Investigate the use of steel plate shear walls in buildings

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Abstract— *For construction activity normally we use materials as concrete and steel to build up buildings. In concrete there are different constituents like aggregate, cement, sand, admixtures, water and plasticizers from which we can achieve the characteristic strength according to our structure. We also use various grades of steel like MS, TOR, TMT, depending on the type of structure. The strip model developed by others and implemented in a Canadian Standard to model steel plate shear walls (SPSW) is used to develop, investigate, and quantify, through plastic analysis, the various possible collapse mechanisms of SPSW. Comparisons of experimentally obtained ultimate strengths of steel plate shear walls and those predicted by plastic analysis are given and reasonable agreement is observed. We are going to study the Performance of Steel Plate Shear Wall during Past Earthquakes events. In this paper we will also study the testing on steel plate and also the different case study of SPSW system.*

Keywords: *Steel plate sheer wall, testing on SPSW, strip model, Deflection*

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1 Introduction

The main function of steel plate shear wall is to resist horizontal story shear and overturning moment due to lateral loads. Steel plate shear walls (SPSW) can be use as a lateral load resisting system for buildings. A typical SPSW (Fig. 1) consists of stiff horizontal and vertical boundary elements (HBE and VBE) and infill plates.

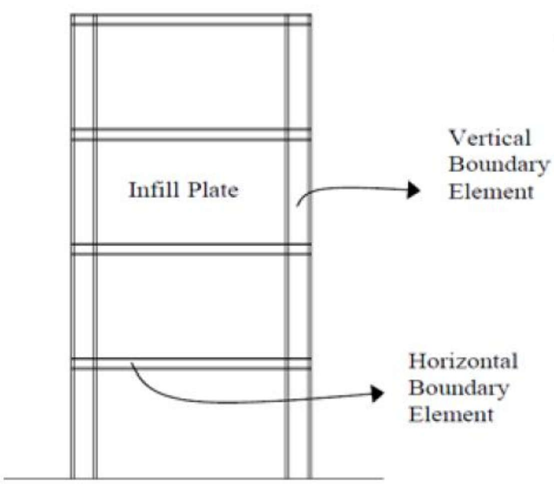

Figure 1: Typical Steel Plate Shear Wall

The resulting system is a stiff cantilever wall which resembles a vertical plate girder. There are two types of SPSW systems, which are the standard system and the dual system. (Fig.2). In the standard system SPSW is used as the sole lateral load resisting system and pin type beam to column connections are used in the rest of the steel framing. In the latter system, SPSW is a part of a lateral load resisting system and installed in a moment resisting frame. In this case forces are resisted by the frame and SPSW. SPSW can have stiffened or unstiffened infill plates depending on the design philosophy.

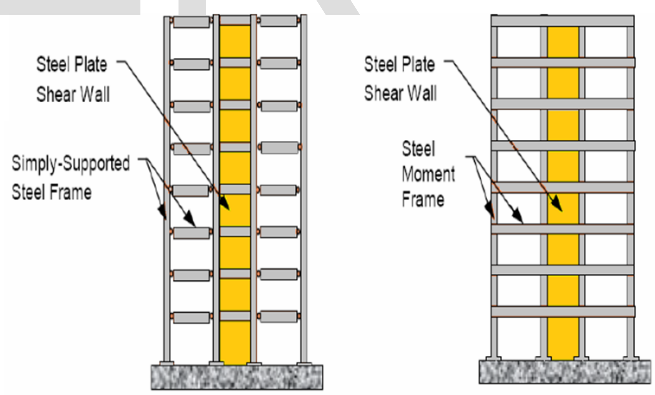

Figure 2: (a) Standard SPSW system (b) Dual SPSW system

Earlier designs used stiffeners to prevent buckling of infill plates under shear stresses. On the other hand, more recent approaches rely on post buckling strength. Based on the work of Wagner, it has been known that buckling does not necessarily represent the limit of structural usefulness and there is considerable post buckling strength possessed by restrained unstiffened thin plates. At the onset of buckling, this occurs at very low lateral loads, the load carrying mechanism changes from in-plane shear to an inclined tension field. The additional post buckling strength due to the formation of tension field can be utilized to resist lateral forces. Due to the cost associated with stiffeners most new designs employ unstiffened infill

International Journal of Scientific & Engineering Research Volume ƛ0(ÚÚÜÌ 0)ÈÕÜÈÙàıl ɣ ł
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plates.

