International Journal of Research in Advent Technology (E-ISSN: 2321-9637) Special Issue
International Conference on Technological Advancements in Structures and Construction
"TASC- 15", 10-11 June 2015

Numerical Simulation of Special Concentrically Braced Frame Structure using OpenSEES

Simi Aboobacker[1] and Nisha Varghese[2]
PG Student, Dept. of Civil Engineering, Vidya Academy of Science and Technology, Thrissur[1]
Assistant Professor, Dept. of Civil Engineering, Vidya Academy of Science and Technology, Thrissur[2]
Email: simi.aboobacker1@gmail.com[1], *nisha.v@vidyaacademy.ac.in*[2]

Abstract- Earthquake is a natural calamity known to mankind for ages. Improving the Seismic resistance of the structures has been the main area of research works. It is found out that structures made up of steel tends to resist Earthquake force by energy dissipation in terms of its cyclic yielding. In this paper, the seismic analysis of two story single bay Special Concentrically Braced Frame (SCBF) structure is carried out. Numerical modeling of structures was done using OpenSEES (Open System for Earthquake Engineering Simulation), a Finite Element research oriented software. OpenSEES Fiber model with lower Degree Of Freedom was used for structure member simulation. The effect of Split-X bracing configuration to that of Chevron bracing SCBF structure was investigated.

Index Terms- Chevron configuration; Dynamic Analysis; OpenSEES; Pushover analysis; SCBF; Split-X configuration

1. INTRODUCTION

Previous earthquakes provide opportunities to learn vital lessons regarding the behavior of structures. After 1904 Northridge Earthquake, Special Concentrically Braced Frame (SCBF) gained popularity amongst the structural engineers because of the unsatisfactory performance of Special Moment Resisting Frame (SMRF). Compared to SMRF, SCBF are more economical due to the lesser quantity of steel and welding at field required. SCBF resist seismic excitation with comparatively less deformations than gravity load resisting system as they form a stiff system.

Extensive research are still conducted on SCBFs with the main goal of improving the SCBF system and performance of beam-column and brace connection. In a SCBF system, the energy dissipation occurs through the consecutive buckling and yielding of diagonal brace member during seismic excitation.

Finite Element software OpenSEES (Open System for Earthquake Engineering Simulation) is an open source object oriented framework used for simulating the seismic response of geotechnical and structural systems. This framework was developed as computational platform for research in performance-based earthquake engineering at the Pacific Earthquake Engineering Research (PEER). Network for Earthquake Engineering Simulation (NEES) Cyber-Infrastructure Center (NEESit) from 2004 uses OpenSEES as a simulation component for. OpenSEES uses physical-theory model to represent the elements

2. OBJECTIVES

The prime objectives of this paper are as follows:

1) To investigate the effect of chevron and Split-X bracing configuration of SCBF structure

2) To examine the local response of HSS bracing members.

3. SPECIAL CONCENTRICALLY BRACED FRAME

Steel structures are generally classified into two types: Braced Frames and Moment Resisting Frame. Concentrically Braced Frames (CBFs) are a class of steel structures which resists lateral loads through formation of concentric vertical truss system. These structures are effective in resisting lateral forces due to the high strength and stiffness provided by them.

Special Concentrically Braced Frames (SCBF) comes under special class of Concentrically Braced Frame that are proportioned and detailed to maximize the inelastic drift capacity. The primary goal of ductile detailing in SCBF is by permitting the cyclic yielding and buckling, without failure at brace end connection

as well as premature fracture of brace member.

Seismic loads are resisted by the main component of SCBF which is the braces. Brace configuration includes: diagonal bracing, single story X-bracing.

4. FINITE ELEMENT MODEL

While performing seismic analysis of structures, if inelastic structural behaviour is taken into account then the numerical modeling of structure needs to be done by considering the inelastic behaviour of structural components. Structures can be idealized through line members (beams, columns and braces) which are connected by nodes.

