investigation behaviour thin steel plate shear walls

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ABSTRACT :

Steel plate shear walls have been used for building design in both North America and Japan, but with different design and detailing strategy. One approach employs heavily stiffened steel plate shear walls to ensure that the wall panel achieves its full plastic strength prior to out-of-plane buckling, An alternative approach is to use slender unstiffened steel wall plates, which exhibit nonlinear behavior at relatively small story drifts as they buckle out of plane. In this paper, a nonlinear finite element model of a one single- and a four-story thin (unstiffened) steel plate shear walls were developed, then by using saved energy in plate and frame of the thin steel plate shear walls, portion of frame and plate from total stiffness of the steel plate shear walls were separated and with varing the columns flexural stiffness, variations of stiffness of the thin steel plate shear wall, frame and plate; effect of interaction between frame and plate on frame and plate stiffness; and also variations reactions in the plate length edge connection to foundation are considered. Results are indicated that increasing of inertia moment of the columns is effected considerably on behaviuor the thin steel plate shear wall.

KEYWORDS: steel, plate, frame, wall, stiffness, column

1. INTRODUCTION:

During the past few decades, research has demonstrated that steel plate shear walls can act as an effective and economical lateral bracingsystem. In particular, steel plate shear walls will respond toseismically induced loading with a high degree of stiffness, stable load versus deflection behaviour, and a capacity for significant energy dissipation (Driver et al. 1998).

Steel plate shear walls have been used for building design in both North America and Japan, but with different design and detailing strategy. A steel plate shear wall assemblage consists of columns intersected at the floor levels by beams, thereby forming a vertical stack of rectangular bays that are then in-filled with steel plates. The connections between the beams and the columns can range from simple to moment-resisting. For steel infill panels, One approach employs heavily stiffened steel plate shear walls to ensure that the wall panel achieves its full plastic strength prior to out-of-plane buckling. Thus stiffened, the wall panels can resist large lateral forces and dissipate earthquake-induced energy ~Takahashi et al. 1973. Such systems are current practice in Japan, where the high-fabrication cost is tolerated in order to guarantee small transverse deformations and stable ~fat! hysteresis loops out to large story drifts. An alternative approach, as studied by Mimura and Akiyama ~1966!, Caccese et al. 1993, and Driver et al. 1998, is to use slender unstiffened steel wall plates, which exhibit nonlinear behavior at relatively small story drifts as they buckle out of plane. This response is accompanied by significant pinching in the hysteresis response, but when properly detailed, the wall strength does not decrease, as tension field action develops and is sustained through highductility demands. This type of system is more popular in North America, to avoid the high-fabrication cost of stiffened walls. Summaries of multinational research on steel plate shear walls, including design models and procedures, are documented in reports by Astaneh-Asl 2001 and Kulak et al. 2001.

In this paper, A nonlinear finite element model of a one single- and a four-story thin steel plate shear walls were developed using the nonlinear program ANSYS 5.4, and are elastical analysed, then by using saved energy in plate and frame of the thin steel plate shear walls, portion of frame and plate from total stiffness of the steel plate shear walls are separated and with varing columns flexural stiffness, variations of stiffness of the thin steel plate shear wall, frame and plate, effect of interaction between frame and plate on frame and plate stiffness and also variations reactions in plate length edge connection to the foundation are considered.

2- Investigation exact of finite element method

a singel story thin steel plate shear walls was tested at Univ. of British Columbia [Lubell 1997] was modeled in the nonlinear program ANSYS 5.4, and comparison of results were indicated that the finite element method is able to properly predict behavior of a thin steel plate shear walls, as shown in Fig. 1.

