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EXTENDED ABSTRACT

Influence of Shape Memory Alloys on Cyclic Behavior of Reinforced Concrete Joints

Mohammad Golmohammadi [a,*], Navid Arvin kheibari [b], Mehdi Mokhtari [c]

[a] *Structural Engineering, Civil Engineering Department, Engineering Faculty, University of Torbat Heydarieh, Khorasan Razavi, Iran*
[b] *Structural Engineering, Civil Engineering Department, Engineering Faculty, Visiting Scholar in University of Torbat Heydarieh, Khorasan Razavi, Iran*
[c] *Structural Engineering, Faculty of Civil Engineering, Semnan University, Semnan, Iran*

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1. Introduction

Shape memory alloy (SMA) is a particular type of metal alloy that has the recovery property of permanent deformation. This alloy includes the typical properties of steel, such as resistance, hardness, performance, and so on. SMAs are used in some applications, including based-isolated buildings, self-repairing building components, aircraft industry, medical industry, mechanical equipment, and effective models for computing tools. In this paper, the effect of SMAs on the cyclic behavior of reinforced concrete (RC) joints is analytically investigated. To this end, after validation of two experimental models in Seismo Struct software, some parametric studies are conducted, such as 1- the effect of compressive strength of concrete, 2- the position of SMA into the plastic zone, 3- the simultaneous use of SMA as longitudinal bars and stirrup, and 4- the use of an equivalent column with a circular cross-section containing spirals or stirrups.

2. Methodology

2.1. Analytical study

In this study, Seismo Struct software was used to analyze concrete joints based on cyclic loading. This software is able to consider nonlinear geometric behavior and nonlinear behavior of materials and can predict frame behavior under static and dynamic loading in large displacements. This software is appropriate to model different materials such as concrete, steel, FRP, and SMA due to its efficiency and precision (Castello, 2016).

2.2. Modeling materials

The axial behavior models proposed by (Auricchio & Sacco, 1997), (Manegotto & Pinto, 1973) were used for beams and columns for specimens with SMA and steel bars, respectively. Auricchio and Sacco's model was the super-elastic model used in the Seismo Struct software, where SMA was subjected to reverse cyclic loadings under stress-induced transformation. Modulus of elasticity of specimens with steel and SMA bars were considered to be 200,000 and 83,000 MPa, respectively. The model for concrete stress-strain was based on the model proposed by (Mander, Priestley, & Park, 1988).

* Corresponding Author
E-mail addresses: m.golmohammadi@torbath.ac.ir (Mohammad Golmohammadi), navidarvin69@yahoo.com (Navid Arvin kheibari), m.mokhtari.civil@semnan.ac.ir (Mehdi Mokhtari).

2.3. Finite element model

In this paper, beams were divided into 2 elements, and columns were divided into 4 elements. The method used for joint analysis was static-time history analysis. Properties of elements in Seismo Struct were defined in the element classes module. The reason for using different elements was to define the properties of the similar element or different sections and materials. To select the frame element, an inelastic force-based plastic hinge frame element type was used. After defining element properties for making and joining elements in modeling, the Element Connectivity module was used. Structure geometry in Seismo Struct was defined in a three-step process. First, all structural and non-structural nodes were defined. Then, the method for joining elements was defined and element connectivity could be determined. Finally, restraints modules were determined by the boundary elements conditions (Castello, 2016). Fig. 1 shows the finite element model of the specimen including the specifications of nodes, members, and joint modeling.

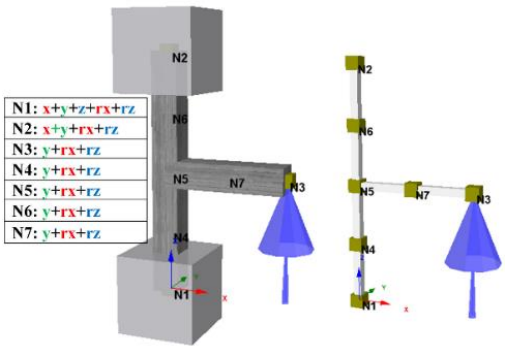

Fig. 1. Finite element model of the specimen

3. Results and discussion

3.1. Effect of compressive strength of concrete

In order to investigate and compare the effect of compressive strength of concrete on the cyclic behavior of RC joints with SMA, the models shown in Table 1 were introduced.

