Chapter

Effects of Creep on RC Frame Subjected to Cyclic Load with Magnetorheological Damper

Daniel Cruze, Hemalatha Gladston, Sarala Loganathan, Tensing Dharmaraj and Sundar Manoharan Solomon

Abstract

The study aims to discuss about a magnetorheological (MR) damper subjected to cyclic load test in reinforced concrete frames (RC). Two RC frames were cast, the dimension and detailing were adopted as per codal provisions. The effects of stress, strain, displacement and load behavior for RC element with various time interval is studied with and without MR damper. The typical creep curve of RC frame reveals, the creep rate decreases with time until reaching the steady state, after the initial deflection. The result shows that the incorporation of the MR damper reduced the displacement by 49% and an increase in load carrying capacity of 55% was attained compared with the RC frame without damper.

Keywords: RC frames, cyclic behavior, dynamic response, creep

1. Introduction

Semi active magnetorheological (MR) damper have a note of attention in the use of control systems to control vibrations in structures during earthquake. There are various semi active control systems which attracted much attention now a days because it possesses the adaptability of active control system. This MR damper makes the viscosity to more apparent, operate in less current, which produce high damping force. In semi active the properties will be varied dynamically, therefore which is quite effective in structural control responses due to its wide range loading condition [1–5]. The main advantage of semi active control device is their low power requirement. Particularly, the most promising device for seismic control is MR, MR fluid is the major constituent in MR damper which results controllable damper [6–9]. The characteristics of MR fluid is when applying magnetic field, their ability to change from liquid to semi solid state with the reaction time of less than 50 milliseconds. A typical MR fluid consists of 25–55% by volume of magnetic iron particles like carbonyl iron, suspended in an appropriate carrier liquid. The diameter of the particle was found to be 3–5 μm in size [10–16]. Furthermore, MR fluid is advantageous due to its unique phase transition property in the presence of magnetic field. However, the major disadvantage faced by MR fluid is sedimentation. Commonly, commercial lubricants were added to reduce gravity settling, which additionally enhance particle suspension [16–20].

The focus of this paper is to experimentally demonstrate the ability of the MR damper to reduce structural responses. Following a description of the experimental setup, cyclic load test is carried out in the RC frame with and without damper. The effects of stress, strain, displacement and load behavior for RC element with various time interval is studied with and without MR damper. The results indicate for seismic response reduction, MR damper is quite effective for wide range.

2. MR fluid

Magnetorheological fluid also called as MR fluid consist of magnetic material and a carrier oil influence effective under the applied magnetic field. The applied magnetic field have influence over most important rheological properties like as yield stress and apparent viscosity as shown in **Figure 1**. Their increased contribution in space technology, through domestic products is noteworthy. Particularly their applications in dampers, power steering pumps, brakes and control valves are significant. In automobile application, micron size particles are acceptable of the frequent vibrations but on move to seismic factor, since the vibrations are not regularly taken place, sedimentation cause major problems. Therefore, many researchers notably civil engineers are currently focusing on fluid behavior in dampers for structures. In the present work, MR fluid was prepared with the help of Nano Fe_3O_4 particle and silicone oil by 60% weight, additionally their efficiency towards MR damper is investigated.

2.1 X-ray diffraction studies

The synthesized nano Fe_3O_4 was well characterized by X-ray crystallographic technique and are depicted in **Figure 2** using the Model (Schimadzu, LAB X,

