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Experimental and Numerical Investigation on Seismic Performance Enhancement of Steel Beam-Column Joints Using Shear Thickening Fluid Dampers

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ABSTRACT

The addition of nano-silica can enhance the viscosity and shear thickening response of the fluid. The major advantage of using nano-silica in STFs is its tunability. The concentration of nano-silica particles can be adjusted to achieve the desired viscosity and shear thickening behavior. By controlling the particle concentration, it is possible to tailor the flow properties of the fluid to specific applications. The research PEG400 (polyethylene glycol). To investigate the predominance of the STF in dampers using ABAQUS software. The particle size, composition, crystalline structure and rheological properties of the STF samples were studied through FESEM with EDAX The variation of viscosity with temperature variation was also studied.

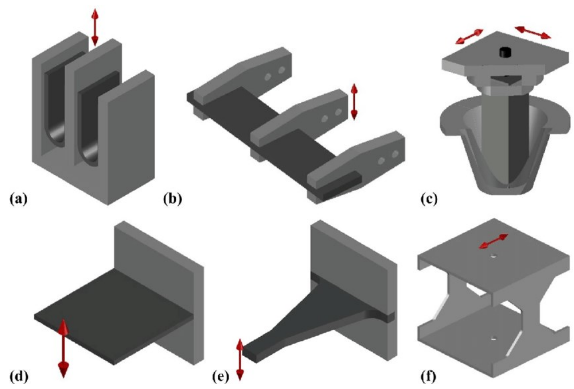
1. INTRODUCTION

Metals can be deformed in an inelastic manner during earthquakes, which is a very effective process for dispersing the seismic energy. Metallic use of this energy dissipation source. Metal dampers need not be replaced after experiencing mild ground vibrations. may still function normally. However, a trustworthy and non-destructive examination of the extent of decide whether or not the dampers need to be replaced. Damage from earthquakes is sometimes, but not always, a gradual process, so a visual check alone cannot determine the damper's "fitness." Damage from

earthquakes with near-fault impulse ground motions occurs abruptly because of the rapid energy transfer from the earthquake to the building. Losses in rigidity, in particular, may be another consequence of a deteriorating structure (i.e., sudden damage). When compared to linear dampers, Typical examples of metallic dampers are shown in Figure 1

Figure 1 Steel plate metallic dampers

Chan & Albermani (2008)



investigated slit dampers and developed new formulas for them. Using slit dampers, Oh *et al.* (2009) connected beams to columns. Some numerical research on slit damper connections was presented by Saffari *et al.* in 2013. Figure 2 shows a sample slit-type damper and its placement in a structure. Frames with steel slit dampers were used in the 2016 study by Tagawa *et al.*

