8th International Conference on Seismology & Earthquake Engineering
11-13 Nov. 2019, Tehran, Iran

# CYCLIC LOADING TEST ON HIGH DAMPING RUBBER BEARING (HDRB) ISOLATORS IN COMBINATION WITH FE-BASED SMA DAMPERS

Rasoul MORADKHAHI
*M.Sc. Student, Amirkabir University of Technology, Tehran, Iran*
*moradkhahi@aut.ac.ir*
Touraj TAGHIKHANY
*Associate Professor, Amirkabir University of Technology, Tehran, Iran*
*ttaghikhany@aut.ac.ir*

**Keywords:** Fe-based SMA, High damping rubber bearing (HDRB), Re-centering force, Manufacturing and test

Seismic base isolations have been developed and used in buildings and bridges as a technique to control their seismic behavior under severe ground motion. Various types of bridge and building isolators have been developed, tested and are in used all over the world as a means of effective earthquake resisting systems. In order to dissipate seismic energy at isolators level, many designers are used hysteretic dampers in combination with isolation systems (Hedayati Dezfuli & Alam, 2017). However, due to residual displacement at base level in this combination, the operating service of structure is interrupted after earthquake. One appropriate solution for this problem is application of shape memory alloy as hysteretic metal in damper. Shape memory alloy is a novel functional material which can be recovered after unloading or upon heating (Song et al., 2006). Due to high cost of Nitinol (as most common types of these smart materials), most of recent researches have been concentrated on finding different types of SMAs with the same quality and lower price (Cladera, 2014). One type of iron-based SMA has been manufactured in Civil Engineering Department of Amirkabir University of technology with good super elasticity effect, shape recovery and lower cost (see Figure 1). In other respect, one high damping rubber bearing (HDRB) seismic isolator was manufactured by separated team using local feasibility in AUT (see Figure 2).

*Figure 1. SMA produced in AUT.*

*Figure 2. HDRB produced in AUT.*

In this paper, at the beginning, many experimental tests has been conducted on thin SMA plates to get their mechanical properties and evaluate the efficiency of produced shape memory alloy in the FEM model. Then, the HDRB isolator individually was tested to evaluate the cyclic behavior via different displacements.

Finally, to employ the benefits of SMA in HDRB, series of cyclic experimental test has been performed on the HDRB isolator equipped with iron-based SMA. According to facilities of the laboratory, the cyclic test carried out with low level frequency (see Figure 3). The behavior of the hyper isolation (Isolation equipped with shape memory alloys) in terms of re-centering and energy dissipating capability studied via models created in general purpose finite element program ABAQUS verified thoroughly against relevant test results (see Figure 4).

The results show that, as expected, it was not observed any delamination in the HDRB during the cyclic tests. The hysteretic showed good dissipated energy. According to the experimental test, the iron-based shape memory alloy has good super elasticity in temperature above Af (Austenite finish temperature) (220 °C) while in the ambient temperature it did not show perfect super elasticity. The results indicated that at induced shear strain equal to 50 %, the isolator has been reverted using shape memory effect of Fe-based SMA. The shape memory alloy showed good performance in terms of recentering the isolator in small shear strain of isolator according to finite element simulation. In the experimental test because of some executive difficulties, significant recentering could not be seen.

Combining SMA plates to the HDRB would result in more stiffness as well as damping ratio in the experimental test. The effective stiffness was increased 64% while equivalent damping was incremented by 5.67%.

*Figure 3. Hysteresis behaviour of Isolator obtained by FE simulation.*

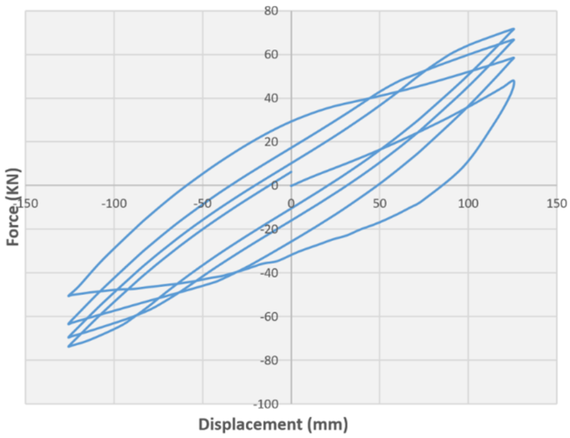


*Figure 4. Cyclic experimental test on the HDRB equipped with Fe-Based SMA.*

## REFERENCES

Cladera, A., Weber, B., Leinenbach, C., Czaderski, C., Shahverdi, M., and Motavalli, M. (2014). Iron-based shape memory alloys for civil engineering structures: An overview. *Construction and Building Materials*, *63*, 281-293.

Hedayati Dezfuli, F., and Alam, M. (2017). Smart Lead Rubber Bearings Equipped with Ferrous Shape Memory Alloy Wires for Seismically Isolating Highway Bridges. *Journal of Earthquake Engineering*, 1-26.

Song, G., Ma, N., and Li, H.-N. (2006). Applications of shape memory alloys in civil structures. *Engineering Structures*, *28*(9), 1266-1274.