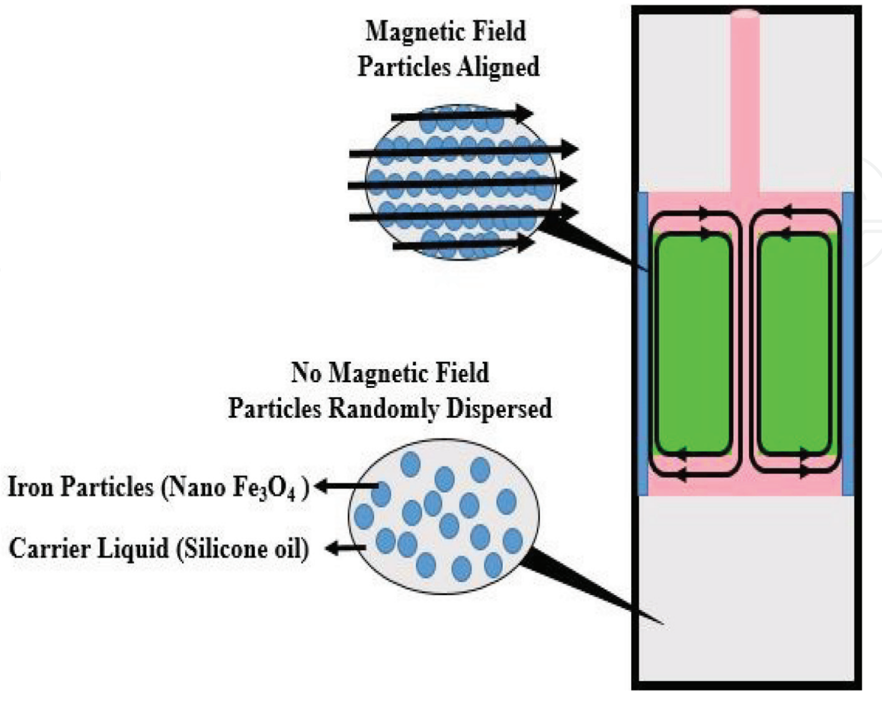

Figure 1.
MR damper with and without magnetic field.

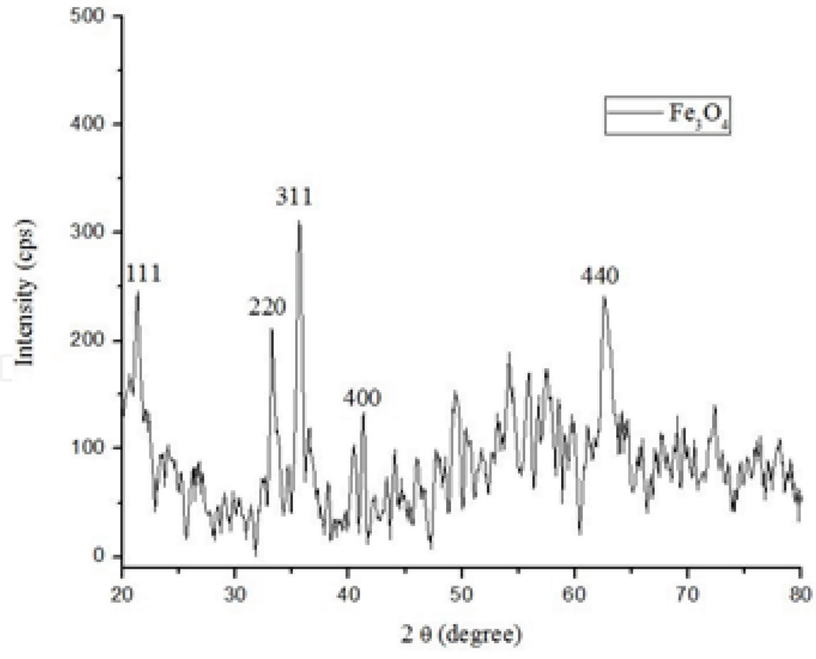

Figure 2.
XRD pattern of Fe_3O_4 iron particles.

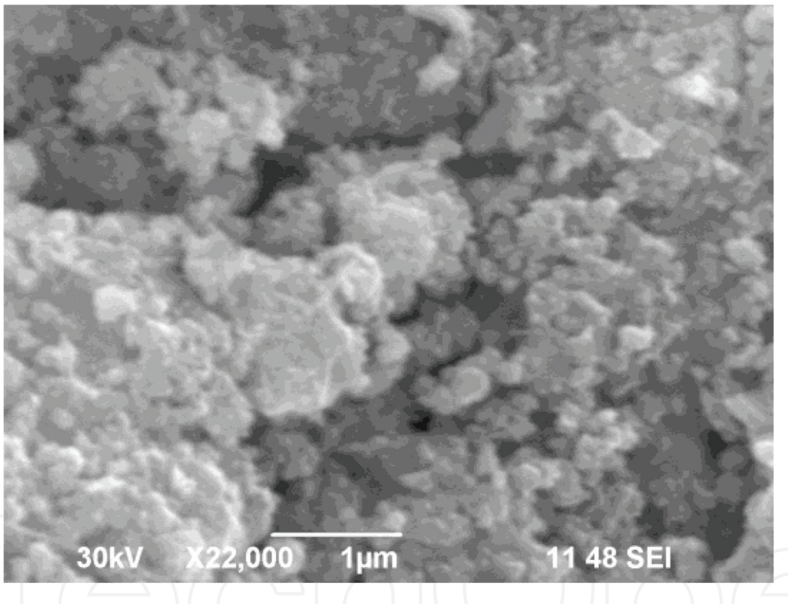

Figure 3.
SEM image of Fe_3O_4 iron particles.