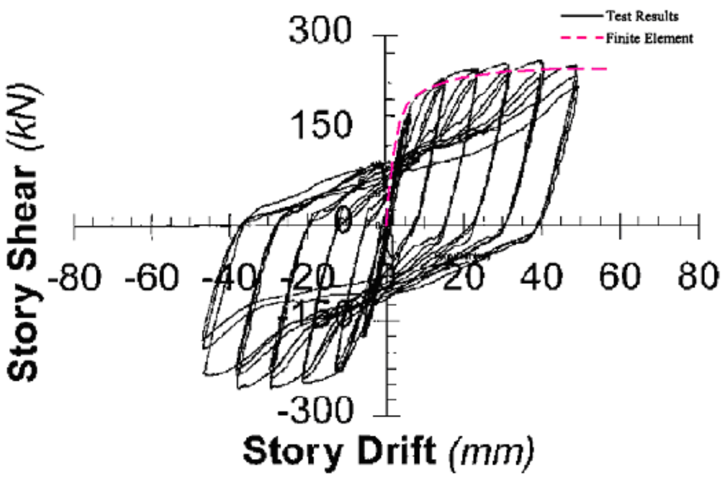

Fig. 1. Comparison of the finite element model prediction and experimental results from tests performed at Univ. of British Columbia [Lubell 1997]

3- FINITE-ELEMENT MODEl

The numerical model for the a single and four-srory steel plate shear wall was develped using the nonlinear program ANSYS 5.4. A 45 x 30 element mesh was used for any panel. The model was loaded individually with horizontal force 15ooKN at each floor level. the deformed configuration a single- and a four-story thin steel plate shear wall when loaded at four floor level and is shown in Fig. 2.

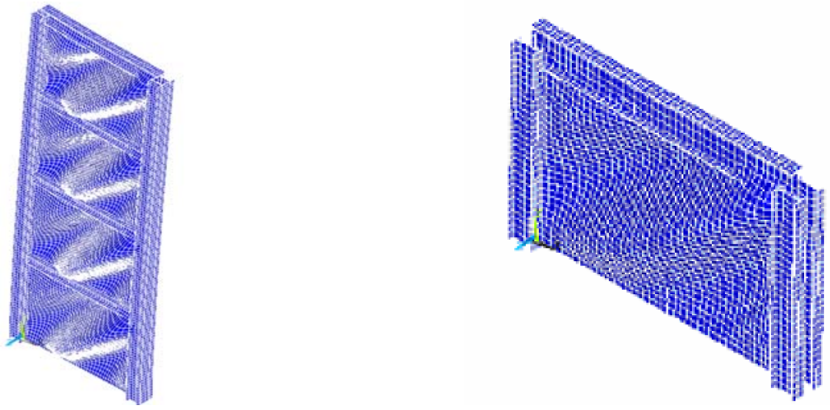

Fig. 2. a single- and a four-story thin steel plate shear wall when loaded

4- Geometry

The infill plates are considered to be connected directly to the beams, columns and foundation. The columns sections are 2IPE that are varied and The beams sections are IPE 550. Moment connections are considereand for all beam-to-column joints.

5- Elements

The beam and columns are modeled using three-node quadratic beam elements (ANSYS 5.4 beam189). This element allows biaxial bending, axial stretching and warping of the cross section and includes linearly elastic transverse shear deformations according to the Thimoshenko beam theory (Timoshenko and Goodier 1970). The shear wall infill plates are modeled using four-node quadratic shell elements (ANSYS 5.4 shell 181). This element has three rotational and three translational degrees of freedom at each node.

6- Mechanical properties of material

A Plate of thin steel plate shear wall normally buckles much sooner then it would yield. Since the elastic post-buckling behaviour of the plate is studied, elastic behaviour of steel is assumed in this work with the following specifications :

$$\mathrm{E} = 206 \, {}^{KN}\!/_{mm^2}$$

$$\mu = 0.3$$

7- STIFFNESS OF FRAME AND PLATE

Because of complex behavior of the thin steel plate shear wall, up to now exactly theory are not present for this purpose that stiffness frame and plate are accurately seprated from total stiffness of the thin steel plate shear wall. In this paper by using saved energy in the frame and the plate of the steel plate shear walls, can portion stiffness of the frame and the plate from total stiffness of the steel plate shear walls are separated. saved energy amount at the frame and the plate the thin steel plate shear wall modled are obtained by the nonlinear program ANSYS 5.4. if relation between force and displasment at elastic condation in the thin steel plate shear wall is linearly assamed, stiffness of the thin steel plate shear wall K_W is obtained from :

