALUES**
Dead Load	5 Kn/m^2
Live Load	2 Kn/m^2
Basic Wind Speed	39 m/s
Riak Coefficient K1	1
Terrain Category	3



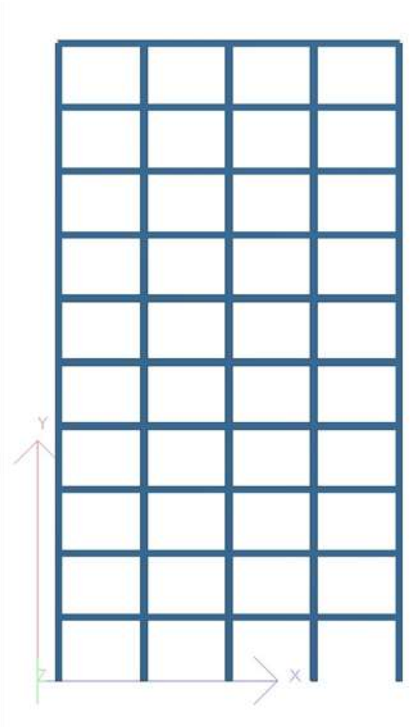
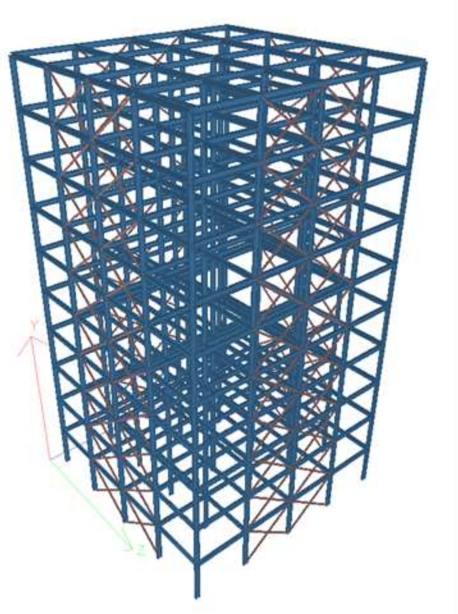


Fig. 1 (a) Structure with Bracing (b) Strcuture without Bracing



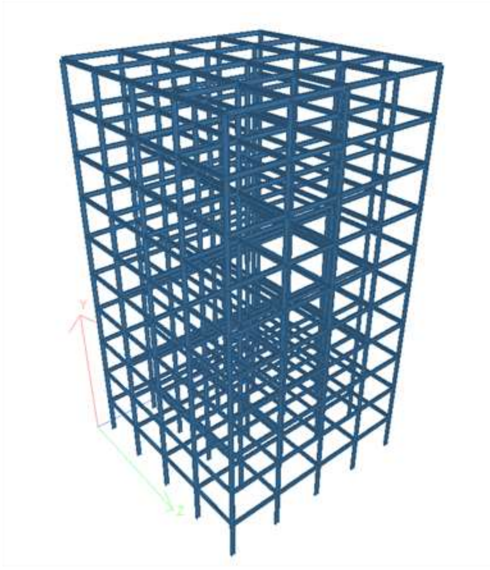


Fig. 2 (a) Isometric view Strcuture with Bracing (b) Isometric View Strcuture Without Bracing

Results-

Results are discussed below for seismic analysis and comparing both the structures deflection criterion.

4.1. Seismic Analysis Results-

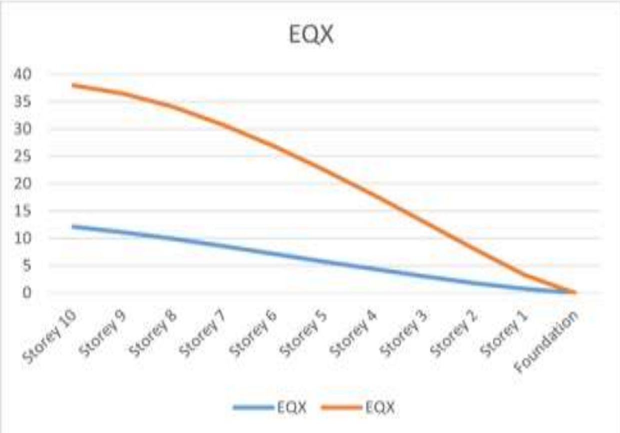


Fig. 3 (a) Deflection of Structure in X direction for with & without bracing (b) (a) Deflection of Structure in Z direction for with & without bracing

4.2. Wind Analysis Results-

Fig. 4 (a)) Deflection of Structure in X direction for with Bracing (b) Deflection of Structure in X direction for without Bracing

Results-

Comparison of Structural Performance with and Without Bracing:

1. Analysis shows that buildings with bracing systems experience **less deflection** compared to those without bracing.
2. The **shear force** is significantly reduced in the braced structure.
3. The **bending moment** is also lower in the presence of bracing.
4. Overall, the use of bracing results in reduced deflection, shear force, and bending moment compared to an unbraced building.
5. During structural design, lower bending moments and shear forces imply a **reduced requirement for steel**, making the braced system more economical and efficient.

5. References-

1. Ketan Chaudhary- Effect of bracing and unbracing in steel structures by using Etabs

2. Jagdish J. S.- A Study on Bracing Systems on High Rise Steel Structures

3. Kumar Vanshaj, Himanshu Kumar Singh, Abhishek Mishra- Comparative study of high-rise steel structure with and without bracing system