XRD-600) using CuKα radiation. The prominent XRD peaks observed were indexed and analyzed using ICDD database. The JCPDS file no. 79-0417 represents a magnetite structure in it. The average particle size of the material was examined using the most intense plane (311) with the help of Scherrer equation. The average particle size is 12 nm.

2.2 Surface morphology studies

The surface morphology of the synthesized Fe_3O_4 was obtained using Scanning Electron Microscopy (SEM, JEOL 6390). **Figure 3** depicts the SEM image of the synthesized compound reveals the uneven spherical like structure for the Nano Fe_3O_4.

3. Experimental studies

3.1 Preparation of MR fluids

The nano sized iron particles (Fe_3O_4) of size 10–12 nm were used as a smart material and silicone oil as the carrier oil. The MR fluid was prepared by mixing 80% of weight of silicone oil and with 20% Fe_3O_4 particles. The addition of Fe_3O_4 was slow and uniform under stirring condition for about 30 minutes. Then, the above mixture is sonicated about 1 hour under the frequency of 0.5 Hz. During sonication, the major proportion dispersed with the silicon oil. Therefore, there discourages the gravity settling. The off-state viscosity of the MR fluid prepared at 27^0c is 0.822 Pa-s. **Figure 4** depicts the schematic representation for the preparation of MR fluid.

3.2 Modeling of MR damper

For the present study, the shear mode MR damper was modeled. **Figure 5a** shows the design and configuration of the MR damper adopted. The fabricated MR damper using mild steel was shown MR damper was fabricated using mild steel shown in **Figure 5b**. Since the proposed MR damper was shear mode, the copper coil was wound around the piston with 260 no. of turns.

From **Figure 5c**, the reasons behind the MR damper under shear mode is clearly explained. In the shear mode MR damper, a thin layer of MR fluid is sheared between the piston and the cylinder, that space is specifically called as annular gap. In order to produce large force, shear mode MR damper is needed.

3.3 Cyclic load test

The dimensions and the detailing of RCC frame adopted for the present work are given in **Figure 6**. The frame was casted according to the details given in **Figure 7**. The damper was scaled to resist forces in a single bay RC frame. The damper was positioned diagonally on the frame. The grade of concrete used for the specimen is M25, The reinforcement details of beam, column and stirrups of 8,8,3 mm. The support condition is fixed for the specimen.

3.4 Test setup

With the help of servo hydraulic actuator, in-plane lateral load was supplied to the specimen at the end of the top beam along its centroidal axis. The opposite side was supported by a strong steel reaction frame two channel section were placed symmetrically on both side of the beam and fitted tightly using strong bolts at regular intervals. The lateral load supplied to the beam using the channel section. In order to avoid the distraction particularly horizontal & vertical movements during

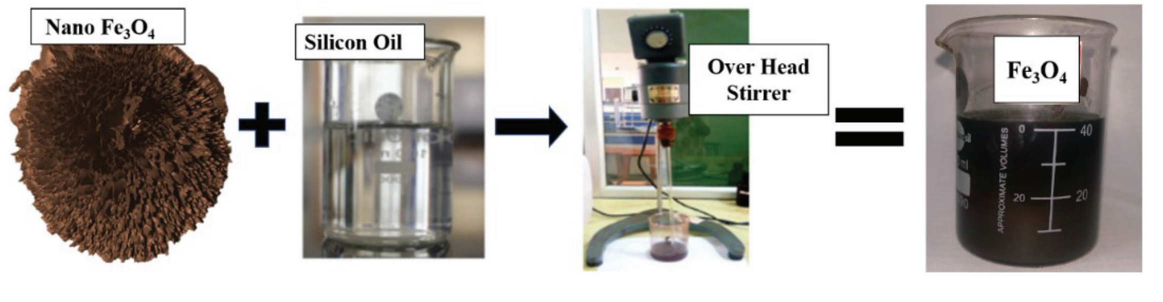

Figure 4.
Preparation of MR fluid.

lateral loading, the footing was fixed firmly in the strong floor. The lateral support was given by the steel sections to avoid it's out of plane movements. The test setup was given in **Figure 8**.

