Analysis of Multistory Semi Rigid Steel Frame with Cross Bracings Subjected to Mainshock and Aftershock Earthquake

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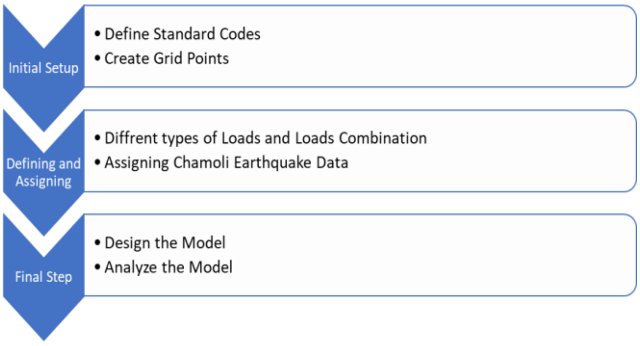
Abstract - *Structure analysis and design are heavily influenced by earthquakes. Seismic evaluation is deemed necessary for the quality and reliability and feasibility of existing and developing structures. Steel structures have played a vital role in the construction industry in the last few decades. It is essential to formulate a structure in such a way that it can withstand seismic loads. The seismic behaviour of a multi-story steel-framed building is developed in accordance with Indian code provisions (IS 800 -2007). Steel bracings in the structural system will increase the ductility of the structure. Retrofitting can also make use of a variety of bracings. Steel bracings can be arranged in a variety of ways, including Braced in various ways, such as X, diagonally, alternatively, V, inverted V, K, etc. Cross bracings are used in the design of a typical multi-story (G+9) steel building frame in this study. Using ETABS software, a static nonlinear Time History analysis is used to examine the performance of the frame. Base shear, joint displacement, kinetic energy, and story displacement are a few of the variables that affect how well a building performs during mainshock and aftershock earthquakes. Each of these variables has a significant impact on how a structure responds to seismic loads and should be considered when evaluating the results.*

Key Words: *Time History analysis, Cross Bracings, Steel Frame, Ground Motions, ETABS software, seismic response*

1. INTRODUCTION

In earthquake-prone areas, man-made structures are subject to a seismic sequence comprising foreshocks, the mainshock, and aftershocks in addition to a single seismic event. Due to changes in both static stress and dynamic stress that take place during the earthquake process, aftershock events are set off by the mainshock [1]. A smaller seismic event known as an aftershock takes place in the same general area as a previous large earthquake. Steel bracings can be added to the structural system to boost the structure's ductility [2]. For retrofitting, various types of bracing can be utilized. Through the use of ETABS and nonlinear Time History analysis, the performance of the frame is investigated. The near-field earthquake ground motion verification may have specific impacts for both forward and backward directivity [3]. The initial's velocity and displacement motions, respectively, exhibit pulse and fling-step characteristics. Therefore, it is crucial to assess how buildings constructed only for the purpose of withstanding the mainshock would fare during subsequent aftershocks[4]. Using modern seismic protection systems, such as base isolations and/or additional dampening devices, that significantly reduce building damages during main shocks and their related aftershocks is one of the appropriate solutions to this issue[5]. Due to changes in both static and dynamic stress that take place during the earthquake process, aftershock events are set off by the primary shock[6]. A lesser seismic event known as an aftershock takes place in the same region as the primary shock after a previous large earthquake. In order to better understand the ground motion features of a sizable collection of mainshock and subsequent aftershock ground motion data recorded in accelerograph stations around the region, this study reviews pertinent literature in the field [7]. The G+9 Braced Steel Frame will be used in this study to perform time history analysis on the mainshock and aftershock data of the Chamoli earthquake provided by the Centre for Engineering Strong Motion Research Ground Motion Database [8]. The IS 800-2007 code is considered when designing. Live loads are measured in accordance with IS 875-part 1, and seismic zone IV is selected for analysis in accordance with IS 1893-2016. This paper's goal is to analyse how braced semi-rigid steel structures responded to a previous earthquake sequence [9]. Different factors will be considered and examined for earthquakes with mainshocks and aftershocks. Moreover we will study the seismic characteristics with Time history analysis for the same building with unscaled data provided by Centre for Engineering Strong Motion Research Ground Motion Database CHAMOLI (NW HIMALAYA) EARTHQUAKE, MARCH 29, 1999, GOPESHWAR STATION (Latitude & Longitude 30’24”N - 79’20”E).

2. Methodology



3. Building parameters:

A G+9 building is modelled in ETABS v16 with a storey height of 3.1 m, a structure's length of 20 m in one direction and 15 m in the other, and member sizes that vary depending on the design specifications. The slab measures 150 centimetres in thickness. As per IS 800-2007 and IS 1893-2016, the model was evaluated and created.

