J. Appl. Environ. Biol. Sci., 6(2S)192-195, 2016

ISSN: 2090-4274
Journal of Applied Environmental and Biological Sciences
www.textroad.com

Seismic Performance of Steel Moment Frame Connection with Shape Memory Alloy

Saeed Jamalpour[1], Abbas Akbarpour[2]

[1] M.sc student, South Tehran I A U,
[2] Member of the faculty, South Tehran, University of I A U

Received: January2, 2016
Accepted: February 29, 2016

ABSTRACT

The Moment Frames are designed to dissipate a substantial amount of energy which induced by earthquake when yield limit of sections in beams and columns is reached, so non-elastic deformation occurred in these sections. Designers require new structural systems and members with high capacity in deformation & ductility, restoration or permanent deformations reduction. The Importance of connections of Moment Frames inevitably makes application of materials or substances with high behavioral and functional change capacity. Shape Memory Alloys (SMA) have super elastic attribute which enables them to bear large amounts of non-elastic stresses, and return to its original state after unloading. Application of such substances in frame connections, which bear significant moments during earthquake which eventually causes major dislocation of frame or complete breakdown of connection, can prominently affect the behavioral change and the increase in ductility. In this paper, the seismic behavior of steel moment frame beam - column connection in Open sees software was modeled and matching software results with similar lab work done and the results were compared with the results of connection with shape memory alloys.

KEYWORDS: Moment frame connection; Shape memory alloy; Supper elastic effect

INTRODUCTION

Shape Memory Alloys are a type of alloy that have the ability to return to their original shape and size when restoration process between two different phases, as a result of change in temperature, takes place. This phenomenon is called Shape Memory. These alloys have a simple behavior; whenever a certain amount of stress is applied on them and as a result some strains are formed , heating them to a certain degree would return them to their original length, fig1 and 2 [2]. A significant attribute that has increased their usage in structural engineering is their super elasticity. The Hooke's law (elastic behavior) is held true to a certain degree for all materials used in structural engineering, but under influence of overloading, some permanent shape shifts in materials take place. For instance behavior of St37 in a strain of close to 3% is still elastic while these alloys in strains up to 22% show super elastic behavior. This is the aforementioned super elasticity.

Microstructures of shape memory alloys

Understanding of general behavior of substances, in part, requires understanding of structure of their crystals. In Austenite and Martensite phases normal memory alloys are stable, in general martensie phase is stable in low temperature and high stresses and austenite phase is stable in high temperature and low stresses. Austenite has cubic crystal structure and Martensites have parallelogram structure. The symmetry in structure of austenites makes them more resistant. Fig. 3 [1] shows general design of these two phases.

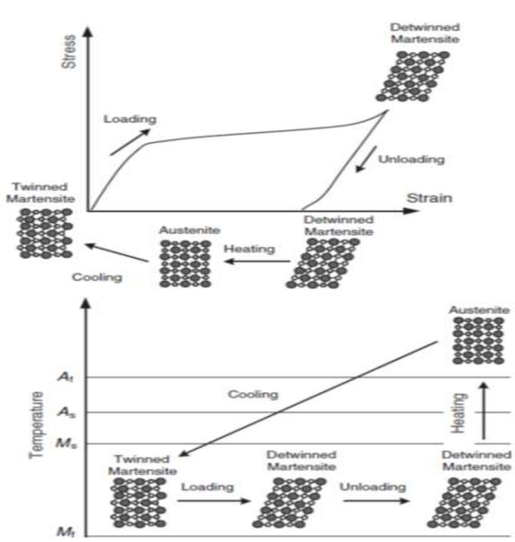

Fig. 1. Diagram of shape memory

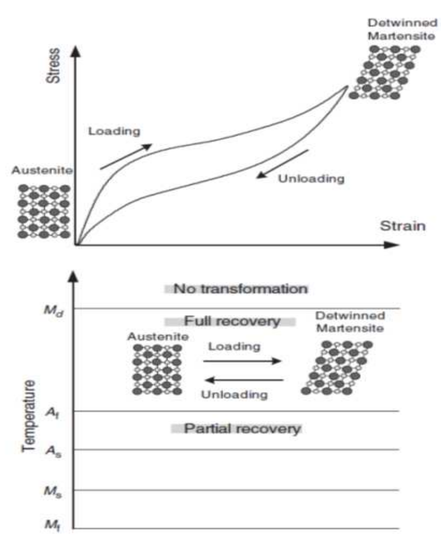

Fig. 2. Diagram of super elastic effect

Corresponding Author: Saeed jamaour, M.sc student, South Tehran I A U, jamalpour_sce@yahoo.com

Fig. 3. General design of shape memory alloy

Most frequently used shape memory alloy

Superelastic SMAs are of different kinds and different compositions. Nitiol (NiTi), composed of Nickel and Titanium, is one of the most frequently used SMAs. High resistance to erosion, high energy absorption and unlimited strength in cyclic loading and unloading (fatigue) are some of the significant properties of this alloy.