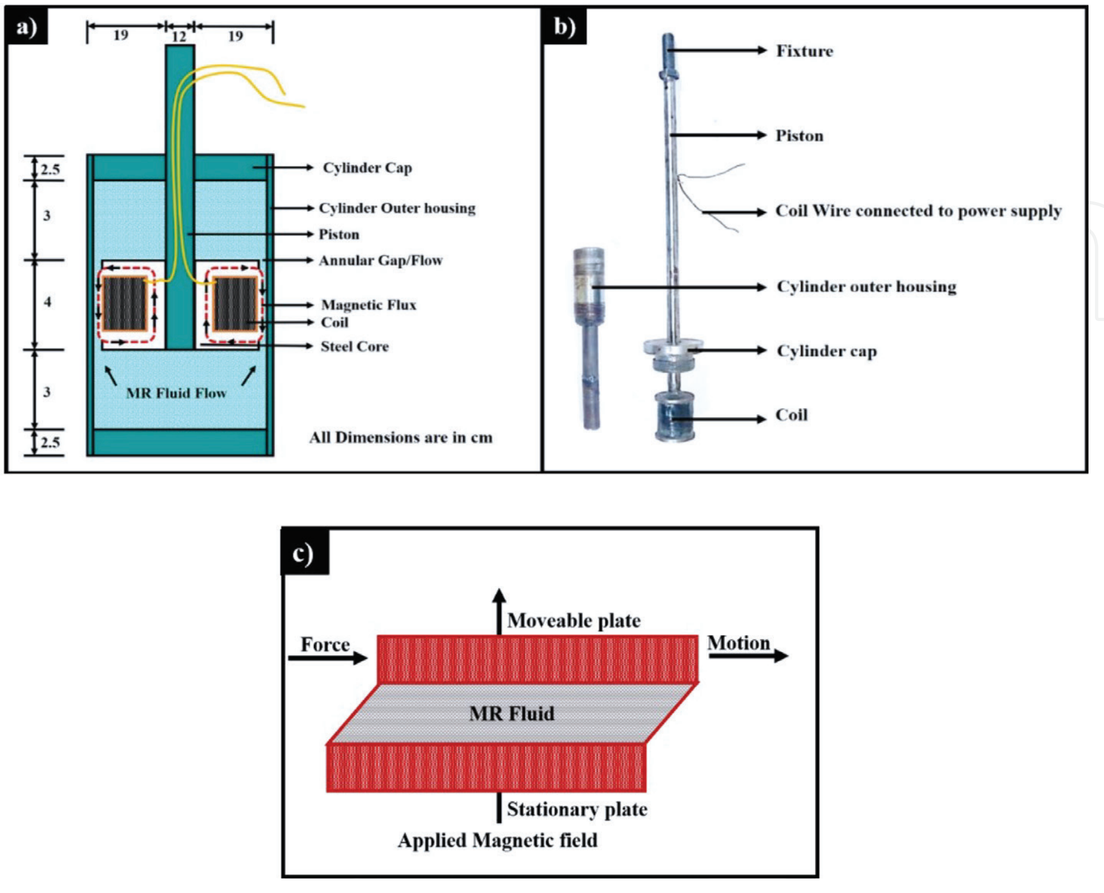

Figure 5.
(a) Schematic MR damper; (b) fabricated MR damper; (c) shear mode.

