IIETA International Information and Engineering Technology Association
Advancing the World of Information and Engineering

Mathematical Modelling of Engineering Problems
Vol. 10, No. 5, October, 2023, pp. 1833-1841
Journal homepage: http://iieta.org/journals/mmep

The Impact of Bracing System Distribution and Location on Seismic Performance Enhancement of Multi-Story Steel Buildings

Ayman Z. Abdulhameed*, Mazin A. Ahmed, Abdulamir A. Karim

Civil Engineering Department, College of Engineering, University of Basrah, Basra 61006, Iraq

Corresponding Author Email: engpg.ayman.zaki@uobasrah.edu.iq

https://doi.org/10.18280/mmep.100536

Received: 6 March 2023
Revised: 2 May 2023
Accepted: 10 May 2023
Available online: 27 October 2023

Keywords:
non-linear time history analysis, inverted v-bracing, SAP 2000 V 20, Mega brace frame (MBFs), X-brace

ABSTRACT

This study employed the ETABS v16 program to design a multi-story steel building subjected to gravity load. Nine variations of bracing systems were subsequently integrated in both the X and Y planes, utilizing different types of braces such as mega-braced frames (MBFs), inverted V-bracing, and X-bracing in various locations and distribution configurations. The intention was to enhance the structural performance, gauged by parameters including maximum roof displacement, base shear, base moments, and drift ratio. To isolate the impact of bracing location and distribution pattern on seismic force resistance, the weight of the bracing at each story was held constant across all models. A non-linear time-history analysis was performed on the models in both the X and Y directions using SAP2000 V20, incorporating the El-Centro earthquake. The analyses revealed that Model 9 outperformed the others, reducing the maximum roof displacement and drift ratio in both directions by averages of 46.1% and 41%, respectively. Moreover, in relation to base shear, Model 9 demonstrated superior performance compared to the other models.

1. INTRODUCTION

Earthquakes are ground vibrations encompassing a wide spectrum of frequencies, triggered by various phenomena such as tectonic shifts, volcanic activity, landslides, rock bursts, and human-induced explosions. Among these, tectonic-induced earthquakes are the most prevalent and impactful, resulting from the fracturing and shifting of rocks along faults within the Earth's crust [1].

In the era preceding modern engineering, traditional materials like timber, clay brick, and stone dominated architecture. However, these materials proved to be highly susceptible to damage in earthquake-prone regions. The recognition of steel's resilient behavior during several earthquakes led to its emergence as a promising structural material, especially for buildings in seismic zones. This preference was predicated on two factors: firstly, steel's inherent properties of exceptional strength and ductility—specifically, its ability to endure substantial inelastic deformation without significant loss of strength, and secondly, the successful performance of steel structures in numerous earthquakes throughout the past century, during which the principles of seismic design were entrenched [2].

In terms of strength, steel buildings have typically exhibited commendable performance during earthquakes. Yield strength and elastic stiffness—two inherent properties of steel—contribute to the elastic resistance of steel structures during moderate earthquakes. However, during more substantial seismic events, a structure may undergo inelastic deformations and rely on its ductility and hysteresis energy dissipation capacity to prevent collapse. Steel, being a ductile material equally strong in tension and compression, is superbly suited for earthquake-resistant structures. Its ductility allows the structure to experience large plastic deformations with minimal loss of strength [3].

Damage to steel buildings observed in previous earthquakes has predominantly been induced by ground movements. This includes damage to beam-to-column connections caused by severe ground motion, buckling of diagonal braces, cracking of the concrete at the column base, and yielding and fracturing of anchor bolts. Nonstructural damage was also extensive in buildings with large open sections, such as gymnasiums and industrial facilities, particularly in ceilings and claddings. Additionally, widespread damage was observed in external finishes composed of mortar over light-gauge metal lath [4].

In this study, the focus will be on the bracing system, one of the various strategies employed to enhance the seismic performance of steel buildings, alongside shear walls and dampers [5]. The concentrically braced frame is a preferred type of bracing system due to its high elastic stiffness and is extensively used as a lateral force-resisting system. This setup comprises horizontal and vertical framing elements interconnected by a diagonal brace member, with intersecting axes. The concentric brace is available in several configurations, including the X-brace, multistory X-brace, inverted V-brace, V-brace, and multibay X-brace [6].

Previous research on the bracing system has been extensive. For instance, Tafheem and Khusru [7] modeled a six-story steel building and assessed its response to wind, earthquake, dead, and live loads using various types of bracing, such as X-bracing and V-bracing with HSS bracing. They analyzed the building's lateral story displacement, story drift, axial force, and bending moment at different levels. Their study showed that X-bracing significantly reduces lateral and inter-story displacement while increasing lateral stiffness.

In their study, Di Sarno and Elnashai [8] scrutinized the