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Experimental study of steel plate shear walls with infill plates strengthened by GFRP laminates

F. Nateghi-Alahi, M. Khazaei-Poul *

Structural Engineering Research Center, International Institute of Earthquake Engineering and Seismology (IIEES), 19395 Tehran, Iran

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ABSTRACT

In this paper, the nonlinear behavior of the composite steel plate shear walls, in which steel infill plates was strengthened by the fiber reinforced polymers (FRP), is experimentally investigated. Tests are designed to evaluate the effect of Glass-FRP layers, the number of GFRP layers and the orientation of GFRP layers on the stiffness, shear strength, cumulative dissipated energy and other major seismic parameters in the composite steel plate shear walls. Experimental models are scaled as one-story steel shear panel models with hinge type connections as boundaries at four corners. In the first test, unstiffened steel infill plate is used for the testing as a reference test. However, in the next four tests, strengthened steel infill plates were used with different numbers and orientation of GFRP layers. Each test was performed under fully reversed cyclic quasi-static loading in the elastic and inelastic response zones of the specimens, in compliance with the ATC-24 (1992) test protocol. The experimental results indicated that by strengthening the infill steel plates yield by laminates strength, ultimate shear strength and cumulative dissipated energy can be significantly increased. The paper therefore presents the background, procedure and set-up used as well as the test results.

1. Introduction and background

Steel plate shear walls (SPSWs) possess significant advantages over many other systems in terms of cost, substantial ductility, high initial stiffness, fast pace of construction, and the reduction in seismic mass [1]. The SPSW system can be used in different configurations, such as:

a. Unstiffened steel plate shear wall;
b. Stiffened steel plate shear wall;
c. Composite steel plate shear wall.

Unstiffened-SPSWs are the basis for the SPSW systems. Unstiffened web plate has negligible compression strength; therefore shear buckling occurs at the low levels of loading. Lateral loads are then resisted through diagonal tension in the web plate. In addition, stiffened web may also be used to increase the shear buckling strength. In this type of SPSWs, the shear strength is the result of a combination of shear buckling strength and the additional strength from the diagonal tension field action [2]. In Composite Steel Plate Shear Walls (C-SPSW), the steel web plate can be stiffened by adding concrete on one or both sides of the web plate. Concrete layers can improve the load carrying capacity of the SPSWs by permitting the utilization of the full yield strength of the infill plates. In addition, the shear strength of the concrete is effective in increasing the capacity of the system all together [1].

FRP laminates are high strength, high stiffness, light weight, flexibility to form in any shapes, easy to handle during construction, and excellent resistance to corrosion and environmental degradation. These superior mechanical properties of the FRP laminates have made them an effective alternative for steel plates used for strengthening and upgrading steel structures [3,4]. Steel infill plates can be strengthened by adding a number of layer of FRP laminates in both sides. In this type of C-SPSW, like unstiffened SPSW systems, the strengthened steel plate has negligible compression strength and shear buckling occurs at low levels of loading cycle. Lateral load is resisted through diagonal tension in the web plate. In C-SPSW, FRP laminate is effective to increase post-buckling strength, initial and secant stiffness of the system as well [5].

During the last four decades many experimental and numerical studies on seismic performance of SPSWs have been carried out. All these works have led to the better understanding of this lateral load resistant system. Wagner [6] was the first researcher who used complete and uniform tension fields to determine the shear strength of a panel with rigid flanges and very thin webs, and inferred that the shear buckling of a thin aluminum plate supported adequately on its edges does not constitute failure. Other researchers conducted works based on this idea in order to develop analytical methods for modeling and analysis of thin SPSWs. Thorburn et al. [7] developed a simple analytical method to evaluate the shear strength of unstiffened SPSWs with thin steel plates and introduced the strip model to represent the tension field action of a thin steel wall subjected to shear forces. Timler and Kulak [8] modified the formula for the angle of inclination of the tension strips by the tests. Elgaaly [9] experimentally investigated the behavior

* Corresponding author. Tel.: +98 9386012122.
E-mail addresses: nateghi@iiees.ac.ir (F. Nateghi-Alahi), m.khazaei@iiees.ac.ir, m.khazaei.poul@gmail.com (M. Khazaei-Poul).

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