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Investigate the Use of Shear Walls in Concrete Structures, Considering the Experimental Results

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ABSTRACT
Buildings with cast-in-situ reinforced concrete shear walls are widespread in manyearthquake-prone countries and regions, such as Canada, Chile, Iran, Romania, Turkey, Colombia, the republics of the former Soviet Union, etc. This type of construction hasbeen practiced since the 1960s in urban regions for medium- to high-rise buildings(4 to 35 stories high). Shear wall buildings are usually regular in plan and in elevation.However, in some buildings, lower floors are used for commercial purposes and thebuildings are characterized with larger plan dimensions at those floors.In this paper, an overview of the various studies conducted on shear walls, Such asExperimental dynamic tests,finite element model, Rocking behavior and nonlinear modeling. So, in the future, the development of FE models of complete buildings will be studied. In the case of a building with several stories, the simplified model of shear wall should be able to account for the overturning phenomenon (the refined model already can). In the case of a single story structure, the main outlook of this work is obviously the development of a FE model and its confrontation to experimental data, which is currently ongoing research.
Keywords: *shear wall, dynamic tests, Rocking behavior, construction.*

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I. INTRODUCTION

Because of the frequent occurrence of earthquakes and the extensive application of high-rise buildings, we have been giving greater and greater attention to seismic performance, especially on the restoring force capacity of shear wall structures [1, 2]. Due to the high brittleness and low tensile strength of concretes, normal reinforced concretes have low crack resistance, low ultimate strength, and weak deformability and energy dissipative capacities, which indicate weak seismic capacity. Because of this, reinforced concrete shear walls are liable to crack and fail under reversed cyclic load, and need to be repaired or strengthened to improve the crack resistant and seismic performance [3–5].

Boudaud et al in 2014 studied on Joints and wood shear walls modeling II: Experimental tests and FE models under seismic loading. That study presents a finite element (FE) model of timber-framed shear walls under seismic loading, which has been validated in Part I under quasi-static loading. In this paper, experimental shake table tests on shear walls are described and some examples of the obtained results are discussed. The simplified model is then used for dynamic calculations and its predictions are confronted to the refined FE model ones, in order to validate its behavior under dynamic loading. Eventually, an efficient method to build the walls of a timber-framed building by coupling simplified FE models is proposed. [6]

Julian Carrillo et al in 2015 investigated on Effect of lightweight and low-strength concrete on seismic performance of thin lightly-reinforced shear walls. Although several research programs have investigated the performance of structural elements made of lightweight concrete, there is a limited understanding of the behavior of lightweight shear walls under seismic conditions. Thus, shear strength of thin lightly-reinforced, lightweight concrete shear walls can be calculated without any modification factor. [7]

Ronny Purba & Michel Bruneau in 2015 studied on Experimental investigation of steel plate shear walls with in-span plastification along horizontal boundary elements. A cyclic pushover test of a three-story steel plate shear wall (SPSW) specimen was conducted to investigate the seismic behavior of this system when plastic hinge was predicted to develop along the span of horizontal boundary elements (HBEs). The experiment demonstrated that the in-span plastification caused a significant accumulation of plastic incremental deformations of HBEs. Several of special moment connections experienced fractures, which is attributed to a higher rotation range prior to fracture of those connections. A finite element investigation of the tested specimen showed similar overall behavior to that observed during the experiment. [8]

A.C. Bradley & W.S. Chang, R. Harris in 2016 studied on the effect of simulated flooding on the structural performance of light frame timber shear walls – An experimental approach. That paper presents the results of a series of tests on timber shear walls exposed to simulated flooding and drying. The results presented here show that there is a permanent loss of mechanical properties in timber shear walls due to flooding. The simulated flooding explored in this paper resulted in a loss of strength of 20–25% when compared to the control specimens. Yield strength and stiffness of the walls also decreased as a result of simulated flooding. The ductility of the walls was found to reduce. Before exposure to simulated flood the walls are ‘‘highly ductile” however after flooding and even after drying they were found to be only moderately ductile. [9]

Weiyi Zhao et al in 2016 investigated on Hysteretic model for steel–concrete composite shear walls subjected to in-plane cyclic loading. They presents (a) the analysis of experimental results of 32 SC wall specimens, and (b) the derivation and calibration of a quadri-linear backbone with negative post-peak stiffness and associated hysteretic rules Calibrations are conducted to suggest the reduction factors for the Young's moduli of concrete and steel that reflect the plasticity extension and damage accumulation.[10]

