Experimental and Numerical Study of Grooved Gusset Plate Damper for Cross-Braced Frames

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The design and implementation of earthquake-resistant structures is the most important factor in preventing human and financial damage caused by the high energy of this natural disaster. Concentric braces are among the common elements in providing stiffness and lateral resistance of structures, which have less energy consumption and ductility compared to other lateral bearing elements. A major defect in the performance of concentric braces is the buckling of the compressive brace before yield and insufficient energy absorption. The idea of using energy-dissipating parts is one of the things that has been widely considered to improve the seismic behavior of such braces. Yielding steel dampers are one of the types of passive energy-dissipating systems that consume the energy of the structural components with the help of their constituent materials and improve the performance of the structure. In this thesis, a new type of concentric bracing system is proposed, 0which is known as grooved gusset plate damper (GGPD). The proposed system operates by generating a new fuse through the creation of grooves in the central gusset plate within the cross-braced frame. In the proposed system, as a less vulnerable or repairable system, the gusset plate is replaceable as a central connection that connects four concentric braces to the gusset plate. In this research, after introducing the details of the proposed damper, the main characteristics of the proposed system have been determined using analytical methods. This method has determined the behavioral characteristics of the new damper, including elastic stiffness, yield strength, ultimate capacity, and energy dissipation capacity, through the application of fundamental material resistance relationships. To experimentally investigate the behavioral characteristics of the cross-braced frame equipped with the proposed damper, four samples were designed and constructed. In this regard, a cross braced frame equipped with one of the four proposed damper samples was built and periodically tested. The evaluation and studies have demonstrated that employing the proposed damper to enhance ductility and optimize the performance of the cross frame is valuable. The value of this idea is that by increasing the ductility and improving the performance of these types of structures, their practical limitations are removed and the use of their other positive and significant features is provided. The results showed that this system as a ductile member is a suitable option for this purpose, because in addition to the ability to absorb energy, it has a significant resistance and the tensile and compressive behavior is the same. According to the materials available in the market, it appears feasible to prepare and install it within a cross-braced frame. Additionally, it appears that replacing the damper after a failure is easily achievable, with low costs and high speed. The proposed damper was able to provide a very good level of energy dissipation; whose ductility factor reaches 4.5. ABAQUS finite element software was employed to numerically assess the behavior of the grooved damper. A non-linear finite element model, incorporating fracture modeling and low-cycle fatigue, was developed and calibrated based on the study system using the test results. The results showed that the nonlinear finite element model is successful in simulating the behavior of the damper and is consistent with the actual behavior during the experiments. In order to address the failure mode of the proposed damper, a new geometrical shape for steel grooved dampers is being proposed. Based on the results of both analytical and numerical methods, it can be concluded that increasing the thickness of the middle plate of the damper to 1.5 times the thickness of the upper and lower parts led to the most favorable outcomes. It should be noted that this modification led to a significant improvement in strength and ductility with an average increase of 30% and 50%. Additionally, the damper can be modified based on shortening the length of the steel strips of the middle plate. The findings indicated that achieving a ratio of 1.4 between the lengths of the strips in the upper and lower sections to those in the middle plate yielded optimal results. Hence, it can be concluded that by performing modification, the occurrence of fracture can be delayed or even eliminated.

Keywords: Grooved gusset plate damper, yielding damper, cross-braced frame, cyclic test, nonlinear finite element, energy dissipation, ductility.