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Investigation of Displacement Behavior and Deformation Capacity of I-Shaped Steel-Concrete Shear Wall due to Cyclic Loading

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1. Introduction

The steel-concrete (SC) composite shear walls have been increasingly used in construction industry. Regarding geometry, I-shaped wall units are frequently considered to be used as structural members of safety class structures. SC shear walls are found to be quite efficient replacement of conventional RC walls. These wall systems are able to withstand high in-plane lateral forces at low displacement levels, used for better seismic resistance and reduce overall buckling of concrete by extra steel confinement [1].

This study focuses on the global structural behavior of walls when steel and concrete are brought in place to act as a unit. The study investigates the load-displacement behavior and deformation capacity of composite SC shear wall through cyclic test and finite element analysis. Including the dynamic test results, details of modeling of structural components, contact conditions between steel and concrete, associated boundary conditions and constitutive relationships for cyclic loading are explained in this paper.

2. Test and Simulation

This section introduces cyclic loading test and numerical simulation of a SC composite element with I-shape performed in this study.

2.1 Cyclic Test

The geometric configuration and details of test specimen is show in Fig. 1. Specimen consists of a hybrid web and two flanges at its ends, supported by 1150 mm thick base slab.

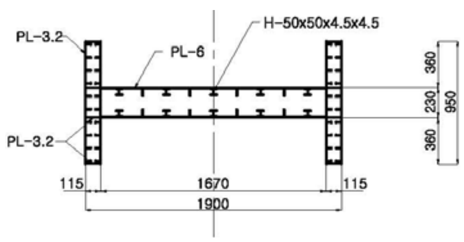

Fig. 1. Geometry and configuration of the test specimen

Cyclic displacements were applied by actuator to the top of the specimen, where concrete slab was provided as the boundary condition for the specimen. The specimen could tolerate 15 cycles of displacement controlled loading with the maximum displacement of 14.61 mm and 5645 KN corresponding load.

2.2 Numerical Analysis

Numerical model of the shear wall was constructed to investigate the behavior of composite SC shear wall under cyclic loading. The hysteretic behavior obtained by experiment was used as an input in material modeling for finite element program ABAQUS [2]. If the material modeling is incorrect, the calculation results of static and dynamic structural response cannot be measured correctly [3]. A steel constitutive model for structural steel in Lu, H. et al [3] [4] is used for cyclic behavior of steel. In this steel material model, hardening of the steel is considered. The deformation of steel includes elastic, elastic-plastic, plastic and hardening, as shown in Fig. 2 and Fig. 3.

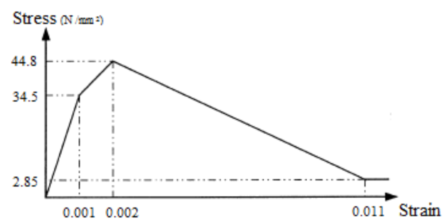

Fig. 2. Material property of concrete used for simulation

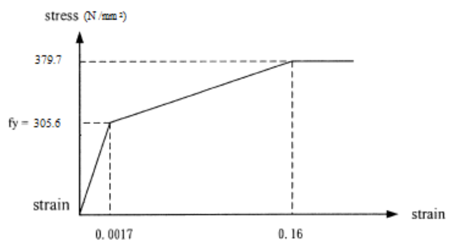

Fig. 3. Material property of steel used for simulation

The steel is assumed to have kinematic hardening behavior; i.e. yielding of steel is independent of the equivalent stress, the center of the yield surface moves in stress space along with expansion and contraction of the yield surface range [2]. Elastic modulus and Poisson's ratio for steel are taken as 2×10^5 N/mm^2 and 0.3.

In numerical simulation, the structure was modeled using C3D8R solid element with the fixed base. The contact interaction method in ABAQUS [2] was used to simulate the bond behavior between steel and concrete. The concrete and steel surface was assigned as master and slave surface respectively. The hexahedral finite element meshes of the simulated shear wall are shown in Fig. 4.

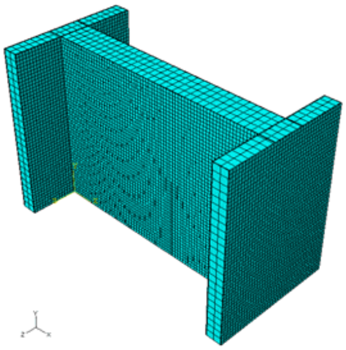

Fig. 4. Element mesh of the simulated shear wall model

The 'penalty' algorithm is used to define the mechanical property of the contact interaction. The tangential behavior was assigned to be frictionless whereas "hard contact" relation was adopted to simulate the normal interface behavior. Load was simulated by applying the displacement control scheme instead of direct of direct loading to generate hysteretic behavior of the composite SC shear wall. A step-by-step procedure in increasing the displacement to reach the maximum displacement capacity (14.61 mm) obtained from the cyclic test.

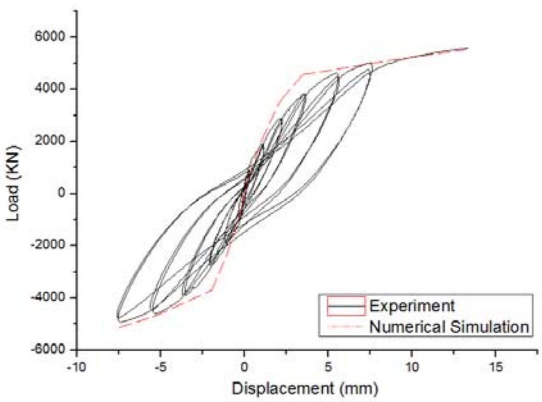

Fig. 5. Comparative P-Δ Hysteresis Skeleton Curve

As a result of the analysis, Fig. 5 shows the comparison between the hysteresis and equivalent skeleton curve of experiment and numerical simulation. It can be clearly observed that results obtained from ABAQUS can find a very precise envelope of deformation capacity curve. However, solid element was used to simulate the composite SC shear wall which reflects less pinching near ultimate load. Though, lesser pinching and softening is observed but skeleton curve converges well with experimental results.

3. Conclusions

A numerical model using solid element to simulate composite SC shear wall is reported, where bond behavior plays a vital role in depicting the progressive pinching and softening effect under subsequent cyclic loadings. The skeleton curve of numerical model shows convergence with the experimental hysteresis curve, deformation envelope seems to be stiffer in some regions due to complex contact interaction.

It can be concluded that solid element well simulates the cyclic behavior of the composite SC shear walls but shows comparatively lesser pinching and softening effect. However, skeleton curve depicts nice reflection of overall behavior of the test results.

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