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EXTENDED ABSTRACT

Numerical Investigation of Ring Shaped Steel Plate Shear Walls with Concrete Filled Steel Box Column as a Vertical Boundary Element

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Steel Plate Shear Wall (SPSW), Vertical Boundary Element (VBE), Ring Shaped Web Plate, Concrete Filled Tube (CFT) Column, Pull Out Deformation.

1. Introduction

SPSW consists of a thin steel plate as a web plate that surrounded by vertical and horizontal boundary elements. Due to transverse loading, the web plate resists lateral forces by developing a tension field action. Development of tension field action applies heavy forces to VBEs. Thus, the authors of this paper considered two strategies: (1) Control of tension field action development by use of geometric property of the ring. (2) Control of yielding and local buckling in VBE by use of CFT steel sections.

2. General Background, Concept, and Validation

Tension field action of a buckled web plate despite of a great energy dissipation capacity makes two major challenges in the design of steel plate shear walls: (1) Heavy load applying to a VBE. (2) Slack of a web plate material causes in cyclic strength reduction.

2.1. Ring Shaped Steel Plate Shear Wall Concept

The concept of ring shaped SPSW is based on the intrinsic property of a geometry of a ring that when deforms in an ellipse, the contraction of one direction is nearly equal to the expansion of normal direction. As the same way, in a ring shaped web plate, the roof displacement causes in lengthening of rings in tension diagonal direction that is almost equal to shortening of them in compression diagonal direction. In solid web plate, shortening in compression diagonal direction is nearly equal to steel poison ratio cross to lengthening in tension diagonal direction which results in slack of material of web plate (Phillips and Eatherton, 2018).

2.2. Boundary Frame Selection

CFT steel columns provide synergetic advantages of steel and concrete, and have a high strength to weight ratio, provide excellent monotonic and dynamic resistance under biaxial bending plus axial force, and improve damping behavior. Thus, the authors of this paper think they can be used in SPSW system as vertical boundary elements (Hu, 2008)

2.3. Ranges and Limit States of Pushover Response

According to Tsai et al (2014) the pushover response of a SPSW could be divided in three ranges and three limit states: The elastic range that continues from start of loading to first limit state named initial yielding (IY)

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state, the progressive yielding range which is beyond of first limit state and ends in second one named uniform yielding (UY) state, and the mechanism range which continues from second limit state to the third one named target hardening (HD) state.

2.4. Local Pullout deformation of the Interior Flange of the Box Column

Calculation of the interior flange of a box column which is connected with the web plate in UY and HD states leads us to develop design check for the pullout action.

3. Methodology, Scope, and Objectives

Based on the studies of the authors, ring shaped panel with its special buckling behavior is an appropriate element for the web plate of SPSW systems. Also, application of CFT steel column which is a good element in high seismic regions as a VBE is useful. As regards, experimental behavior of a ring shaped SPSW with CFT steel column as a VBE isn't investigated yet; the authors put the modeling calibration of mentioned elements in their list and then create their proposed model by using ABAQUS (Dassault, 2013).

Design of ring shaped web plate requires identifying different geometric properties such as radius and width of the rings, width of the links, and the outer radius to width of the rings ratio, and choice proper ranges for calculation of VBE applied force due to web plate goes to the author's to-do list.

4. Proposed Model and Related Equations

The proposed model is a 2-story and 1-bay SPSW with ring shaped web plate and CFT steel VBE. This section focuses on two general scopes: (1) Yielding of VBE at a story drift of 2.5% rad. And (2) the magnitude of pullout deformation at the middle of the height of interior flange of left VBE in 2nd story at a drift of 2.5% rad.

4.1. Equations of Demand to Capacity Ratios in Ring Shaped SPSW

An important parameter in the capacity design of VBEs is a bending moment demand to bending moment capacity ratio or DCR. This ratio is calculated in UY and HD states. Equations for calculating of these ratios are presented in this section.

4.2. Local Pullout deformation of the Interior Flange of the Box Column

By determination of limited zones for design of ring shaped SPSW, four specimens in different thickness were modeled. For each selected thickness, a solid panel is modeled too.

In this section, after modeling geometry of frames and material properties, initial imperfection was specified on the panels. The imperfection distribution was determined from the superposition of the first two buckle mode shapes for each panel obtained from an ABAQUS buckle analysis. Two steps of nonlinear static analyses were performed for each model: (1) Applying vertical loads equal to 0.3 of column axial capacity on the top of each 2nd floor column. And (2) conducting the displacement control pushover analysis by a displacement equals to a story drift of 2.5% rad.

5. Results and Discussion

In this section, results id ABAQUS analyses and answers of proposed computational equations are presented.

After conducting displacement to models, the yielding condition of them is presented by using of Von Mises criterion. For investigation of pull-in force of web plate on the VBE, the magnitude of pullout deformation of interior flange in mid-height of it at the 2nd floor id computed by using of nodal displacement of finite element model.

Through proposed equations for computing pullout deformation of interior flange, these magnitudes are computed for different models and results are compared to ABAQUS analyzed results. The DCR ratios of models are computed by proposed equations and presented here.

6. Summary and Conclusion

Early buckling of web plate and pull out of VBE due to tension field action of web plate are some of problems in convenient SPSW design. In this paper, application of ring shaped web plate studied to wipe out these problems. For this reason, the pull out deformation of interior flange of VBE and yielding of it are studied:

- Application of ring shaped web plate diminishes yielding of mid-height of 2nd floor VBE.
- Pull out deformation of interior flange of VBE in ring shaped SPSW is reduced significantly.
- Bending moment demand to bending moment capacity ratio in UY and HD states computed for each model. For ring shaped SPSW, these ratios are below of one and this fact shows that yielding is not occurred in VBE of these models.

7. References

Dassault, Abaqus version 6.13 Documentation, 2013.

Hu J, "Seismic performance evaluations and analyses for composite moment frames with smart SMA PR-CFT connections", Dissertation Presented to the Academic Faculty in Partial Fulfillment of the Requirement for the Degree Doctor of Philosophy in the School of Civil and Environmental Engineering, Georgia Institute of Technology, 2008.

Phillips AR, Eatherton MR, "Computational study of elastic and inelastic ring shaped steel plate shear wall behavior", Engineering Structures, 177, 2018, 655-677.

Tsai K, Li C, Lee H, "Seismic design and testing of the bottom vertical boundary elements in steel plate shear walls", Part 1: Design methodology, Earthquake Engineering and Structural Dynamics, 2014, 43 2237-2259.