1.1 Material properties

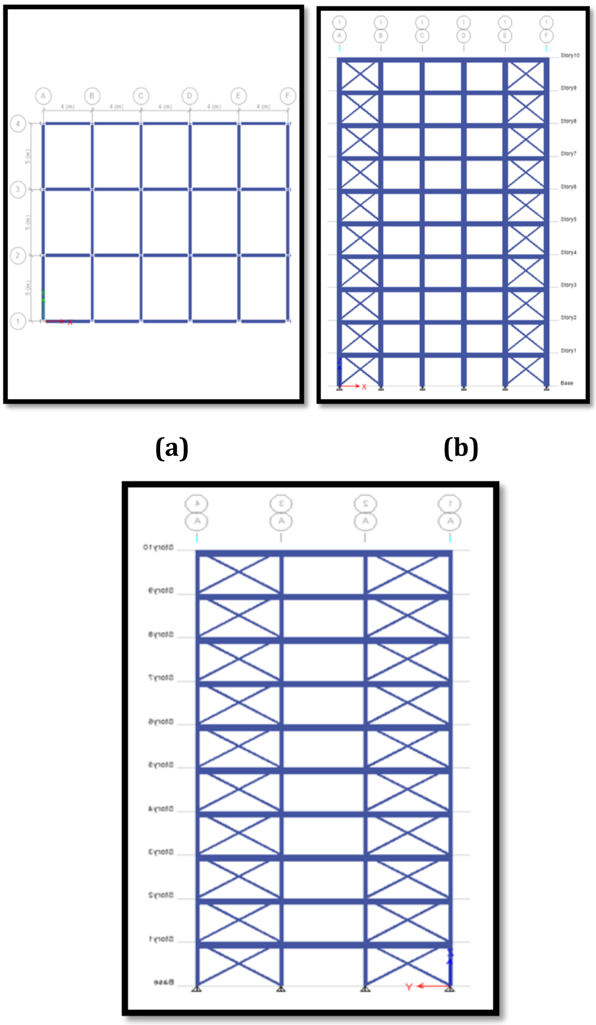
Table -1: properties of material

Plan dimension	20X15 m^2
No. of stories	9
Floor to floor height	3100mm
Beam size	ISWB 400 as per IS:800-2007
Column size	ISHB 450 as per IS:800-2007
Bracing	ISA 150*150*15 as per IS:800-2007
Grade of steel	Fe345
Deck Size	3 inches

1.2 Loads on building

Loads are taken from Indian standard codebooks for dead loads we have IS 875 part 1, for Live loads IS 875 part 2 and seismic analysis is done according to the IS 1893 part 1 2016.

<u>Loading data Type of Load</u>	<u>Intensity of Load</u>
Live load	2 kN/ m^2 (IS 875-Part 2)
Super Dead	1 kN/ m^2 (IS 875-Part 1)
Seismic zone	IV
Cladding load	5.0 kN/m^2 (IS:875-Part 2)
Response reduction factor	5
Importance factor	1.5
Scale factor (I.g/R)	1.9622D-plan extruded



(a) (b)

(c)

