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Finite Element Analysis of Self-Centering Moment Resistant Frames with and without Steel Plate Shear Wall

Anju Sreekumar[a]*,A K Asraff[b],Jayasree Ramanujan[a]

[a]*Department Of Civil Engineering Mar Athanasius College of Engineering,Kerala,686666, India*
[b]*SDAG,LPSE,Valiamala,Kerala,695547, India*

Abstract

The Northridge earthquake on January 1994 damaged a large number of buildings all through Los Angeles. The most recurrent pattern of structural damage was the brittle failures at beam column junction in steel moment-resisting frames (MRF's)[6] This event brought out the need for further improving the Moment Resistant Frames and its connections. A new system of Moment Resisting Frames (MRF) commonly known as Self-Centering Moment Resisting Frames (SC-MRF) was developed. These designs are capable of resisting the seismic loads without sustaining much damage. The paper studies the behaviour of Self-Centering Moment Resisting Frames (SC-MRF) with and without steel plate shear walls subjected to cyclic loading. A detailed three dimensional finite element modeling using plate elements available in ANSYS FEA code is done. Geometric and material nonlinear stress analysis of the frame and a detailed comparison of the frame with and without steel plate shear walls is done. It can be observed that the sway of the SC-MRF frame is much higher than that of a conventional frame, but by introducing a thin steel plate shear wall this deformation can be brought down to a much lower value.

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* Corresponding author. Tel.: 9349352684.
*E-mail address:*sreekumaranju@gmail.com

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1. Introduction

Throughout the years it was observed that the performance of steel structures was not up to mark. The efficiency of the steel frame was not as expected. It was observed that the steel frames that was subjected to seismic loads undergoes failure even when the steel was in their elastic limit. This was mainly due to joint failure due to brittle cracking. When steel frames are designed it is assumed that all the joints are rigid and its deformations are hence neglected but in reality it is not so. Hence, a large number of studies were conducted to improve the performance of the steel frames under seismic loading.

Prior research in this area includes the use of Haunch Brackets at the joints, predetermining the formation of plastic hinge in beams, Post-Tensioned connections in concrete structures, Post-Tensioned connection with various energy dissipation devices and finally Post-Tensioned steel frame with steel plate shear walls. These frames with Post-Tensioned strands are known as Self-centering Moment Resistant Frames (SC-MRF).

Self-centering Moment Resistant Frames (SC-MRF) are those structures which survive seismic loads without much damage. These frames are capable of retaining its structural integrity after a seismic load. The beam column joints are not fixed as in a wielded or bolted joints, hence relative movement occurs without much hindrance. The major components of these frames that make it different from the ordinary Moment Resistant Frames are the Post-Tensioned (PT) Strands and the long slotted shear tabs. The re-centering property of the frame is imparted by the PT Strands. The Shear Tabs are designed in such a manner that only the shear forces are transferred and the rotation of members at the joint is not restricted.

This paper involves the Three Dimensional finite element modelling of a typical frame using the plate elements available in ANSYS FEA code. A detailed study on the structural behaviour of the frame under static loading is done. The study involves geometric and material nonlinear stress analysis of the frame with and without steel plate shear wall. A comparative study of SC-MRF with and without steel plate shear wall is done.

2. Major Components of SC-MRF

Self Centering Moment Resisting Frames (SC-MRFs) is a highly ductile system. It undergoes large inelastic deformations without degradation in strength and stability.

2.1. Post-Tensioned (PT) Strands

The PT Strands spans throughout the length of the beam. It is anchored to the outer flanges of the column. These high strength steel Post-Tensioned strands help to resist the moment at the beam-column interface. The PT Strands is the major component that provide for the re-centering property of the frame.[3] A SC-MRF beam span is shown in Fig.1.(a)

2.2. Shear Tab

Shear tab helps to connect the beam and column at the joint. Its sole function is to transfer the shear forces acting at the joint. The shear tab is bolted on to the beam. The long slotted holes in the shear tab helps to ensure that the rotation is not arrested. The shear tab is shown in Fig.1.(b)

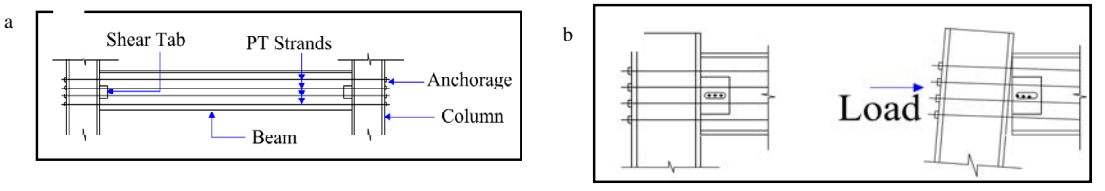

Fig.1.(a) SC-MRF Beam Span, (b) Shear Tab Mechanism