Introducing laboratorial specimen

In order to extract the results of laboratorial specimen we used “laboratorial study and behavior analysis of connections in steel moment frames using beams with double profile sections” article, published in Journal of Structure and Steel. Laboratorial specimen was chosen from a residential 8-storied building that in length included four moment frames with four 5m bays & five moment frames with three 5m bays in width & was 3m high in each story. The specimen was put in agenda by the name of DIP1 and its details are described in fig. 4 [3].

Cover sheet column	Vertical continuity plate	Horizontal continuity plate	Section of beam	Section of column	Specimen
PL 22*1.0	PL 75*20*1.0	PL 18*4.5*1.2	IPE 240	2IPE 200	**DIP1**

Fig. 4. Detail of laboratorial specimen

Verification of numerical modeling

Numerical model of the aforementioned connection in Opensees software was made. Note that specification of the steel of the modeled beam and column are the same as laboratorial specimen. As shown in fig. 5 (color blue marks laboratorial specimen’s curve and the red color marks numerical specimen’s curve) there’s an acceptable accordance between the results of numerical modeling and testing of specimen. The difference shown in higher cycles is obviously because of existing limitations in complete investigation of connecting parts of structure and also a result of neglecting real behavior of structure’s elements such as change in steel’s crystal configuration.

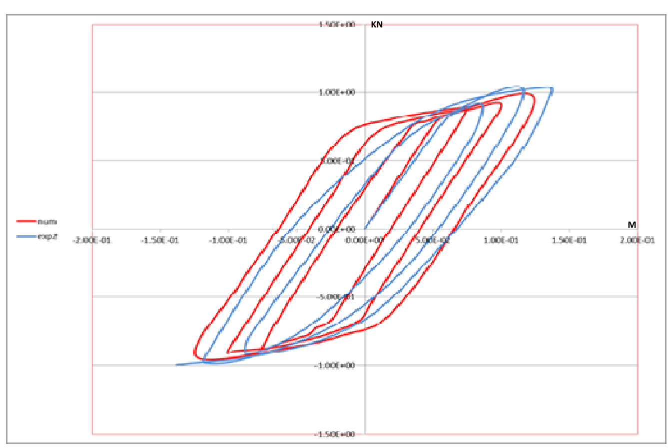

Fig. 5. Comparison between numerical modeling and laboratorial specimen

Loading

According to the study of seismic performance of connection, location changing loading with a maximum 20cm change in position is applied to the free end of column. The application manner of this loading is domain and loading protocol of laboratorial specimen so that loading would cause no difference in results of numerical and laboratorial models.

Using Shape Memory Alloy in numerical model

At the connection of beam to column, SMAs are modeled with a small space from the column to follow operating regulations of moment frames. Specifications of shape memory alloys are described in table 1. Note that incorporated alloys of Nitinol are modeled like fig. 6 and measure 22mm in diameter in top and bottom of beam's section and are 20cm long [4].

Table 1. Specifications of shape memory alloys

F_{FA} (Gpa)	F_{SA} (Gpa)	F_{FM} (Gpa)	F_{SM} (Gpa)	ε(%)	E (Gpa)	SMA (N_iT_i)
100	300	500	400	0.06	60	measure