Fig – 1: Plan and Elevation view

4. Shock type

4.1 Mainshock Earthquake:

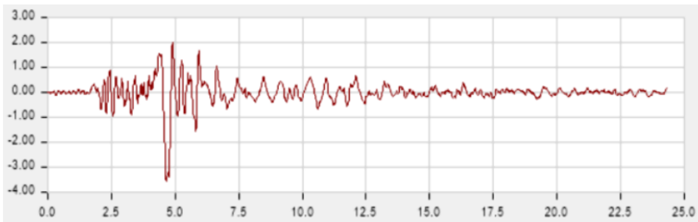


Fig – 2: Acceleration vs Time data along Horizontal N-E Direction

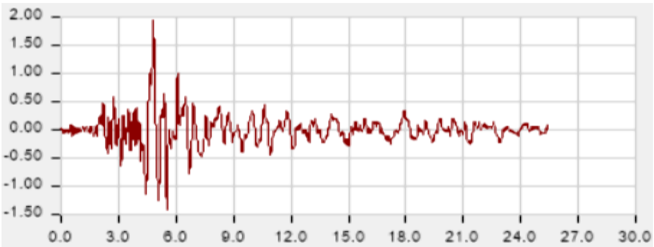


Fig -3: Acceleration vs Time data along Horizontal N-W Direction

4.2 Aftershock Earthquake:

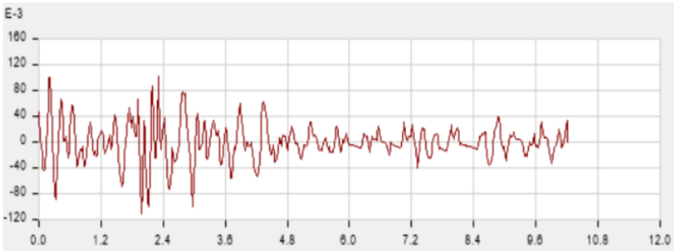


Fig – 4: Acceleration vs Time data along Horizontal N-E Direction

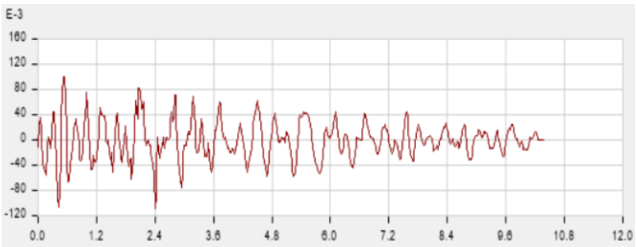


Fig – 5: Acceleration vs Time data along Horizontal N-W Direction

5. Results and discussion

5.1. Storey Displacement for Braced and Unbraced Steel Frame –

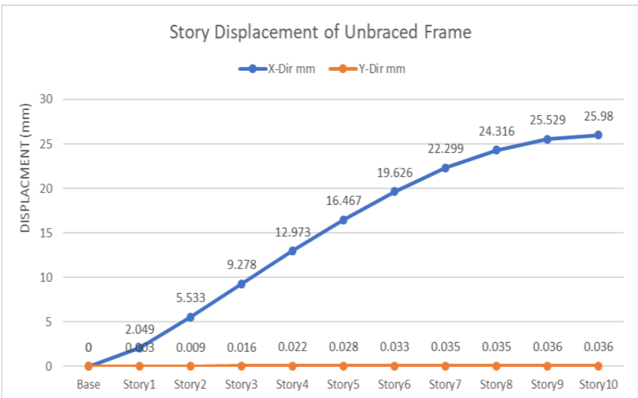


Chart 1- Storey Displacement of Unbraced Frame

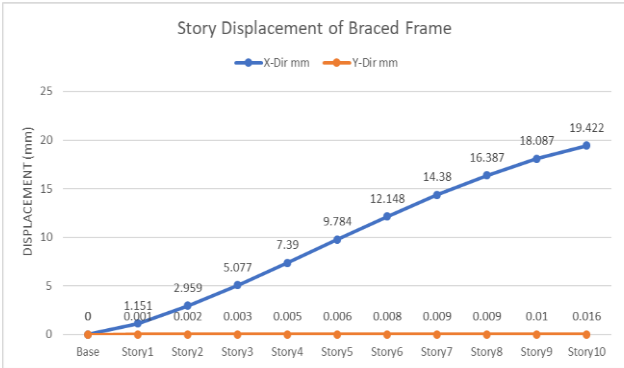


Chart 2- Storey Displacement of braced Frame

The graph displays the displacement of the tale for the braced and unbraced models. While the braced model exhibits lower levels of story displacement in both axes for both the Mainshock and the Aftershock earthquake, both models exhibit behavior that is essentially the same