$$K_W = \frac{P}{\Delta} \tag{7.1}$$

saved energy at the frame of the thin steel plate shear wall is obtained from :

$$U_F = \frac{K_F \Delta^2}{2} \tag{7.2}$$

And therefore, stiffness of the frame of the thin steel plate shear wall is :

$$K_F = \frac{2U_F}{\Delta^2} \tag{7.3}$$

And stiffness of the plate of the thin steel plate shear wall is obtained from ;

$$K_P = K_W - K_F = \frac{P}{\Delta} - 2\frac{U_F}{\Delta^2} = \frac{(P\Delta - 2U_F)}{\Delta^2} \quad (7.4)$$

8- Solution strategy

The nonlinear nature of the problem dictates that an iteration scheme be used to achieve successive solutions along the equilibrium path. in general, ANSYS uses a load control Newton-Raphson and Modified Newton-Raphson scheme as a default solution strategy.The Newton-Raphson strategy is used at low load levels up to the point where a solution can no longer be achieved. Subsequently, the Modified Newton-Raphson method is used to explore higher load levels. In all cases, the step sizes used must be small in order to achieve convergence.

9- RESULTS OF FINITE ELEMENT ANALYSES

For the single-story thin steel plate shear wall, curve of stiffness of frame, plate and the thin steel plate shear wall for different values of inertia moment columns is shown at in Fig. 3. variations of inertia moment of columns, when that values of inertia moment is low, greater effect on variations of stiffness of the plate is exerted. when that inertia moment columns is very increased, beacase which that diagonal tention force is extremely developed, variations of inertia moment columns is not effected on variation of stiffness of the plate.variations curve of a reaction of vertical (F_Y) and horizontal (F_X) of the plate on the foundation for each node are shown In Fig.4 and Fig. 5. by increasing inertia moment of columns, curve of variations of the reactions is more uniformed that is indicated by increasing inertia moment of columns, Distribution of stress and strain at surface of plate are more uniformed that to cause increase stiffness of the plate.

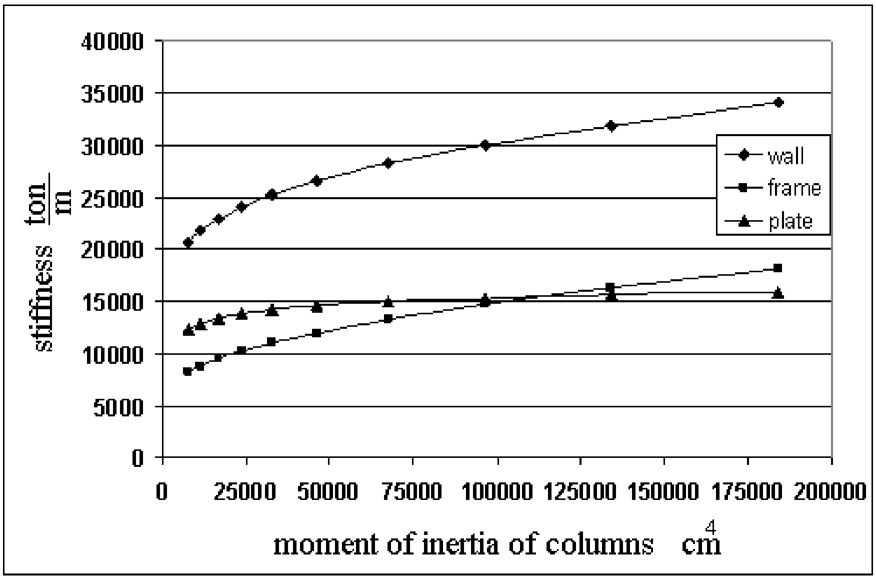

Fig. 3.Stiffness of frame, plate and the thin steel plate shear wall for model of the single-story