Design recommendations for SPSW systems are newly introduced into the AISC Seismic Provisions for Structural Steel Building. These provisions basically present guidelines on the calculation of lateral load capacity of SPSW as well as recommendations on the seismic characteristics. Lateral load resisting capacity of SPSW systems has been studied experimentally and numerically in the past and procedures for computing the nominal capacity are developed. These experimental and analytical studies led to the development of code provisions [Astaneh, 2001].

The high rise buildings mostly fail due to bucking therefore we have use to SPSW system for the lateral force resisting system. In this paper we will study the behaviour of SPSW. [Jadhav and patil, 2014]

Qu et al in 2008 testing of full-scale two-story steel plate shear wall with reduced beam section connections and composite floors. A two-phase experimental program was generated on a full-scale two-story steel plate shear wall with reduced beam section connections and composite floors, to experimentally address the replaceability of infill panels following an earthquake and the seismic behavior of the intermediate beam. In Phase I, the specimen was pseudodynamically tested, subjected to three ground motions of progressively decreasing intensity. The buckled panels were replaced by new panels prior to submitting the specimen to a subsequent pseudodynamic test and cyclic test to failure in Phase II. It is shown that the repaired specimen can survive and dissipate significant amounts of hysteretic energy in a subsequent earthquake without severe damage to the boundary frame or overall strength degradation.

Alinia and Sarraf Shirazi in 2009 were investigated on the design of stiffeners in steel plate shear walls. They describes a numerical investigation to provide a practical design method for stiffening thin steel plate shear walls. The procedure considers one-sided transverse and longitudinal flat stiffeners located in various arrangements on shear plates which effectively divides the plate into subpanels and expands tension fields across the infill walls. The results obtained from several nonlinear static analyses are employed to draw applicable empirical relationships for evaluating optimal dimensions of stiffeners. The procedure also ascertains the effects of optimised stiffeners on the postbuckling behaviour and ultimate load bearing capacity of stiffened shear walls.

Alinia et al in 2009 studied on Nonlinearity in the postbuckling behaviour of thin steel shear panels. Their paper discusses the nonlinear postbuckling path of thin shear panels, emphasizing on (i) an intermediate limit state when panels experience first yield points and (ii) the growth pattern of yield zone. It is also observed that the postbuckling behaviour of shear panels is mostly governed with geometrical nonlinearity.

Chen and Jhang in 2011 were investigated on Experimental study of low-yield-point steel plate shear wall under in-plane load. They describes the study of the low-yield-point (LYP) steel plate shear walls under in-plane load. In the LYP steel plate shear wall system, LYP steel was selected for the steel plate wall while the boundary frame was constructed by the high strength structural steel. A series of experimental studies examined the inelastic shear buckling behavior of the LYP steel plate wall under monotonic in-plane load. The effects of width-to-thickness ratio on the shear buckling of LYP steel plates were examined. The stiffness, strength, deformation, and energy dissipation characteristics were investigated by performing cyclic loading tests on the multistorey LYP steel plate shear walls. Excellent deformation and energy dissipation capacity were obtained for all specimens tested. The LYP steel plate shear wall system is able to exceed 5% of storey drift angle under lateral force.

Topkaya and Atasoy in 2009 investigated the Lateral stiffness of steel plate shear wall systems. In their paper, two alternative methods are developed. The first one is an approximate hand method based on the deep beam theory. The classical deep beam theory is modified in the light of parametric studies performed on restrained thin plates under pure shear and pure bending. The second one is a computer method based on the truss analogy. Stiffness predictions using the two alternative methods are found to compare well with the experimental findings. In addition, lateral stiffness predictions of the alternate methods are compared against the solutions provided using finite element and strip methods of analysis for a class of test structures. These comparisons reveal that the developed methods provide estimates with acceptable accuracy and are simpler than the traditional analysis techniques.