5.2. Base shear (kn) of semi rigid steel frame under mainshock and aftershock earthquake data

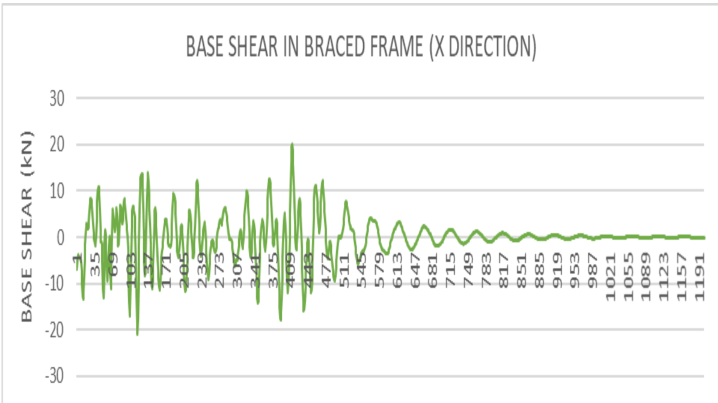


Chart 3: Aftershock Base shear in X direction

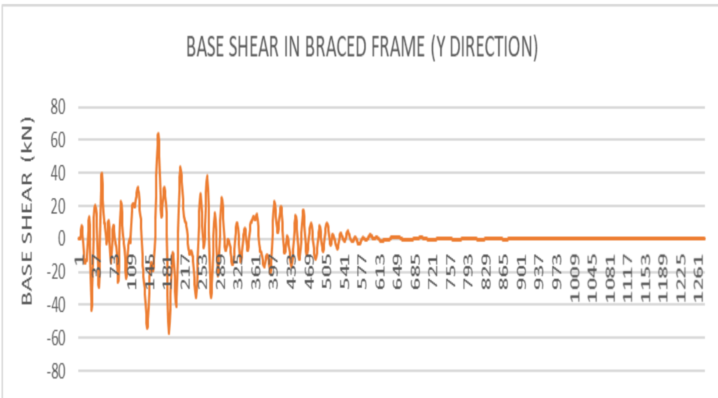


Chart 4: Aftershock Base shear in Y direction

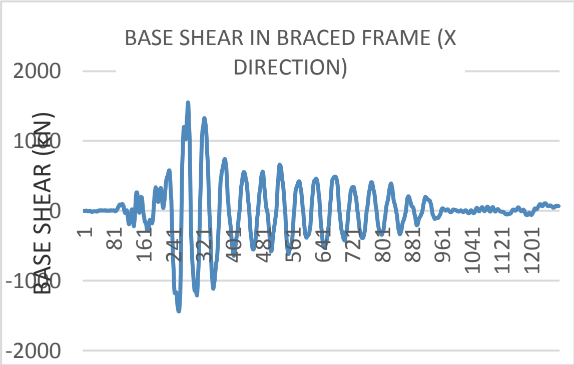


Chart 5: Mainshock Base shear in X direction

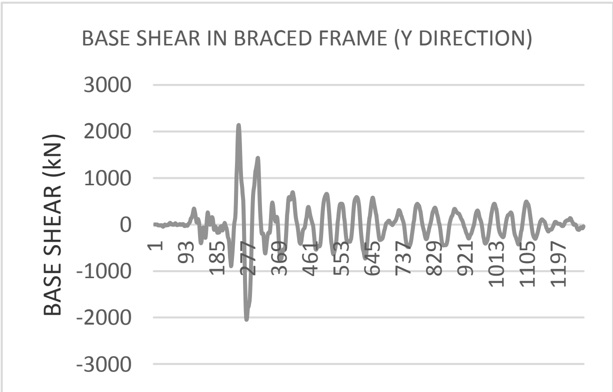


Chart 6: Mainshock Base shear in Y direction

5.3. Joint Displacement for Storey 10:

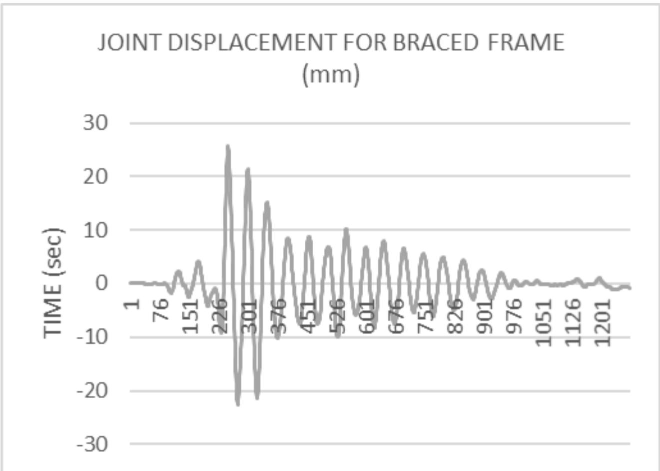


Chart 7: Mainshock joint displacement

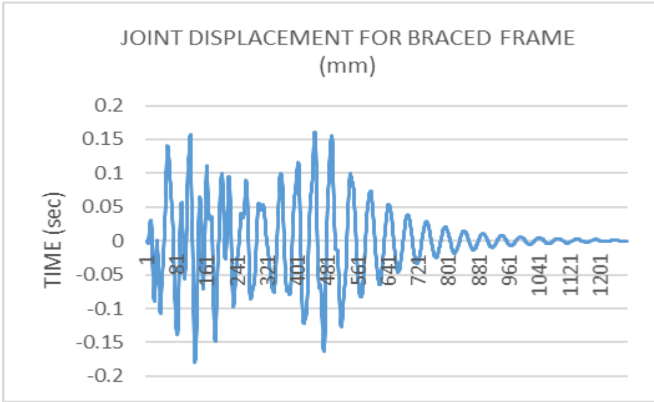


Chart 8: Aftershock joint displacement

5.4. Kinetic Energy Stored during Earthquake

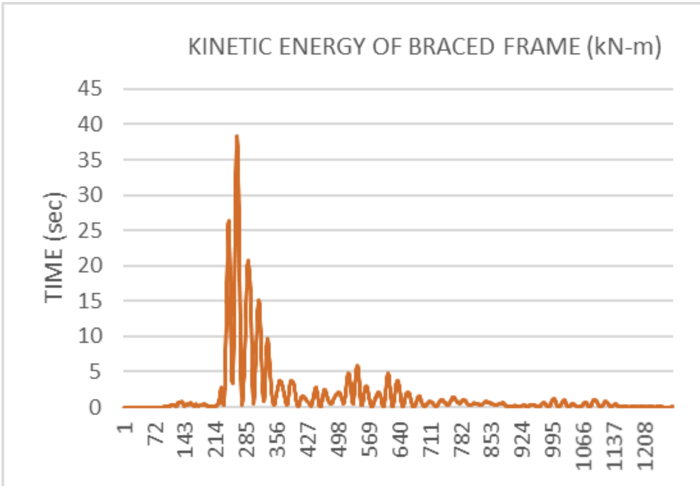


Chart 9: Mainshock Kinetic energy stored during earthquake

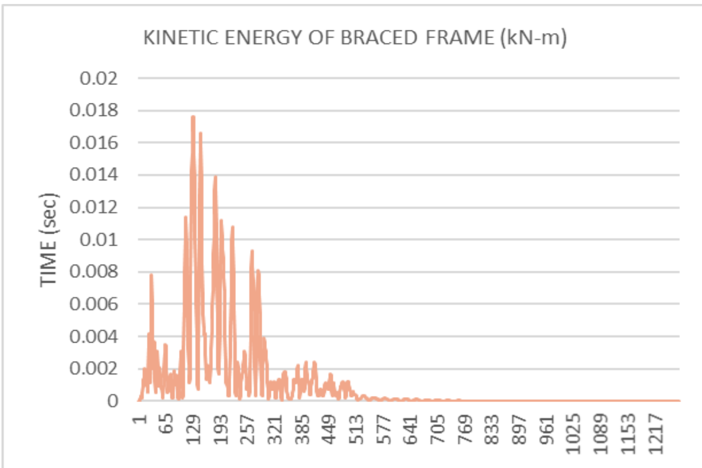


Chart 10: Aftershock Kinetic energy stored during earthquake

As a result of comparison with Mainshock and Aftershock Earthquake on G+9 RC structure, following has been observed:

- As per IS 1893 (part 1) : **2002 CI. 7.11. 3**, the storey drift in any storey due to the minimum specified design lateral force, with partial load factor of 1.0, shall not exceed 0.004 times the storey height and according to the graphs obtained the maximum drift is 0.019418, which is within the permissible limits[10].
- Frequency of Joint Displacement and Base Shear is greater in case of Aftershock as compared to Mainshock.
- Maximum value of Joint Displacement of Storey 10 joint during aftershock is approx. 2 percent of joint acceleration during Mainshock for Unbraced section and its approximately negligible for Braced frame.
- Maximum Kinetic Energy building during aftershock is approx. 11.52 percent of Maximum Kinetic Energy stored during Mainshock for Unbraced section and its 9.5 percent for Braced frame.
- It is observed that storey drifts, storey displacement and stiffness are in permissible limits as recommended by the IS 1893 code

3. CONCLUSIONS

Based on time history analysis, conclusions for structural framework have been established for a G+9 structure in India with various types of soil in seismic zone IV.

1. According to the discussed results, aftershocks are unavoidable earthquake sequences that should always be considered when building earthquake-resistant structures, especially when the structure has previously sustained damage from a far more powerful mainshock.
2. Any structure that has already experienced a mainshock can suffer fatal consequences from aftershocks with higher frequency and lower strength on the Richter scale.
3. The story shear starts out low at the first level of the construction and proceeds rising to the top storey. The magnitude of story shear grows along with a building's height.
4. The base isolation system, which separates the structure (superstructure) from the base, can be supplied to prevent the mainshock and aftershock sequence (foundation or substructure). The amount of energy that is delivered towards the structure during a seismic event is greatly decreased by separating the building from its base.
5. Time history analysis is a sophisticated programme that helps you see how well a building and its components—such as the supporting columns, beams, and slab—are working. By choosing an appropriately selected ground motion data of an earthquake that has already occurred, the seismic performance of the building can be determined.
6. Cross bracing can also be employed to keep structures stable during seismic occurrences like earthquakes and when the wind blows

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