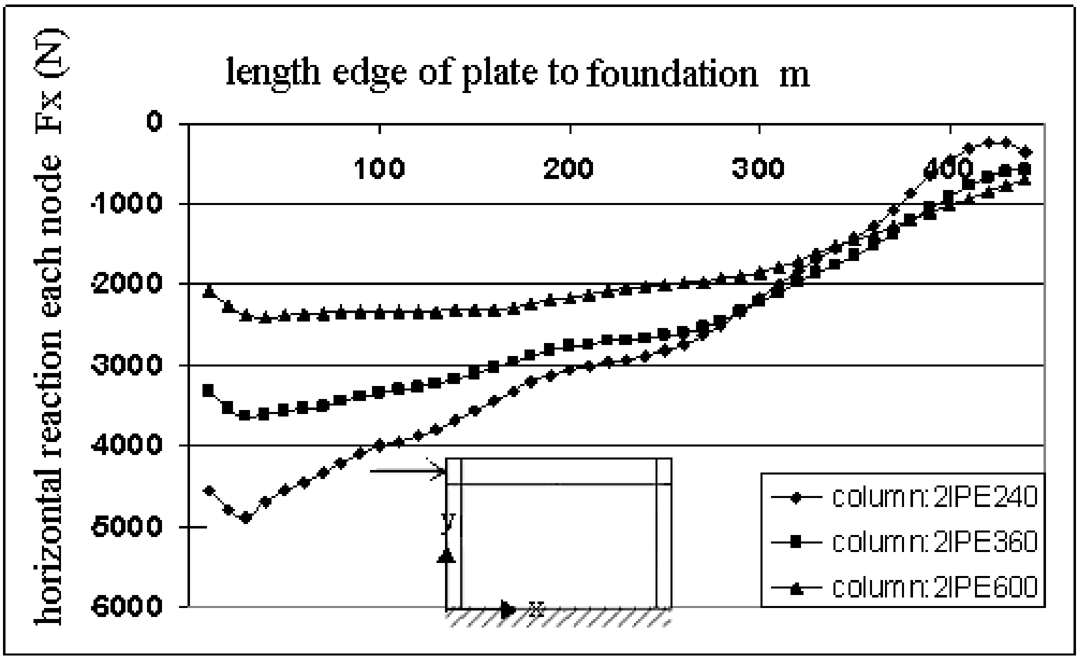

Fig.4. variations Curve of horizontal reaction (F_X) of plate to foundation for each node