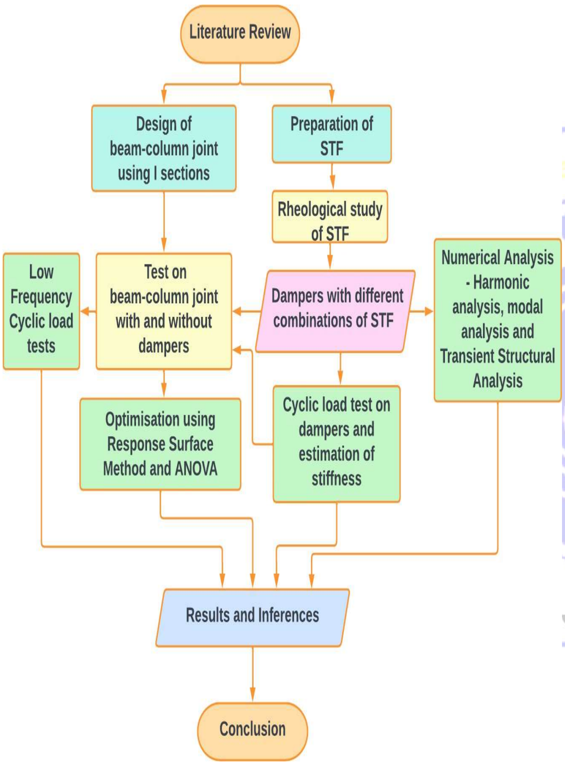


Figure 2 Metallic slit-type damper

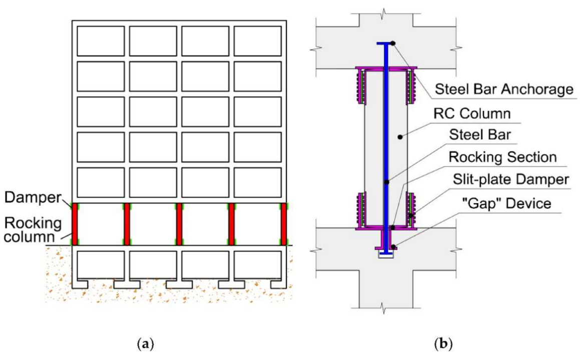


Figure 3 Architecture of the proposed research

2. OBJECTIVES OF THE PROPOSED WORK

The objectives of the research for the studies on the proposed beam-column joint include

- To study the synthesis and characterization of shear- thickening fluid.
- To design a shear-thickening fluid damper and investigate the behaviour under cyclic loads.
- To study the effect of shear-thickening fluid dampers in the steel beam-column joint under dynamic loads through experiments.

3. METHODOLOGY

The architecture of the proposed research methodology is shown in Figure 3. An extensive literature study has been done as discussed in the filled with different proportions of STF were studied under dynamic loading. The beam-column joint designed using I sections was fabricated and the frames were tested under static and dynamic loading. The model was also analysed using ANSYS for different types of loading. The optimisation was done using Response Surface Method. The results from the experiments on dampers and frames were incorporated in the analytical study of a building with STF dampers

Figure 4 Materials used in the preparation of samples for the research work

Further, the prepared samples of STF (nano-silica dispersed in PEG400) and STF with oil were also studied under FESEM to understand the dispersion and the structural morphology. The wet samples were dried using an autoclave and then examined. Figures 4 show the samples of STF and STF with 50% silicone oil respectively and their corresponding images from FESEM. Figure 5 shows the composition of STF sample from the EDX results

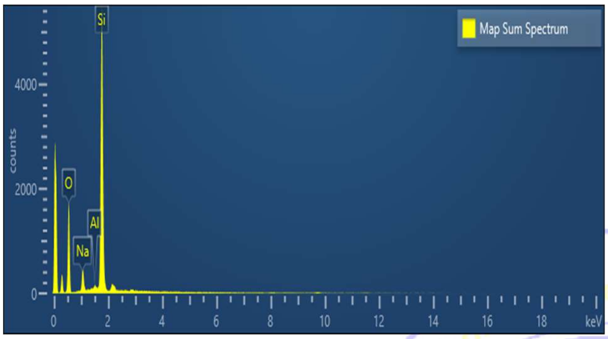


Figure 5 Result from EDX showing composition of nano SiO_2 sample

The data provided is from the rheometer analysis STF. As the shear stress and shear rate increase, the instantaneous viscosity initially decreases, indicating shear thinning behavior, but then starts to increase, which is characteristic of shear thickening behavior. 500 s^{-1} to 1000 s^{-1} where the viscosity starts to increase significantly. The strain values increase consistently over time, which is expected as the material is subjected to continuous shear. This also indicates that the material is accumulating deformation as the test progresses. At the beginning (0.1429 s^{-1}), the shear stress is low (10.92 Pa) with a high viscosity (76.42 Pas), indicating a more viscous behaviorto 1000 s^{-1}), the shear stress also increases significantly (e.g., at 1000 s^{-1}, the shear stress is 996.5 Pa). The viscosity at this point drops but then starts to rise again. The data confirms fluid, where the viscosity increases with increasing shear rate after a certain threshold. This is beneficial for applications requiring materials that become more resistant under high strain rates, such as protective gear. The increasing viscosity at higher shear rates implies that the STF can dissipate more energy under high shear conditions. This property is crucial for applications like damping or impact resistance. By comparing the results obtained from the experiments performed, it can be concluded that sample 3 is the best mix proportion as the critical

shear stress of sample 3 is high compared to all other samples. The high critical shear stress of Sample 3 indicates that it is more resistant to deformation under stress compared to other samples, despite its moderate viscosity. This combination of properties could make it suitable for applications requiring materials that remain stable under high stress but can still flow or deform when needed. Sample 4 is only marginally higher. Based on the study, fumed silica particles in combination with PEG as a solvent has produced an excellent performance in terms of its behaviour as a non- Newtonian fluid. Nano-silica is known to be a universal thickening agent, and have particle size ranging from 5-50 nm. These particles are also non-porous. PEG solvent has some of the salient features which include its ability to disperse and stabilize nanoparticles. Nano-silica particles tend to agglomerate due to their high specific surface energy and hence when it is dissolved in PEG, it inhibits the effect of agglomeration. This combination of nano-silica in PEG suspension has shown excellent mechanical strength under the application of stress.