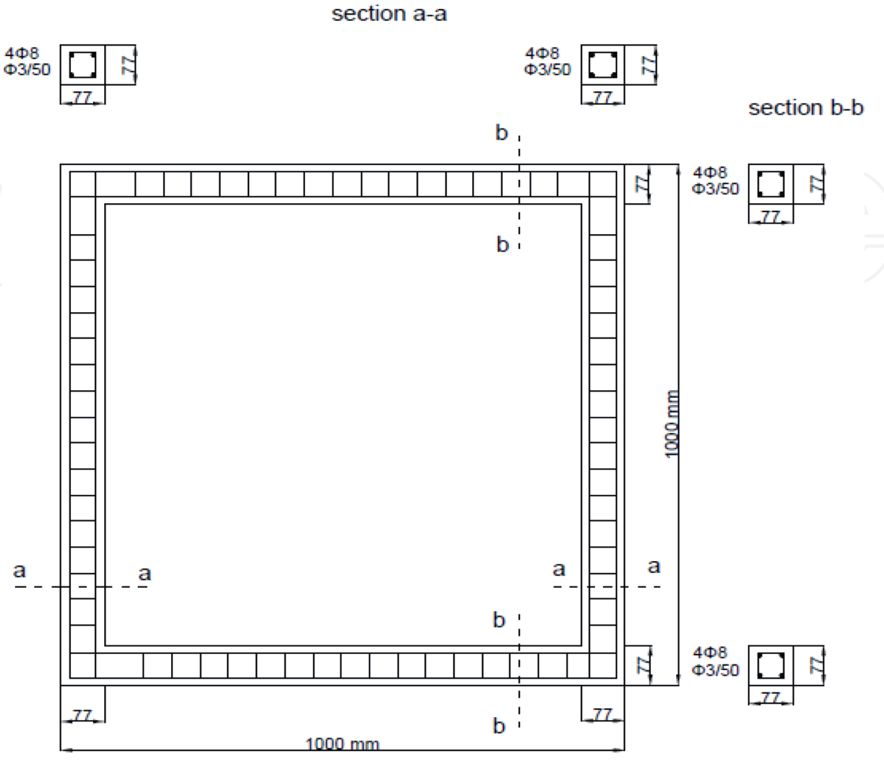

Figure 6.
Typical sketch of RC frame specimen detailing.

Figure 7.
Casted RC framed specimen.

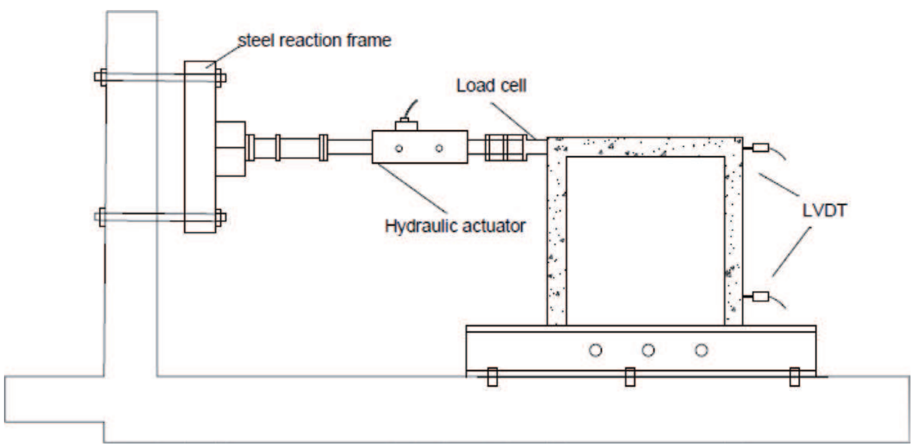

Figure 8.
Sketch of test setup.

3.5 Single bay frame without damper

Moreover, to estimate the efficiency of the MR damper, bare RCC frame without MR damper was also fabricated and tested as depicts in **Figures 9** and **10**. The loading pattern for the present experiment was depicted in **Figure 11**. From the results, it is clear that the first crack was observed in the 10th displacement cycle at the load of 6 kN applied loading pattern for the test experiment. The displacement was found to be 9.583 mm with the crack width of 1 mm. The maximum load carrying capacity was found to be 19 kN.

3.6 Frame with damper

To determine the ultimate load carrying capacity for the frame with MR damper. The experiment was carried out by supplying 3 A current to the MR damper placed in the RCC frame depicts in **Figures 12** and **13**. In the experiment, the first crack was observed at 16th displacement cycles at a load of 8kN which is higher than the bare frame. The displacement of 5.463 mm and a crack width was found to be 1 mm. The load carrying capacity was increased by 55% was observed for the frame with MR damper than the bare frame at 37.7 kN.

