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Seismic Performance of a New Self-Centering Repairable RC Shear Wall

J. Hosseini, F. Basaligheh*, J. Shafaei

Faculty of Civil Engineering, Shahrood University of Technology, Shahrood, Iran

ABSTRACT: Permanent deformation after an earthquake increases the cost of the retrofit and even the implementation of the rehabilitation plan. A resisting system to control the lateral forces due to earthquakes is to use shear walls with good energy dissipation capability. Permanent deformation and cracking in the border and critical areas of the wall after relatively strong earthquakes leads to a decrease in the seismic performance of the wall. In this research, the responses and cyclic behavior of concrete shear walls under the cyclic loading protocol are investigated. For this purpose, using OPENSEES software platform, concrete shear wall modeling based on SFI-MVLEM method or wall modeling using multiple vertical elements based on the macro fiber method has been studied. The main models analyzed in this study include 2 concrete walls with steel rebars and memory alloy (SMA) with different dimensions and arrangement of reinforcements and innovative concrete wall with separate border elements in the form of concrete columns made of engineered concrete (ECC) and SMA rebars. Validation of the models was based on previous studies. After validation of the initial models, the parametric study of the models was performed in order to investigate the effects of the dimensions of the boundary areas, the type and arrangement of the reinforcements and the amount of gravitational forces on the shear walls in the models. The results obtained from the outputs show that the use of SMA materials in the boundary areas of the wall has a significant effect on the self-centering behavior of the wall and the energy dissipation of the shear wall is reduced by using SMA materials.

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1- Introduction

Nowadays, due to the high cost of construction, if the design of the structures is such that it has a completely elastic behavior against severe earthquakes and does not enter the nonlinear region at all, the implementation of these types of structures is not cost-effective at all; For this reason, active and passive control methods are used in the seismic design of structures. In the passive control method, a number of structural members suffer damage during moderate to severe earthquakes with elastic behavior and energy absorption, in order to deplete the energy of the earthquake. This energy consumption reduces the forces on the members of the structure, which should behave elastically, and the structure is protected from serious damage.

The shear wall is one of the seismic control systems of the structure, which is used in reinforced concrete structures to withstand the lateral force of the earthquake. Due to the hardness and high resistance of these members compared to the concrete bending frame, they absorb a significant share of the base shear, and it seems that the name shear wall is for these structural members and not because of the shear behavior of these members (in walls with the relatively high height that is used in today's structures, mainly the walls work in a curved form), but because of the significant amount of the contribution of the shear force of the base. For structures up to 20 floors, it is up to the designer to use or not use the shear wall. But for structures with more than 30 floors, the designer is forced to use these structural members for economic reasons and lateral drift control [1]. The use of a shear wall reduces the shape changes caused by an earthquake on the entire structure, as well as the changes in the shapes and forces of the structural members, including the shape changes of the shear wall itself [2].

In this research, the analytical investigation of the seismic behavior of shear walls with reversibility after an earthquake has been done. For this purpose, the combination of HPFRC concrete (ECC concrete combined with SMA) has been used along with SMA rebars at both ends of the wall. SMA rebars and strong concrete, in addition to providing the reversibility of the structure, can reduce the amount of cracking in the critical areas of the wall and put the performance of the wall in the desired range in terms of resistance and energy loss.