Typical Finite Element analysis on any software requires the below data:

i. Geometry or Spatial locations of Nodal points
ii. Elements connecting the nodal points
iii. Mass properties of members
iv. Material and section properties
v. Conditions of boundary or restraints
vi. Details of loading or forcing function
vii. Analysis options

5. OPENSEES NUMERICAL MODELLING

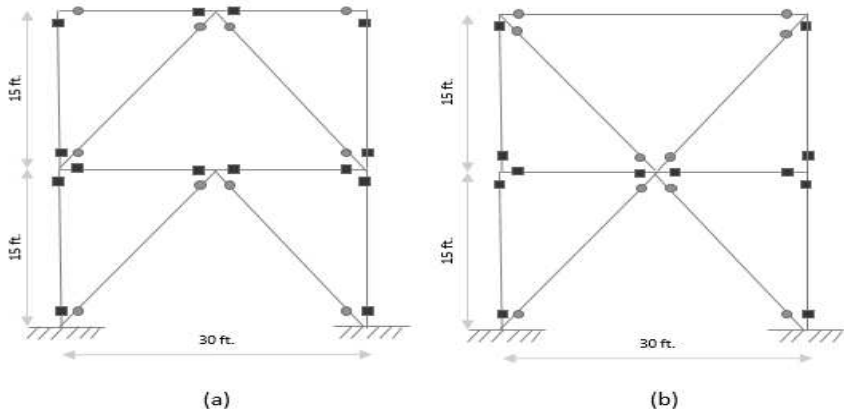

Fig.1: Brace configuration: (a) Chevron braced, (b) Split X braced

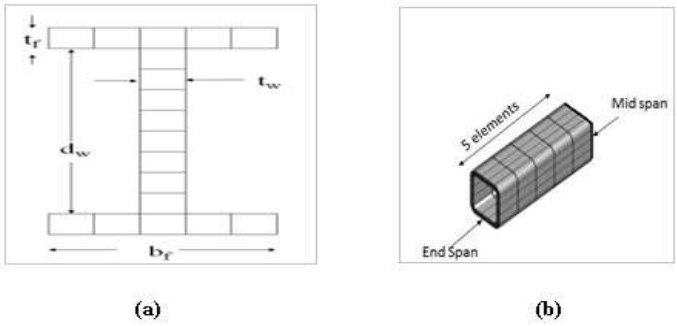

Fig. 2. Fiber details of (a) W-Section, (b) HSS Section

The geometry configuration of the SCBF building used for this study is as shown in Fig.1. Story height for the building is 15 feet and width of bay is 30 feet.

Two approaches in OpenSEES for modeling the elements (Beams, columns and braces) using physical theory model are:

i. Distributed Plasticity - Plasticity spread along the element.
ii. Lumped Plasticity - Plasticity concentrated at the ends over a specified length and interior of element behaves elastic.

In this paper, first method is adopted. Formulation of a fiber model as shown in Fig 2 is done by dividing the structure into discrete number of elements (beams, Columns). Further, these elements are discretized into number of sections. Sections divided into number of Fibers. Based on plane section assumption, fiber strains are then used to determine the section deformations.

In OpenSEES, distribution of plasticity for fiber formulation models is done by numerical integrations through the member cross sections and along the member length. Each flange and the web of the W-sections were divided into 8X5 fibers as shown in Figure.2 (a). More number of fibers were provided in the expected direction of bending in plane of the frame. Brace of the SCBF was divided into 10 elements each. Each region of the square HSS section were divided into 10x10 fibers as shown in Figure.2 (b). Initial imperfection of 0.1% was provided in braces to account for the brace buckling (global buckling). Minimum of 4 Numerical integration points were considered for columns and beams of Split-X and Chevron braced SCBF. Gauss-Lobatto (quadrature integration) is used for the integration along the element. Beams, columns, braces and gusset plates of all types of models were modelled using the command Steel02 Material in OpenSEES. In order to capture the steel behavior in nonlinear region, strain hardening ratio of 3% was assumed. Material properties for the column, beam and gusset plate members are having minimum yield strength of 55ksi (379 MPa) and HSS braces of 60 ksi (413MPa). Member size used in the models for the first story are beams of W27X84 section, columns of W14X176 section, and HSS brace of HSS10X10X5/8 section. Similarly, for second story beams of W18X46 section, columns of W14X176 section, and HSS brace of HSS8X8X1/2 section.