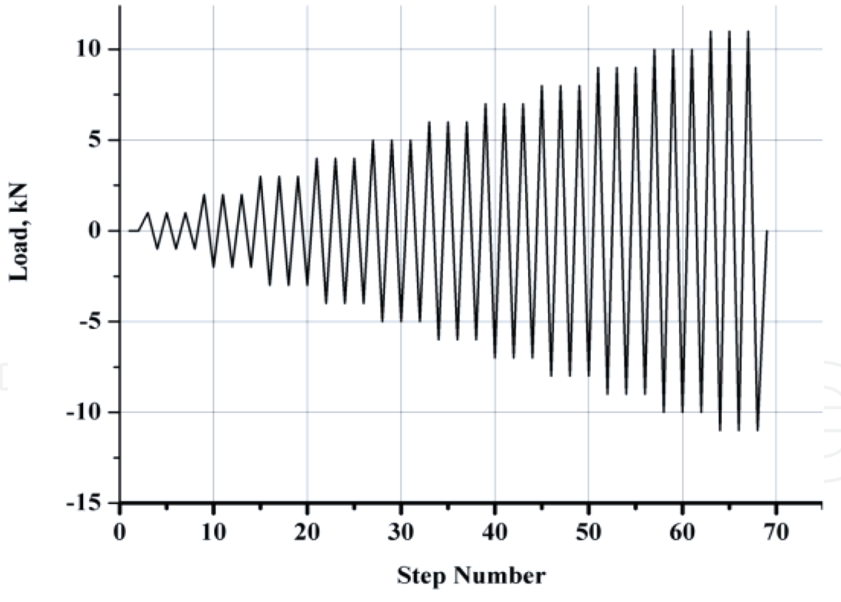

Figure 9.
Photograph of bare frame without damper.

Figure 10.
Load versus deflection for bare frame without MR damper.

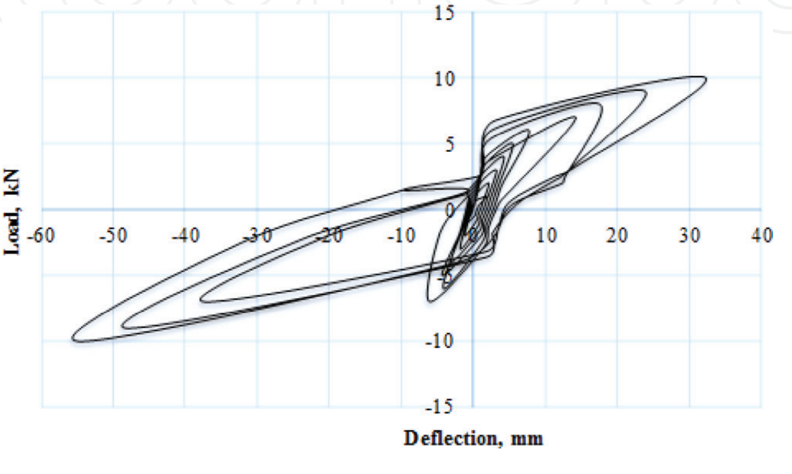

Figure 11.
Loading pattern of cyclic load test.

Figure 12.
Experimental setup of single bay frame with damper.

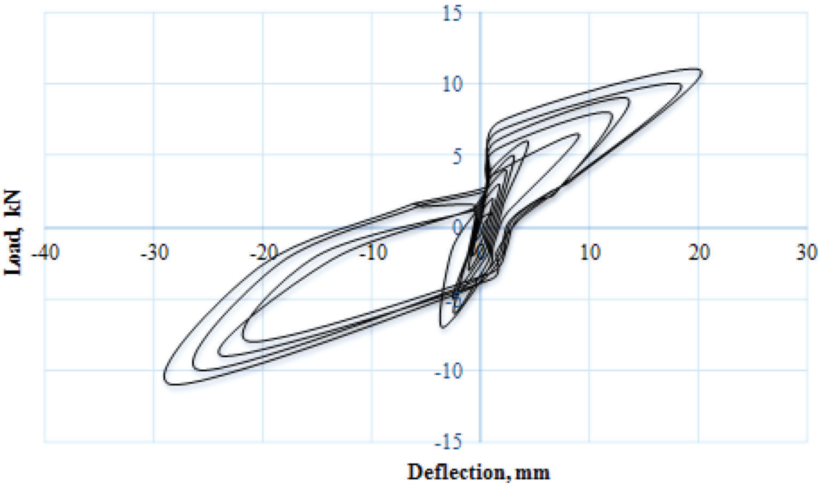

Figure 13.
Load versus deflection for frame with MR damper.