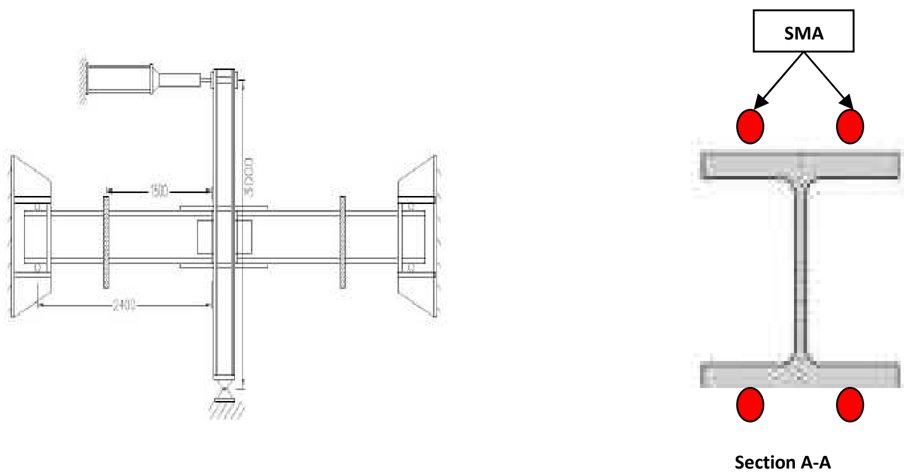

Fig. 6. Detail of using shape memory alloy in numerical model

Comparison of results

In fig. 7 hysteresis curve of connections containing shape memory alloys and hysteresis curve of connections lacking shape memory alloys are shown. As depicted, in connections containing shape memory alloys base shear has decreased substantially, softness of structure has increased and consequently connection's circulation in elastic area increases. Hysteresis curve's slope has decreased which in turn leads to a decrease in permanent shape shifts in structure.

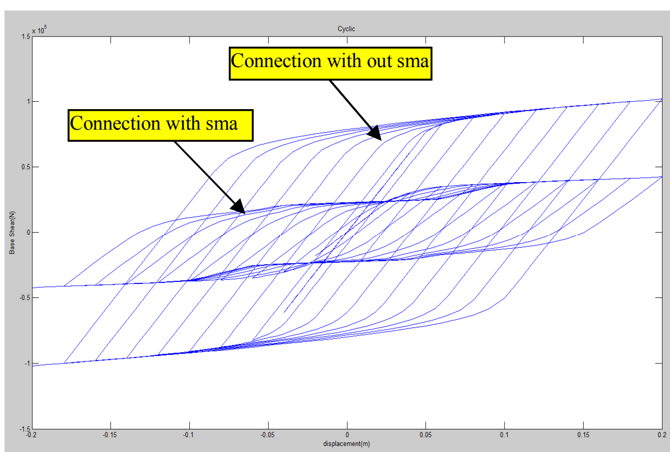

Fig. 7. Comparison between Hysteresis curves

Conclusion

Regarding results of numerical modeling of shape memory alloy containing connection and connections without shape memory alloys following notes are taken:

1. Decrease in base shear in connections containing SMA; it occurs as a result of reduction in load transfer surface where memory alloys are used. However in SMA containing connections we can use smaller sections for column which makes structure lighter and diminishes costs.
2. Decrease in permanent shape shifts in SMA containing connection; as a result of super elastic property of SMA, slope of hysteresis curve has changed (decreased) and consequently less permanent shape shifts after unloading are seen as compared to SMA-less connections. Note that in primary loading cycles permanent shape shifts are almost non-existent and it is visible in difference between graphs of fig. 7.
3. Increase in energy dissipation in SMA containing connections; the decrease in base shear and permanent shape shifts in connection lead to increase in amount of absorption and dissipation in SMA containing connection. It is the case as less energy is needed in equal transfers by SMA containing connections as compared to SMA-less connections.
4. Using shape memory alloys increases suppleness and side travels and it should be controlled using regulations in Code 2800 and other regulations on controlling shaping of frames.
5. It is noteworthy that the decrease in permanent shape shifts, the increase of energy dissipation and the rest of positive points that are told about the SMA containing alloy connection are all specific to one connection and for a moment frame with multiple bays all previous studies should be repeated.

REFERENCES

1. Ozbulut, O. E. Hurlebaus, S. and Desroches, R. Seismic Response Control Using Shape Memory Alloys, Journal of Intelligent Material Systems and Structures, 5 August (2011)

2. Saeed Jamalpour, Reza Jamalpour, “Introduction of Shape Memory Alloys and study of their performance in moment frames’ connections.”, National conference of applied studies in civil engineering, architecture and civil management, Tehran, Iran, March (2015).

3. Sazmand, Agha Kuchak, Mazrouie, “Laboratorial study and analysis of connections’ behavior in steel moment frames with column and double profile section”, Scientific Journal of structure and steel, 7th year, No.10

4. Matthew, S. Speicher, Reginald. DesRoches, Leonb. Roberto, T. Experimental results of a NiTi shape memory alloy (SMA)-based recentering beam-column connection, Construction and Building Materials, 33 (2011) 2448–2457