Hadi Moghadasi Faridani & Antonio Capsoni in 2016 studied on Investigation of the effects of viscous damping mechanisms on structural characteristics in coupled shear walls. This study addresses energy dissipation mechanisms to investigate the effects of the internal and external viscous damping on structural characteristics in coupled shear walls. The results reveal that the bending and shear damping are somehow efficient where the linear classical damping is incapable to be always a proper mechanism. [11]

Chao Dou et al in 2016 studied on Elastic shear buckling of sinusoidally corrugated steel plate shear wall. This paper deals with elastic shear buckling behavior of infill panels in sinusoidally corrugated steel plates hear walls, and fitting equations predicting the shear buckling loads are presented Based on extensive FEA numerical results, fitting equations with good accuracy are proposed to estimate elastic shear buckling loads of sinusoidally corrugated panels, which are improved much compared with the solutions in previous studies.

It is found that, the formulae for bending rigidities of corrugated plates revised in this paper are accurate compared with the previous ones. [12].

II. OVERVIEW ON SCOPE AND FINITE ELEMENT MODEL

Sinusoidally corrugated SPSWs are studied and analyzed via the finite element package ANSYS R13.0 [13]. Both the infill panel and the surrounding frame are modeled by four-node shell elements SHELL 181 with six degrees of freedom at each node. This element based on the first-order shear-deformation theory (Mindlin–Reissner shell) is capable to linear, large rotation, and/or large strain nonlinear applications from thin shells to moderately-thick shells. It has been proven by previous studies that SHELL181 element can be applied to simulate the buckling and load-carrying behavior of structures with corrugated plates. Liew et al. [14] compared the results of trapezoid ally and sinusoid ally corrugated plates between the proposed mesh-free Galerkin method and the ANSYS solution. Guo et al. conducted an experimental study of in-plane buckling strength of steel arches with sinusoidally corrugated webs accompanying by analyses with the SHELL181 element in ANSYS. Li et al. conducted a study on local buckling of compression flanges of H-beams with corrugated webs, in which the results from SHELL181 elements in ANSYS were compared with those from tests. Kalali et al. investigated the hysteretic performance of SPSWs with trapezoidally corrugated infill panels based on the experiment by Emami et al. by means of numerical analyses using ANSYS software. For elastic buckling analyses in this study, the material modulus of elasticity

E = 206 GPa and the Poisson ratio v = 0.30.

As shown in Fig. 1, L, H and t are the overall width, height andthickness of the infill panel respectively, and Ca and Cl are the sinusoidalcorrugation depth and the wavelength respectively. The sinusoidal curve of the corrugated infill plate is presented withinone wavelength as follows:

$$C_x = C_a \sin\left(\frac{2\pi x}{C_l}\right), \quad 0 \leqslant x \leqslant C_l \tag{1}$$

For investigation of shear buckling of the infill panel, the surrounding frame is assumed rigid and the beams and columns are pinned connected, in order to eliminate the contribution of the surrounding frame to lateral stiffness of the wall system (Fig. 1).

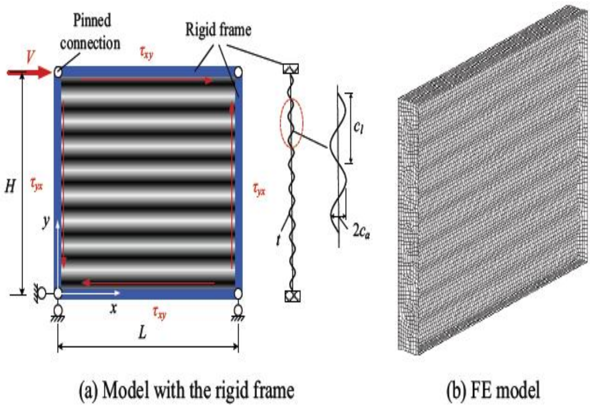

Fig. 1 Models for numerical analysis of CSPSWs in pure shearing.[15]

III. REFINED FE MODEL

3.1 Experimental dynamic tests

Dynamic tests were performed on a 6 × 6 m unidirectional shake table at the FCBA Technological Institute in Bordeaux, France. Two types of shear wall were tested. One was the P16 shear wall described in Part I, and the other specimen was similar to the OSB12 shear wall except for its nails, which were 2.5 mm in diameter and 55 mm in length. For the sake of comprehensiveness, the main characteristics of the shear walls are listed here: C24 strength class timber is used for the frame, the particleboard panel is 16 mm thick, the OSB panel is 12 mm thick, nail dimensions are 2:5 _ 55 mm and the spacing is 150 mm on the panel edges and 300 mm in the middle, one reinforced bracket is used at the bottom of each of the two exterior studs. Fig. 2 shows the test facility.