Jahanpour et al in 2012 were investigated on Seismic behavior of semi-supported steel shear walls. In their paper, the interaction between the wall plate and the surrounding frame is investigated experimentally for typical SSSW systems in which the wall-frame has a bending dominant behavior. Based on the possible story failure mechanisms a simple method is proposed for design of the floor beams. A quasi static cyclic experimental study has been performed in order to investigate the collapse behavior of the wall-plate and surrounding frame. Furthermore the test setup has been developed in order to facilitate standardized cyclic tests corresponding to those described by ECCS. From this investigation hysteresis loops are obtained and it is seen that pinching occurs in the loops, since the plate system is un-stiffened. The results of the experimental study are compared to the results obtained using the proposed analytical method. As predicted the study shows that the frame has the capability of developing a tension field in the wall plate, so that the wall plate yields before the frame.

Kurata et al in 2012 examined the Steel plate shear wall with tension-bracing for seismic rehabilitation of steel frames. A rehabilitation technique that utilizes a thin steel plate as a supplemental shear wall system for small, low rise steel structures is described. In the proposed system, the plate and surrounding boundary elements are installed in the middle of the bay, separate from existing columns. This geometry intends to eliminate the need to strengthen the existing columns, as these typically would have been designed only for the combined forces of gravity and wind. The system employs supplemental elements as tension-only elements to speed up the construction work and to enforce strict capacity design principles (i.e., overstrength is capped). A prototype system was designed using a hierarchical flowchart and a simplified analysis model, and its performance was evaluated through large scale testing.

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The system achieved stable hysteretic behavior without showing major strength deterioration until large story drifts were reached. A high-fidelity FE model of the system was also developed to reproduce the experimental behavior. The model well traced the test results and was used as a tool for validating the effectiveness of the proposed system geometry.

Vian et al in 2009 investigated on special perforated steel plate shear walls with reduced beam section anchor beams. II: analysis and design recommendations. They present a comparison of analytical and experimental results from an investigation of specially detailed ductile perforated steel plate shear walls (SPSWs). These SPSWs had low yield strength steel infill panels, anchor beams with reduced beam sections connections, and were specially detailed to accommodate utility passage through the wall while remaining ductile. Finite-element models of full SPSWs and subelement strips are developed using the finite element software package ABAQUS/Standard to facilitate a comparison with experimental results and to investigate the influence of localized distribution of panel stress and strain between perforations. Based on the analytical and experimental results, recommendations for the design of these special detailed perforated SPSWs are presented.

2 Analysis And Design of Steel Plate Shear Walls - CAN/CSA S16-01

The CAN/CSA S16-01 seismic design process for steel plate shear walls follows the selection of a lateral load resisting system (i.e., shear walls with rigid or flexible beam-to- column connections), calculation of the appropriate design base shear, and distribution of that base shear along the building height by the usual methods described in building codes. Preliminary sizing of members is done using a model that treats the plate at each story as a single pin-ended brace (known as the equivalent story brace model) that runs along the diagonal of the bay (Fig. 3a). From the area of the story brace, *A*, determined from that analysis, an equivalent plate thickness can be calculated using the following equation based on an elastic strain energy formulation [Thorburn et al, 1983]:

$$t = \frac{2A\sin\theta\sin 2\theta}{L\sin^2 2\alpha} \qquad (1)$$

where Θ is the angle between the vertical axis and the equivalent diagonal brace, *L* is the bay width, and α is the angle of inclination of the principal tensile stresses in the infill plate measured from vertical, which is given by:

$$\tan^4\alpha = \frac{1+\frac{tL}{2A_c}}{1+th_s\left(\frac{1}{A_b}+\frac{h_s^3}{360 I_c L}\right)} \qquad (2)$$

where *t* is the thickness of the plate, *Ac* and *Ic* are respectively the cross-sectional area and moment of inertia of the bounding column, *hs* is the story height, and *Ab* is the beam cross-sectional area [Timler et al, 1983]. CAN/CSA S16-01 also provides the following equation to ensure that a satisfactory minimum moment of inertia is used for columns in steel plate shear walls to prevent excessive deformation leading to premature buckling under the pulling action of the plates [Kuhn et al, 1952]:

$$I_c \geq \frac{0.00307\, t h_s^4}{L} \qquad (3)$$

Once the above requirements have been satisfied, a more refined model, known as the strip or multi-strip model, that represents the plates as a series of inclined tension members or strips (Fig. 3b) is required for the analysis of steel plate shear walls (with α as calculated by Eq.(2)). Through comparison with experimental results, the adequacy of the strip model to predict the ultimate capacity of SPSW has been verified in several studies such as Driver [Driver et al, 1998].