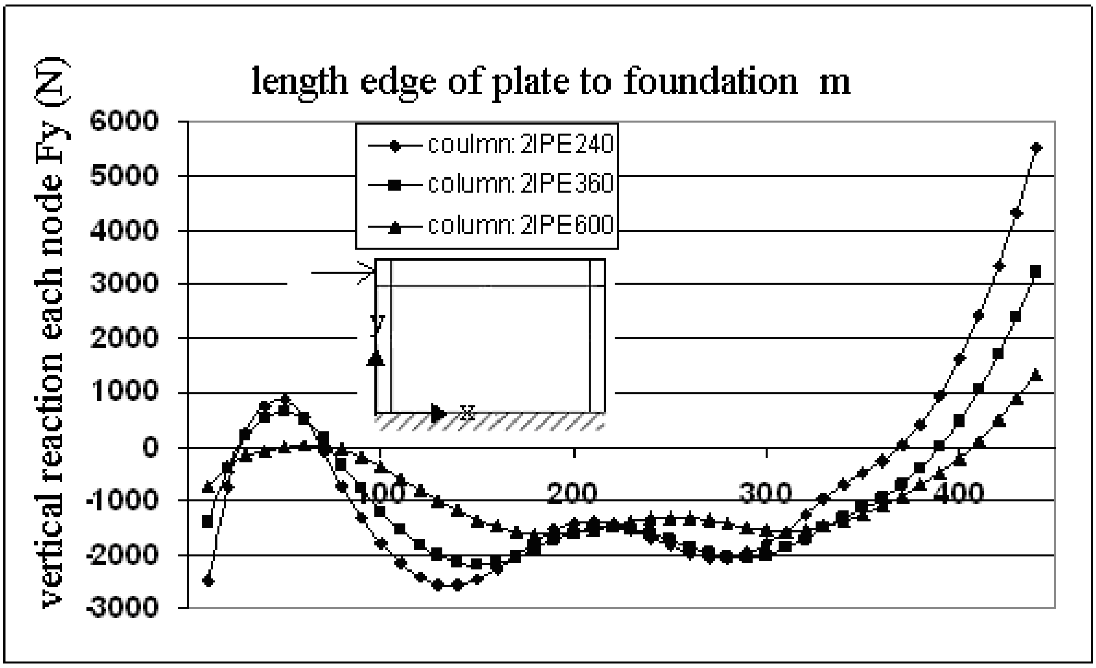

Fig. 5.variations Curve of vertical reaction (F_Y) of plate to foundation for each node

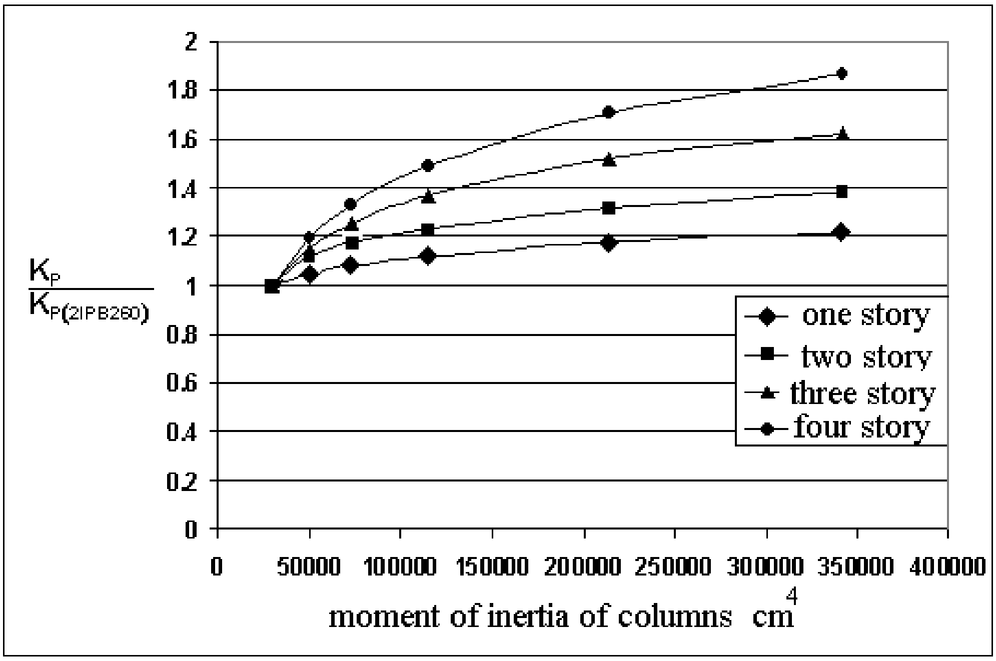

Fig. 6.stiffness variations curve of plate versus different values of inertia moment columns

For four story the thin steel plate shear wall, stiffness of plate versus stiffness variations Curve of plate for different values of inertia moment columns with minimum inertia moment columns for different storyis shown at in Fig. 6. This curve is indicated, increasing inertia moment of columns are effect geartly on increase stiffness of plate at upper story and variations of inertia moment columns, when that values of inertia moment is low, effect geartly on variations of stiffness of the plate at upper story.