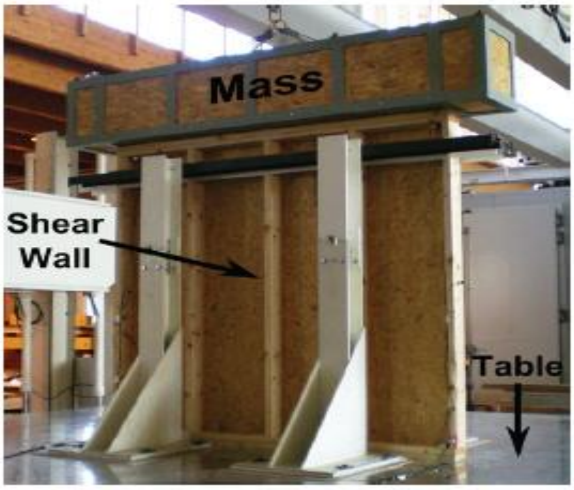

Fig. 2 Dynamic tests set-up on the shake table (FCBA Technological Institute).[6]

3.2 Experimental setting

The specimen was positioned in the East to West direction and anchored to an existing floor plate (1.5 in. thick, 9 ft. by 12 ft. dimension) using thirteen 3=4 in. diameter A490 high-strength slip-critical bolts on each column base plate (1 in. thick with 14 in. by 12 in. foot print), capable of transferring the plastic moment capacity of the columns. The existing floor plate was anchored to the 24 in. thick concrete strong floor using 22 high strength tension rods (i.e., Fy = 130 ksi; Fu = 150 ksi) of 11/8 in. diameter, with a corresponding tributary area of 24 in. by 24 in. per rod. A gravity column system was used to apply loads and provide lateral supports to the specimen [16]. As shown in Fig. 3b, the gravity column system sandwiches the SPSW specimen and is fitted with supports to prevent lateral torsion al buckling of the beams. The angles connecting the gravity mass to the specimen (Fig. 3c) served both to provide out-of-plane lateral support and as a load transfer mechanism. In addition, three angles at the bottom side of the gravity mass were added to laterally brace the beam bottom flanges (Fig. 3d). Lateral supports were also added at the column locations both on the top and bottom sides of the gravity mass (Fig. 3e). Furthermore, lateral supports for the bottom anchor beam (HBE0) were welded to the floor plate, where two WT3_ 4.5 sandwiched the beam at its mid-point. To reduce friction between the specimen and its lateral supports, 1/8 in. thick polytetrafluoroethylene (PTFE) sheets were used on each angle-to-angle and angle-to-specimen surfaces. The specimen was instrumented to collect experimental data, including displacement transducers (i.e., string pots and Krypton sensors), uniaxial and triaxial Rosette strain gauges, load cells, and video cameras. Details of the instrumentation can be found in Purba and Bruneau [17].

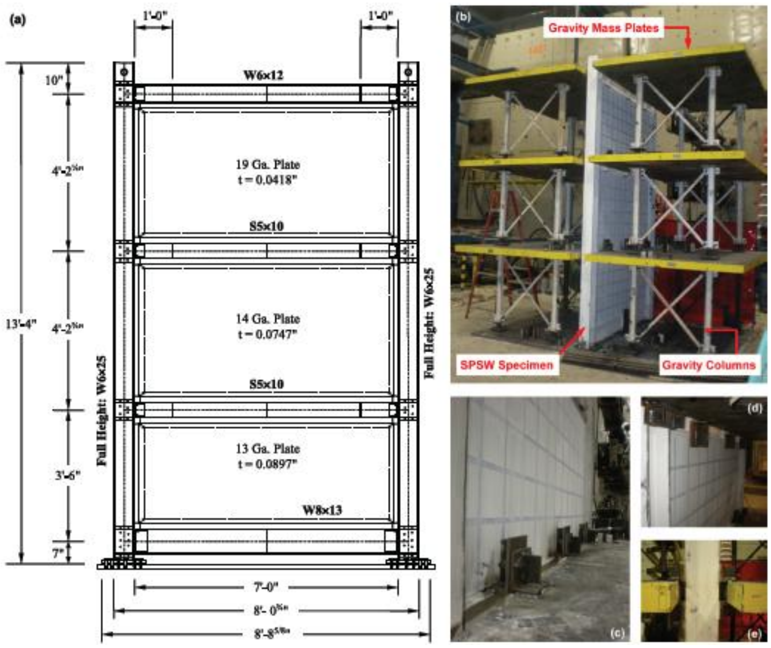

Fig. 3 Three-story SPSW specimen: (a) elevation view; (b) experimental setup with gravity column system; (c) angles for load transfer mechanism; (d) and (e) angles for lateral supports at HBE bottom flange and both sides of VBEs.