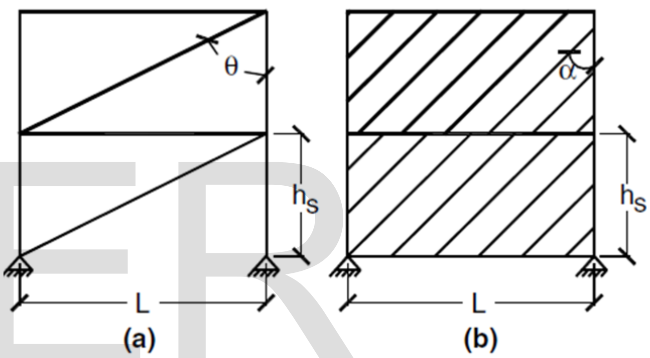

Figure 3 (a) Equivalent Story Brace Model (b) The Strip Model [Jeffrey et al, 2004]

3. The strip model for the design of SPSWs

The strip model proposed by Thorburn et al is widely used for the analysis of SPSW frames. In this model, two series of inclined pin-end truss members as shown in Fig. 4 are used to repre- sent the cyclic tension field action in the steel plate.

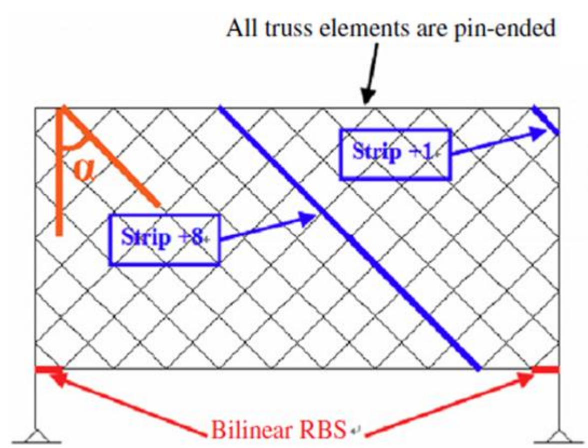

Figure 4. The strip model

The incline angle α of the strip can be calculated from the equation (2). In a typical interior panel, the upward and the downward components of the tension field will nearly balance one another. Thus, in Eq. (2), the beam flexural strain energy is not included. In past research [Driver et al, 1998 and Shishkin et al , 2009], it has been found that the capacity of the SPSWs is not especially sensitive to the angle of inclination. In this study, a more accurate method of computing the incline angle of the strips including the strain energy of all boundary beams has been developed [Tsai et al, 2006], and it is presented in Eq. (4):

$$\tan^4\alpha = \frac{\frac{h}{tL} + \frac{h}{2A_c} + \frac{L^3}{360I_b}}{\frac{h}{tL} + \frac{h_s^2}{A_bL} + \frac{h_s^5}{360I_cL^2}} \qquad (4)$$

where I_b is moment of inertia of the boundary beams. It has been found that the incline angle α computed from Eq. (4) is more accu- rate than Eq. (2) in predicting the tension field direction observed in the tests of large-scale single-story SPSWs [Lin et al, 2004].

4 Conclusion

By the reviewing above papers we can conclude that the steel plate can be used for high rise building to dynamic evaluation of lateral force resisting system. The steel plate shear wall system is depending on the steel what we used and it depends on design specification of building. Also by using SPSW system the stiffness of the building is increased. Then we can adopt this system for multistoried building. Also The strip model can be effectively applied to study the deformation demands imposed on the various parts of the steel infill. The analytical results show that the tension field action is substantially more pronounced in the center of an SPSW than in the corner.

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