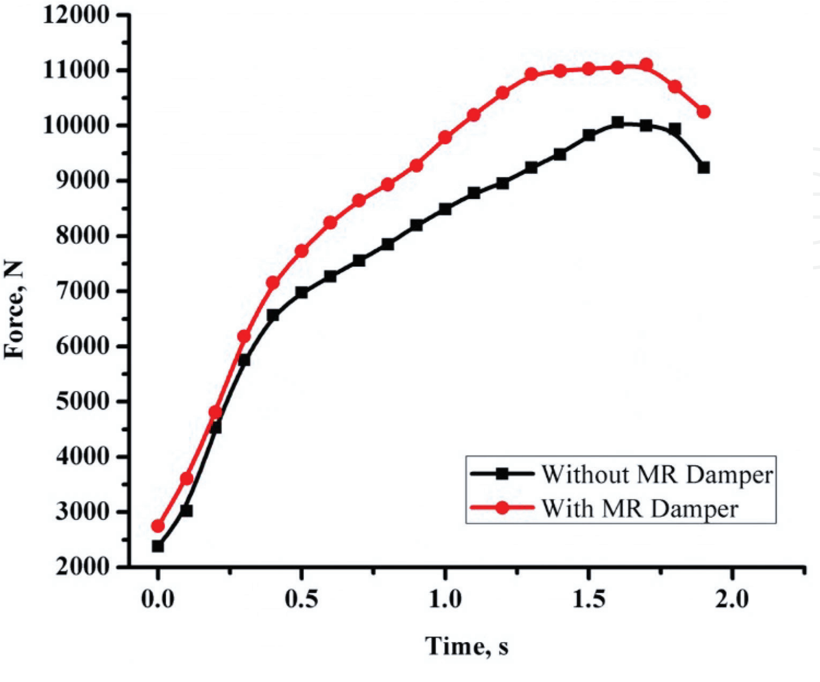

Figure 14.
Force versus time for with and without MR damper in RCC frame.

Figure 14 shows the force versus time curve for with and without MR damper. For this creep study the maximum load and deflection values for damper with and without RC frame are considered. The RCC frame with MR damper has the force of 10.24 kN. On comparing the force results for with and without MR damper, 9.79% of force was increased for RCC frame with MR damper.

Figure 15 shows the displacement versus time curve for with and without MR damper. The RCC frame with MR damper has the displacement of 19 mm. On comparing the displacement results for with and without MR damper, 39.85% of displacement was reduced for RCC frame with MR damper.

Figure 16 shows the stress versus time curve for with and without MR damper. The RCC frame with MR damper has the stress of 5124 N/mm^2. On comparing the

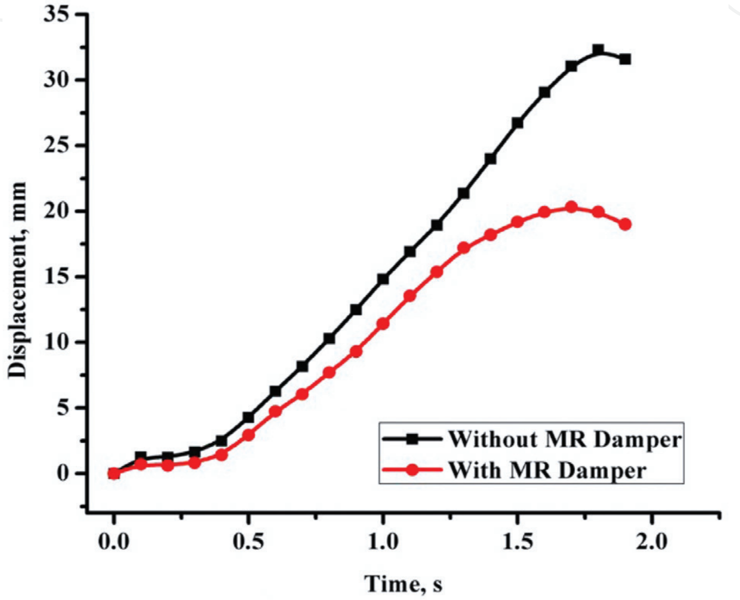

Figure 15.
Displacement versus time for with and without MR damper in RCC frame.