IV. ROCKING BEHAVIOR AND NONLINEAR MODELING

In this section, the connection of base rocking system is detached at contact surface for providing free rotation and releasing bending moment demands. It is generally assumed that sliding movement caused by shear is prevented at rocking sections. Therefore, rocking behavior models are nearly nonlinear and elastic and have minor material nonlinearity and dissipating energy resulted from hysteretic responses. Theoretically, such a response is stable until excessive lateral displacement or toe crushing at the base degrades lateral strength and afterward instability will be probable; even although such a behavior is stable, it does not produce enough hysteretic energy to meet seismic demands. To overcome such deficiency in response, it is necessary to add a dissipation energy device. The location and type of an appropriate energy dissipation device should be also investigated. However, these issues were not the subject of the current research. Employing any dissipation energy device will cause change in the hysteretic response from nearly elastic nonlinear to flag-shaped behaviors. In addition, a tool is usually designed for getting the structure back to the original position after earthquakes. The post-tensioning cables have been widely used to improve both characteristics of self-centering and yielding lateral forces. In the current research, all the involved mechanisms needed for rocking section were taken into account over the height of shear walls. Fig. 4(a) and (b) shows physical multi-rocking section and provides a numerical nonlinear model. In order to model the rocking behavior of shear wall, an equivalent beam–column element with the properties of actual wall is defined and a horizontal rigid beam element is used at the contact surface. The locations of such mild steel rebars and the assigned stress–strain curves are shown in Fig. 4(a) and (b).

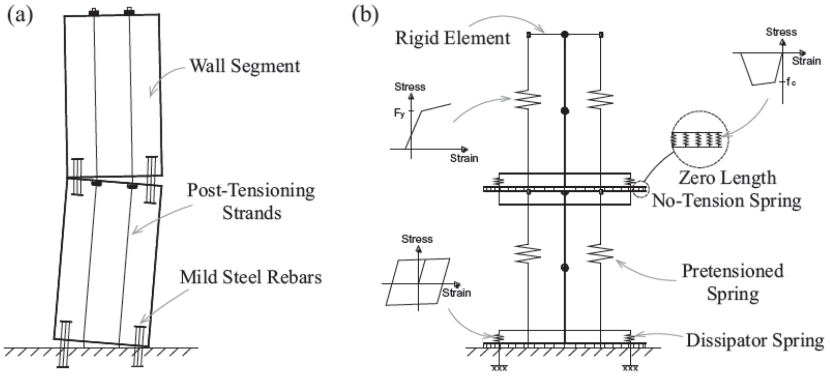

Fig. 4 Multiple rocking system (a) physical model, (b) analytical model and component behavior.

As shown in Fig. 4(b), the 1D spring element was used for modeling the post-tensioning strands. In the current research, it was assumed that all the post-tensioning tools connect panels vertically from the top of the upper panels to the top of lower one and no horizontal movement is allowed between two panels at the contact surface. From the physical position point of view, their locations and effects on behavior were first investigated; then, the reported results were based on the best suggested location. The nonlinear stress–strain curve of the strands is shown in Fig. 4(b).

It should be noted that, in order to avoid complexity in the analysis and results, in-plane shear behavior of wall segments was assumed to be elastic and no shear displacement was taken in rocking sections. Elastic behavior was defined for out-of-plane behavior.

V. CONCLUSIONS

Through the analysis of experimental data, the restoring force models steel fiber reinforced concrete shear walls are discussed and the conclusions can be made as follows.1- Based on the experimental skeleton curves of steel fiber reinforced concrete shear walls, the feature points, which included the crack point, the yield point, the ultimate load point and the ultimate displacement point, were analyzed. Using the regression method, the formulas of the above four points and corresponding stiffness were calculated to get the expression of the skeleton curves. 2- According to the characteristics of the experimental hysteretic loop, the whole hysteretic loop was divided into four feature points and eight segments. The four feature points were the fixed point, stiffness mutation point, peak point and pinched point. The values of the four feature points and the stiffness of the eight segments can be calculated by analyzing the key points of the test hysteretic loops.

In the future, the development of FE models of complete buildings will be studied. In the case of a building with several stories, the simplified model of shear wall should be able to account for the overturning phenomenon (the refined model already can).In the case of a single story structure, the main outlook of this work is obviously the development of a FE model and its confrontation to experimental data, which is currently ongoing research. An experimental study that comprised quasi-static cyclic tests and shake table tests of twenty walls was conducted to provide information on the effect of lightweight and low-strength concrete on shear strength and displacement associated to different limit states of thin lightly-reinforced shear walls.

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