Table 1. Models with variable compressive strength of concrete in the joint

Model name	Compressive strength of concrete (MPa)	Strength variation compared to the initial state
Reference model	30	0
SMA+10	33	+10%
SMA+15	34.5	+15%
SMA+20	36	+20%
SMA+25	37.5	+25%
SMA+30	39	+30%
SMA-10	27	-10%
SMA-15	25.5	-15%
SMA-20	24	-20%
SMA-25	22.5	-25%
SMA-30	21	-30%

3.2. Effect of simultaneous use of SMA as longitudinal bars and stirrup

In order to assess the effect of using SMAs in joints as longitudinal bars and stirrups simultaneously, the following models, shown in table 2, were generated and analyzed.

Table 2. Models with the simultaneous use of SMA as longitudinal bar and stirrup

Model name	SMA type	Compressive strength of concrete (MPa)
SMA-Kh-b	Longitudinal bar and stirrup	30
SMA-Khamoot	Stirrup	30

3.3. Effect of use of an equivalent column with a circular cross-section containing spirals or stirrups

In this case, a column with a circular cross-section and a capacity equivalent to the reference model was proposed. Fig. 2. shows the FE model of the equivalent column with two different types of transverse rebar (spiral and stirrups).

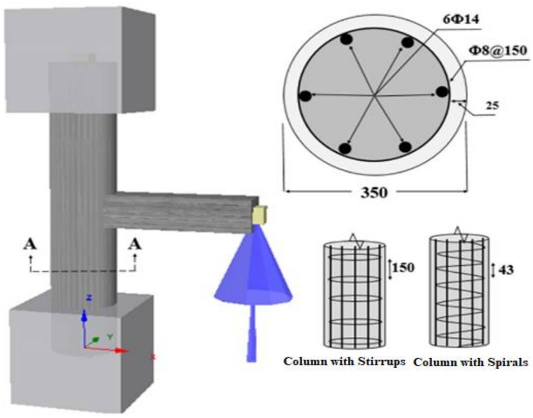

Fig. 2. Finite element model of the equivalent column

In order to investigate the effect of SMA on the equivalent model, the FE models mentioned in table 3 were generated and analyzed.

Table 3. Equivalent models with spiral and stirrup

Model name	Type of transverse rebar	Compressive strength of concrete (MPa)	Strength variation compared to the initial state
C-Sp	Spiral	30	0
C-Sp-10%	Spiral	33	+10%
C-Sp-20%	Spiral	36	+20%
C-Sp-30%	Spiral	39	+30%
C-Sp-50%	Spiral	45	+50%
C-St	Stirrup	30	0
C-St-10%	Stirrup	33	+10%
C-St-20%	Stirrup	36	+20%
C-St-30%	Stirrup	39	+30%
C-St-50%	Stirrup	45	+50%

4. Conclusions

The analytical results showed that the compressive strength of concrete had no effect on the hysteresis behavior of the RC joint in the elastic zone of the joint, while with a 30% increase in the concrete compressive strength in the plastic zone of the joint, the load-bearing capacity increased by about 2%. Also, using SMA in the plastic zone of the beam led to increase in the stiffness, and absorbed cyclic energy. In the case of using the longitudinal bars and stirrups simultaneously as SMA, the pinching effect was disappeared from the hysteresis behavior of the joint, and consequently, high cyclic energy absorption was achieved. Finally, it was observed that implementing the equivalent column with a circular cross-section had the elastic stiffness more than the reference model.

5. References

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