4. CONCLUSION

- The selection of materials, proportion 5 parts of PEG 400 was proven with excellent complex viscosity.
- The SEM images reveal the particle size of 35-55 nm and morphology, while EDX provides the

elemental composition, showing the presence of silicon, oxygen, sodium, and aluminum in nano-silica. X-ray Diffraction (XRD) analysis shows the crystallographic properties of nano-silica particles, indicating a small crystallite size.

- When tested in a rheometer, the dynamic shear rate reaches 460 s-1, then the complex viscosity of the STF fluid tends to decrease. This trend continues, indicating that the shear-thickening mechanism of the STF is related to the production of jamming clusters. The inclusion of nano-silica contributes to this phenomenon.

- The damper was designed and different samples were considered for the study, namely, silicone oil, 26% STF with silicone oil, 50%STF with silicone oil, 60% STF with silicone oil and 100% STF with silicone oil.

- The analysis of the fluid was simulated in ABAQUS. The average von Mises stress was found to be in the range of 0 to a maximum of 8.5 Pa and the maximum displacement was 4 mm.

- The results indicated that the sample with 50% STF with oil has the highest maximum viscosity among the samples studied.

5. REFERENCES

6. Eurocode 3. (n.d.). Design of steel structures – Part 1-8: Design of joints. [Standard details / publisher needed].

7. Yeh, F.-Y., Chang, K.-C., Chen, T. W., & Yu, C. H. (2014). The dynamic performance of a shear thickening fluid viscous damper. Journal of the Chinese Institute of Engineers, 37(8), [pages unclear].

8. Fathizadeh, S. F., Dehghani, S., Yang, T. Y., Vosoughi, A. R., Noroozinejad Farsangi, E., & Hajirasouliha, I. (2021). Seismic performance assessment of multi-story steel frames with curved dampers and semi-rigid connections. Journal of Constructional Steel Research, 182, [article/pages unclear].

9. Fischer, C., Braun, S. A., Bourban, P. E., Michaud, V., Plummer, C. J. G., & Månson, J. A. E. (2000). Dynamic properties of sandwich structures with integrated shear-thickening fluids. Smart Materials and Structures, 15(5), [pages unclear].

10. Forberger, A. ([year unclear — "201η"]). Calculating the dissipation in fluid dampers with non-Newtonian fluid models. Mechanics Research Communications. [volume/pages unclear]

11. Gawade, S. S., & Jadhav, A. K. (2017). A review on electrorheological (ER) fluids and its applications. https://doi.org/10.13140/RG.2.2.35785.34407

12. Rodgers, G., Mander, J. B., & Chase, J. (2022). Experimental testing and analytical modeling of damage-avoidance steel connections using HF2V damping devices. [Journal/conference and pagination needed].

13. Bonchev, G., & Mualla, I. (2017). Linked column with friction dampers as a technique for seismic retrofit of steel moment resisting frames. [Journal/conference and pagination needed].

14. Zhou, G. (2023). Design and optimization of viscous damping outrigger vibration reduction for ultra-high structures. [Journal/conference and pagination needed].

15. Zhang, G., Fan, Q., Lu, Z., Zhao, Z., & Sun, Z. (2020). Experimental and numerical study on the seismic performance of rocking steel frames with different joints under earthquake excitation. Engineering Structures, 220, Article 110974.

16. Han, M., Wangwang, Y., Niu, M., Zhang, Z., & Li, C. (2018). Shear thickening fluid and preparation method thereof. [Patent / journal details needed].

17. Akbari Lor, H., Izadinia, M., & Memarzadeh, P. (2018). Experimental and numerical study I-shaped slit dampers in connections. [Journal/conference and pagination needed].