*Corresponding author's email: f_basaligheh@shahroodut.ac.ir

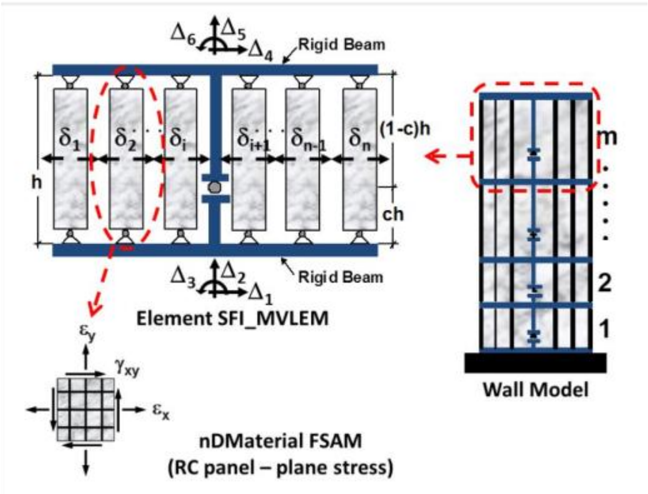

Fig. 1. Place of the macro fibers in the SFI-MVLEM element in the cross-section of the wall [4]

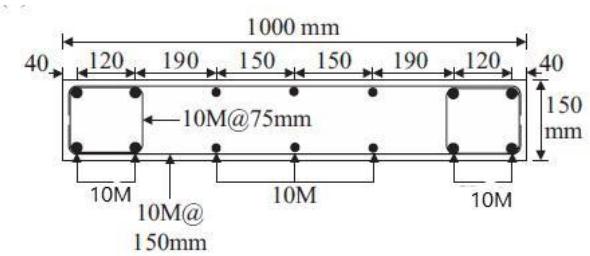

Fig. 2. Cross section of W1-SR shear wall [3]

2- Theoretical modeling

In this research, the effect of using SMA smart materials in shear walls is investigated in order to reduce permanent deformations. A total of four models were selected for validation from three different articles and were modeled and validated in Appensis software. In the first article written by Abdolreza and Palermo [3], the performance of two types of shear walls has been investigated. The two walls have the same dimensions and differ only in the specifications of the rebars in the border areas. The first wall has steel bars in the border areas and the second wall has SMA and steel bars in the border areas. The walls are subjected to reverse cyclic loading and the graphs related to base shear-node displacement above the wall are drawn.

3- Software modeling

OpenSees software was used to validate and analyze the models investigated in this research. This software is provided by members of Berkeley University and as a powerful finite element software, it has many capabilities in the field of macro and micro model analysis. Multiple vertical elements have been used to model the shear wall in this research. In this shear wall modeling method, multiple linear vertical elements called SFI-MVLEM are used. In this method, the interaction between the axial force applied to the shear wall and the bending anchor created under the applied forces is considered by modeling the wall with several vertical elements that are modeled in parallel. Figure 1 shows the schematic of concrete shear wall modeling by multiple vertical elements method.

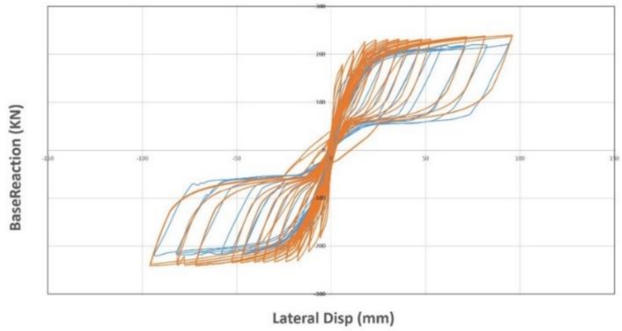

Fig. 3. Validation of the cyclic diagram of base shear-lateral displacement of the wall under constant axial load of 0.1AgFc

4- Analytical model validation

In the first article, written by Abdul Reza and Palermo [3], the performance of two types of shear walls has been investigated. The two walls have the same dimensions and differ only in the specifications of the rebars in the border areas. The walls are subjected to reverse cyclic loading and the base shear-nodal displacement graphs are drawn at the top of the wall. In order to better distinguish the type of walls, W1-SR letters, where S indicates the wall with normal malleable steel rebar, and W2-NR letters, where N indicates the wall has NiTi (nickel-titanium) and mild steel composite materials, have been used. The characteristics and parameters of the walls are selected from the studies of Abdul Reza and Palermo [3]. The W1-SR wall has malleable steel bars with a rectangular cross-section of 1000 × 150 mm^2, where 1000 is the wall width and 150 is the wall thickness. The height of the wall is 2200 mm, which results in an aspect ratio of 2.2 (height divided by width). The dominant behavior of the selected shear walls is the bending behavior according to the dimensional ratio of the wall.