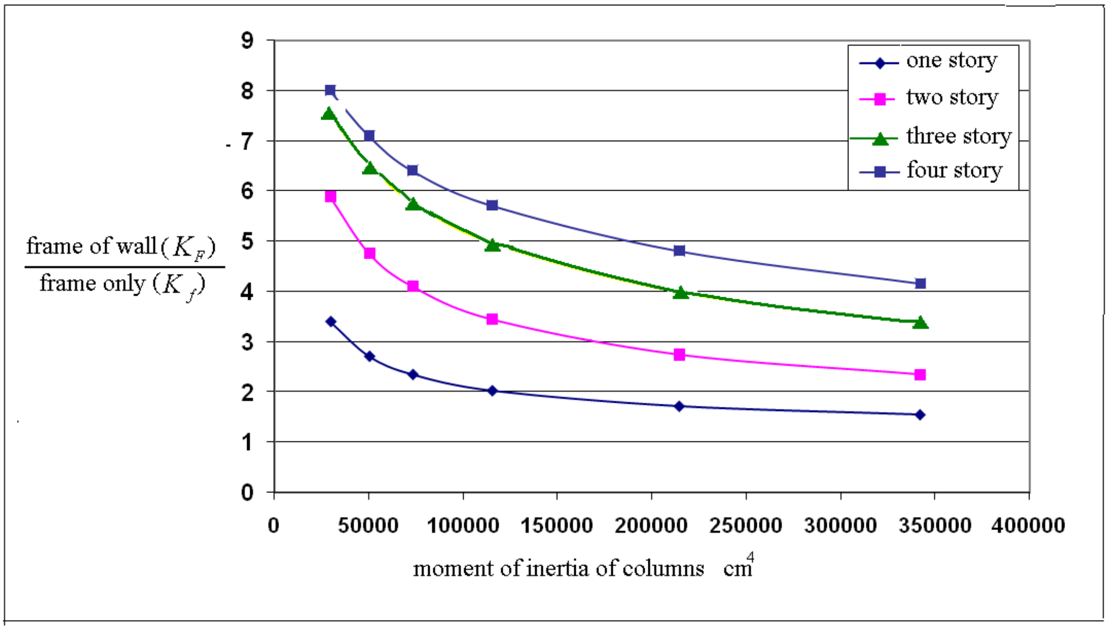

Fig. 7. variations curve of $\frac{K_F}{K_f}$ versus different values of inertia moment columns

Ratio of stiffness of frame K_F in the thin steel plate shear wall to stiffness of frame only K_f for different the values of inertia moment columns is shown in Fig. 7. for entire of story, this ratio for minimum values of inertia moment columns is maximum and by increasing inertia moment of columns, this ratio is decreased that indicates effect of interaction between plate and frame on increase stiffness of frame with increasing inertia moment of columns is decreased. at upper story ratio K_F / K_f is increased that indicates effect of interaction between plate and frame on increase stiffness of frame of the thin steel plate shear wall at upper story is increased.

10- SUMMARY

A single and four-srory steel plate shear wall was modeled using the finite-element methods and The models was loaded individually with horizontal force 1500 KN at each floor level. Then models was elastical analysed, and by using saved energy in frame and plate of the thin steel plate shear walls, portion stiffness of frame and plate from total stiffness of the thin steel plate shear walls were separated. In addition distribution curve of variations of reaction of vertical and horizontal of plate to foundation for each node are shown.

11- CONCLUSIONS

by varing inertia moment of the columns, stiffness of plate is varied that by increasing inertia moment of the columns, tensity of this variations is decreases. variations of stiffness of plate by varing inertia moment of columns at upper story is increased. increasing inertia moment of the columns, Distribution curve of variations of reactions is more uniformed. at upper story, effect of interaction between plate and frame on increase stiffness of frame of thin steel plate shear in comparison with only frame wall is increased and inertia moment of the columns, this effect for each story is decreased.

12- APPENDIX . NOTATION

The following symbols are used this paper :

E = elasticity modulus;
F_X = horizontal reaction of plate to foundation for each node;
F_Y = vertical reaction of plate to foundation for each node;
K_W = thin steel plate shear wall stiffness ;
K_F = frame stiffness in thin steel plate shear wall;
K_f = frame only stiffness;
K_P = plate stiffness;
P = horizontal force;
U_F = saved energy in frame of thin steel plate shear wall;
Δ = deflection of thin steel plate shear wall;
μ = Poisson's ratio.

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