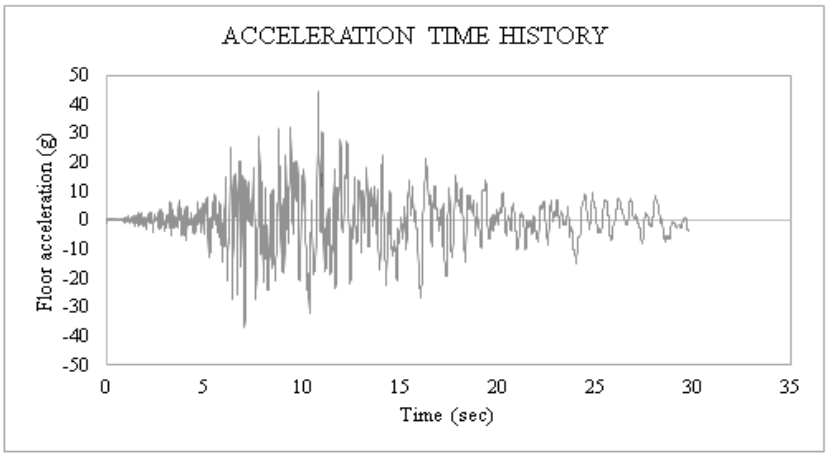

Fig. 3. Acceleration Time History for Superstition Hills ground motion

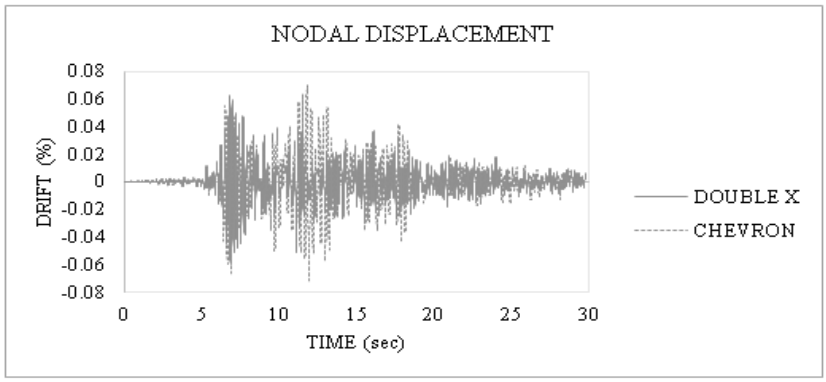

Fig. 4. Drift response for roof node

Earthquake ground motion used for this study will be referred as 'Superstition Hills' ground motion, which is Imperial Valley Earthquake, occurred in Imperial County, California, USA in 1987 and was recorded at station Wildlife Liquefaction array taken from PEER database. Acceleration-Time history for the Superstition Hills Earthquake was obtained as shown in Fig 3.