Figure 3 shows the base shear-lateral displacement diagram of the highest level of the shear wall of W1-SR and W2-NR walls under cyclic analysis and axial load at the rate of 0.1 AgFc. In this figure, the cyclic diagrams of base shear - lateral displacement of W1-SR and W2-NR walls obtained from the studies of Abdul Reza and Palermo [3] are given as a reference model to compare and validate the results obtained from the modeling of these walls in the software. has been Cyclic loading of models is done according to ATC24 protocol.

Figure 4 shows the RNE column and connecting detail.

Figure 5 shows the cycle diagram of the combined model of the WSH3 wall with RNE columns under variable parameters of the height of the base columns (connecting the wall to the underlying foundation). According to the

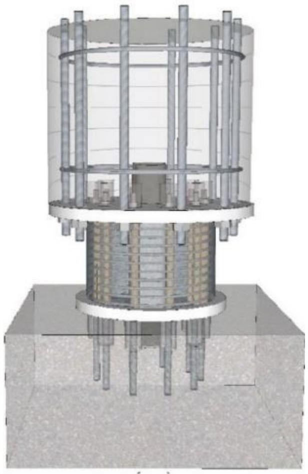

Fig. 4. RNE column and connecting detail [5].

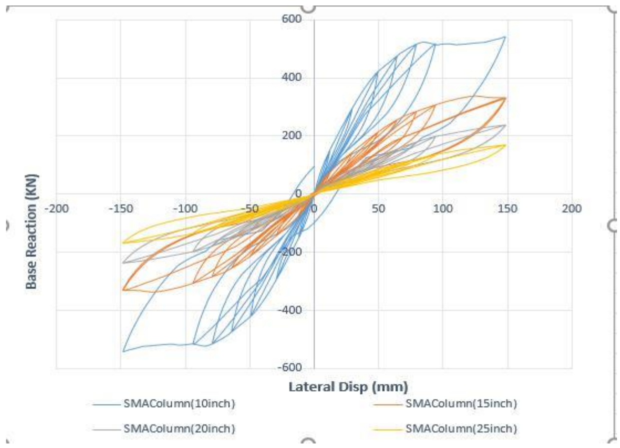

Fig. 5. Cyclic diagram of the combined model of WSH3 wall with RNE columns

diagram, it can be seen that the placement of the RNE column in the critical areas of the shear wall reduces the permanent deformation to the minimum and causes centripetal behavior in the shear wall.

5- Conclusions

The most important results are:

1-The use of SMA rebar in the boundary areas of the shear wall has a great effect on reducing permanent deformations and the centralization property of the shear wall. By using SMA rebar in the W2_NR model, permanent deformations were reduced by more than 80% compared to the W1_SR model.

2- The amount of energy absorption in the W2-NR model is 37% less than the W1-SR model. Therefore, the use of SMA rebar in the shear wall reduces energy absorption in the wall.

3- With the increase in the width of the border areas of the shear wall, the permanent deformations are greatly reduced, so the model with the width of the border area of 250 mm has 56% less permanent deformation compared to the model with the width of the border area of 150 mm. put

4- Regarding the combined model of the wall and RNE columns, according to the graphs and tables obtained, it can be stated that the composition of the RNE column has a significant effect in reducing the permanent deformation of the WSH3 wall, and as the vertical length of the border columns of the wall increases, the overall stiffness and strength of the wall decreases. will find. Due to the fact that short columns have higher hardness than other columns, the amount of power absorption and wasted energy is higher in models with shorter columns (10 inches).

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