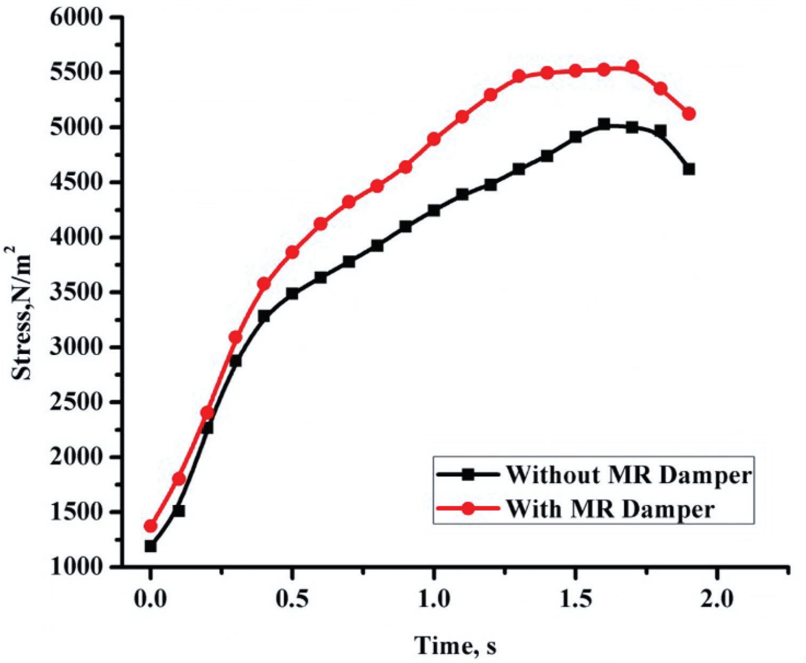

Figure 16.
Stress versus time for with and without MR damper in RCC frame.

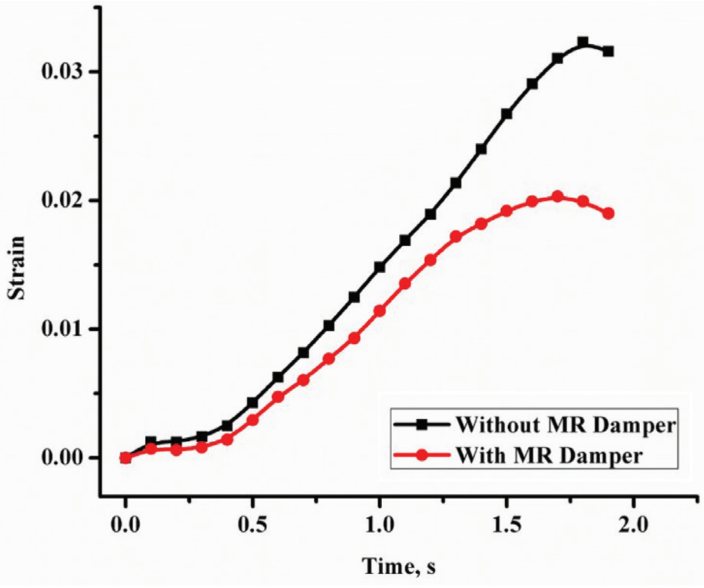

Figure 17.
Strain versus time for with and without MR damper in RCC frame.

strain results for with and without MR damper, 9.79% of strain was increased for RCC frame with MR damper.

Figure 17 shows the strain versus time curve for with and without MR damper. The RCC frame with MR damper has the stress of 0.019. On comparing the strain results for with and without MR damper, 38.09% of strain was decreased for RCC frame with MR damper.

4. Conclusions

Finally, it is concluded, for seismic resistance, MR damper are advantageous comparing to other supplementary dampers. In the present work, the developed MR damper with the MR fluid containing magnetic nano Fe_3O_4 and silicone oil as the carrier liquid was studied for MR damper application. On state and off state rheology of MR fluid was studied and its damping ability was compared. However, experimental investigation shows 76% of damping force was increased for the MR damper under on-state condition. From the cyclic load test, it is proven that 49% of displacement was reduced. The smart material, nano Fe_3O_4 was characterized using XRD and SEM and the average size of nano Fe_3O_4 was calculated and found to be 12 nm respectively. The experiment results reveal, the first crack was at 6 kN for RCC frame without MR damper and at 8 kN for the frame with MR damper. The ultimate value of the specimen reaches at 17 kN for frame without damper, MR damper it reaches a maximum load carrying capacity of 37.7 kN. The ultimate load carrying capacity and energy dissipation for RC frame with damper was increased by 55 and 45% respectively on compared to the bare frame. The effects of stress, strain, displacement and load behavior with respect to time for RC element with various time interval is observed with and without MR damper.

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