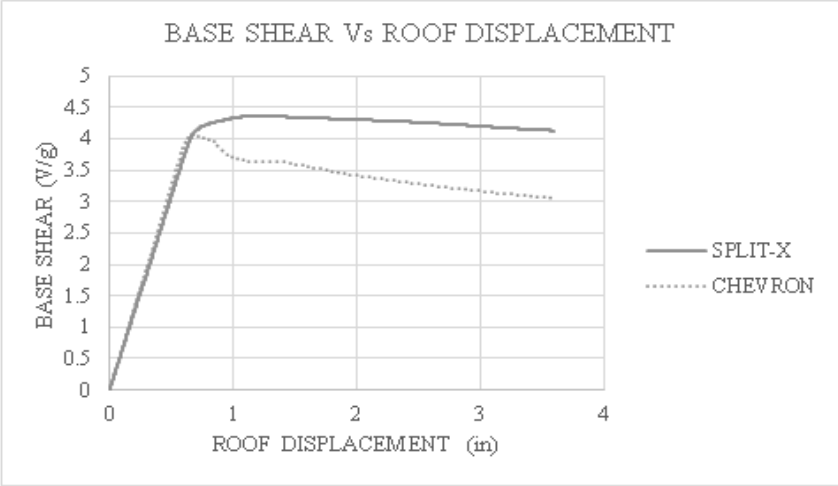

Fig. 5. Pushover curve for SCBF bracing configuration

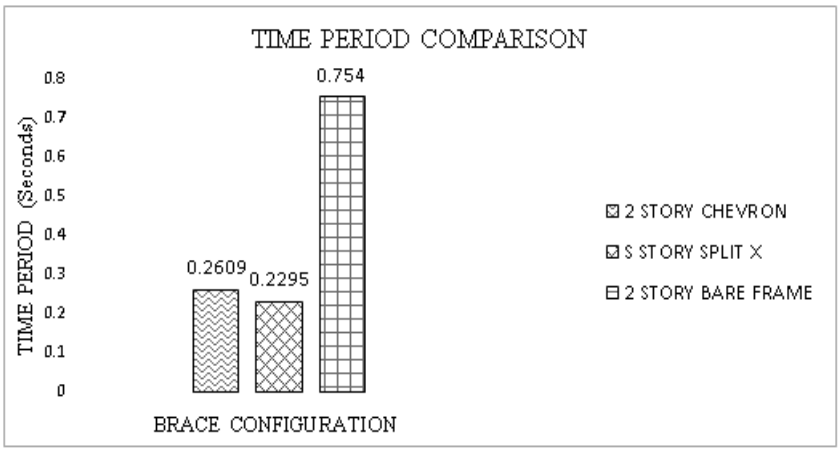

Fig. 6. Time Period comparison for 2 story SCBF

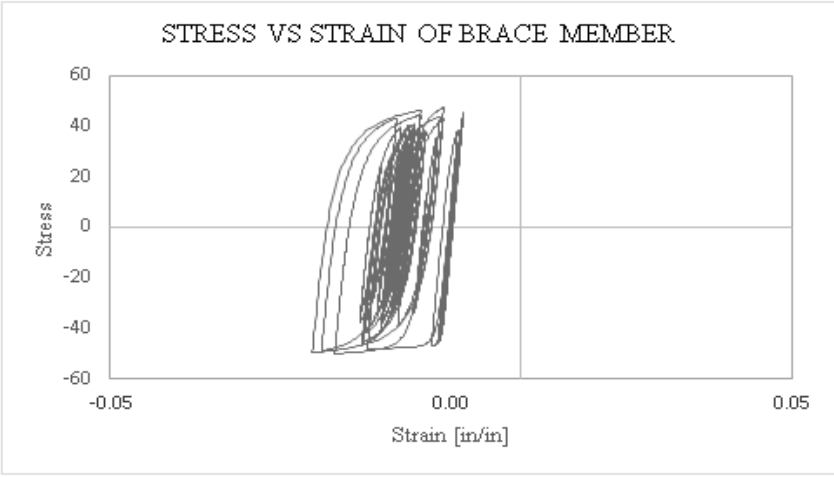

Fig.7. Local response stress Vs Strain of HSS brace members

6. RESULTS AND DISUCSSION

From the nonlinear dynamic analysis, nodal displacement for split-X and chevron configuration was plotted for the studied models are as shown in Fig.4. Split X has got lesser displacement than Chevron configuration.

From the nonlinear static analysis, Base shear vs. roof displacement was plotted for the studied models are as shown in Fig.5.

Time period for the brace configuration compared to that of bare frame for varying number of stories were plotted as shown in Fig.6.

Local response of HSS brace was plotted using stress vs. Axial Strain members as shown in Fig.7.

7. CONCLUSION

Nonlinear static and nonlinear dynamic analysis were performed on the Chevron and Split-X SCBF brace configuration to that of bare Frame was performed. From the study, it is clear that compared to Chevron braced and bare frame, performance of Split X braced configuration was better.

REFERENCES

[1] Sabelli, R., Roeder, C. W., & Hajjar, J. F. Seismic Design of Steel Special Concentrically Braced Frame Systems.

[2] Karamanci, E. and Lignos, D. (2014): Computational Approach for Collapse Assessment of Concentrically Braced Frames in Seismic Regions, J. Struct. Eng. 140, SPECIALISSUE: Computational Simulation in Structural Engineering, A4014019

[3] Chen, C. H., Lai, J. W., & Mahin, S. (2008, October). Seismic performance assessment of Concentrically braced steel frame buildings. In the 14th World Conference on Earthquake Engineering, Beijing, China.

[4] Salawdeh S., Goggins J., 'Numerical model for steel brace members incorporating a fatigue model'. Engineering Structures 46 (2013) 332–349

[5] Gregory L. Fenves, Frank McKenna, Michael H. Scott ; Yoshikazu Takahashi(2004): An object-Oriented Software environment for collaborative network simulation, 13WCEE, (Paper No.1492)

[6] Silvia Mazzoni, Frank McKenna, Michael H. Scott, Gregory L. Fenves, et al.,OpenSees Command Language Manual.

[7] Patxi Uriz, Stephen A. Mahin (2008): Toward Earthquake-Resistant Design of Concentrically Braced Steel-Frame Structures, PEER Report 2008/08.

[8] Liwei Lin (2005) : ME128 Lecture Notes - Introduction to Finite Element Modeling, UC Berkeley Department of Mechanical Engineering, Computer-Aided Mechanical Design

[9] L. Chen and L. Tirca, Simulating the Seismic Response of Concentrically Braced Frames Using Physical Theory Brace Models, Open Journal of Civil Engineering, Vol. 3 No. 2A, 2013, pp. 69-81.

[10] Danila, N (2013). Numerical Modelling and Design of Low-rise Concentrically Braced Frames with Double-Pin Dissipative Connections, Master of Applied Science (Civil Engineering).