IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 3 Issue 6, June 2016
ISSN (Online) 2348 – 7968 | Impact Factor (2015) - 4.332
www.ijiset.com

The Optimization of Shear Wall Displacement by Using Longitudinal and Transversal Stiffeners

Farhad Riahi[1*], Naser Zandi[1], Mansour Darvishi[1]

1- Young Researchers and Elite Club, Sardasht (Mahabad) Branch, Islamic Azad University, Sardasht (Mahabad), Iran

Abstract__ Steel shear wall is a lateral bearing system. One of the ways to improve buckling behavior of steel shear walls is to use stiffeners. The stiffeners lead to improve the performance of steel shear walls by preventing them from buckling before yielding. Attaining to a desirable layout of horizontal and vertical stiffeners that simultaneously is able to ensure the mentioned parameters, is of aims of the present study. Finite element software, ABAQUS, is used in this study because of having the required facilities for studying on the steel shear walls. The specimens are modeled in this software and 10 cm-displacement curves are obtained for two modes of steel walls including; steel walls reinforced by horizontal and vertical stiffeners, and unreinforced shear walls. The results show that the use of stiffeners by significant increase in the amount of energy absorption, strength, and initial stiffness, leads to increase the buckling capacity of shear wall and a desirable combination of above parameters can be achieved by applying an appropriate layout of horizontal and vertical stiffeners.

Keywords: Steel Shear Wall, horizontal and Vertical Stiffeners, Finite Element, Buckling and Post-Buckling capacity

1.Introduction

One of the major issues in design of these plates, is their resistance against local buckling phenomenon which is caused due to excessive force at a point of plate. But when the plates are used for surfaces with high length, this phenomenon can destroy the plate under much less pressure than the buckling pressure and cause collapse for the plate. Buckling is one of the most complex phenomena in solid mechanics. This phenomenon threatens structures that are very thin and are located in areas under compressive force or compressive stresses. Since this study is conducted in finite element form and with an innovative method, the used numerical analysis method is constructed based on the following assumptions. Considered assumptions in the numerical analysis of samples are:

1. After bending, the cross-section of the panel remains without deformation.
2. Cross-section of the middle line remains elastic.
3. The proportion of the primary to secondary deformations of the hinge is plastic.
4. The height of the stiffeners mounted on plates using relations associated with Orthotropic plates theory, is adjusted the way so that the total and local buckling modes synchronize with each other.

2. Background

[1]Ph.D. Student, E-mail:riahi.farhad@gmail.com
* Author for Correspondence

Timoshenko (1925) explored the buckling of uniformly compressed rectangular plates that are simply supported along two opposite sides perpendicular to the direction of compression and having various edges along the other two sides. The various boundary conditions considered include SSSS, CSCS, FSSS, FSCS, CSES (S - simply supported edge, F - free edge, C - clamped or built-in edge and E - elastically restrained edge). The theoretical results were in good agreement with experimental results obtained by Bridget et al. (1934). Lundquist and Stowell (1942) used the integration method to solve ESES plates by assuming that the surface deflection was the sum of a circular arc and a sine curve. They also discussed the critical load of ESFS plates by both integration method and the energy method by assuming that transverse deflection was the sum of a straight line and the cantilever deflection curve. Walker (1967) used the Galerkin's method to give accurate values of critical load for a number of the edge conditions as mentioned before. He also studied the case of ESFS plates. Xiang et al. (2001) considered the elastic buckling of a uniaxially loaded rectangular plate with an internal line hinge. Using the Levy's method, they succeeded in presenting the exact solution for many different boundary conditions such as SSSS, FSFS, CSCS, FSSS and SSCS plates. Readers who are interested in plastic buckling of plates may obtain further information from these published papers: Shrivastava (1995), Betten and Shin (2000), Soh et al. (2000), Chakrabarty (2000), Wang et al. (2002) and Wang (2003).we can see that although much work has been done, the buckling of rectangular plates subjected to end and intermediate loads remain hitherto untouched.

3. Finite element models

In this research, two parameters of the height and numbers of stiffeners have been evaluated in the investigation of the shear wall deformation. For this purpose, the variation of the height of rectangular longitudinal stiffener raging from 0.05 m to 0.10 m in two modes 3 and 5, of 5 existing modes in the specimen, is investigated according to the previous research experiences. The stiffeners have been used with numbers of 2, 3, 3, and 6 for reinforcing the walls in two X and Y directions. In this research, a plate with identical dimensions was selected for modeling the specimens.

3.1. Material Properties

Table 1. Material properties

Steel			
M.D (Kg/m^3)	E(MPa)	σ_y (MPa)	ν
7850	200000	180	0.3

where,
M.D = mass density;
E = young's modulus;
σ_y = yield stress; and
ν = Poisson's ratio.

3.2. Wall Properties

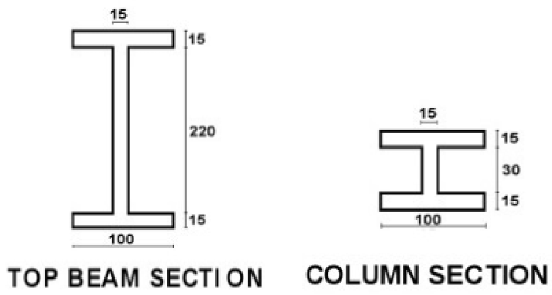
Table 2. Wall properties

Wall properties		
t (m)	h (m)	L (m)
0.007	1.040	1.10

where,

t = thickness;
h = height;
σ_y = yield stress; and
L = Length.

3.3. Column and beam properties



(a) (b)

Figure 1. (a) beam, and (b) column dimensions

3.4. Stiffener Properties for the First Height

Table 3. Stiffener properties for the first height

Stiffener properties			
Direction	t (m)	h (m)	L (m)
X	0.007	0.1	1.10
Y	0.007	0.1	1.14

4. The modeling Assumptions and the Zoning and Naming of Studied Models

It should be noted that in this comparison, according to the use of force control method, the maximum numerical value of shear wall deformation is considered as the result of the study. Hence, with accordance to previous works, the wall is discretized into 4 zones, accordingly, our analysis is performed between the intended elements and joints in each specified zone. In order to investigate the deformation value, the specimen is discretized into 4 zones as shown in figure 2. The specimen has been named as follows:

SW-XY

Where,
SW = shear wall;
X = the number of stiffeners in x direction; and
Y = the number of stiffeners in y direction.

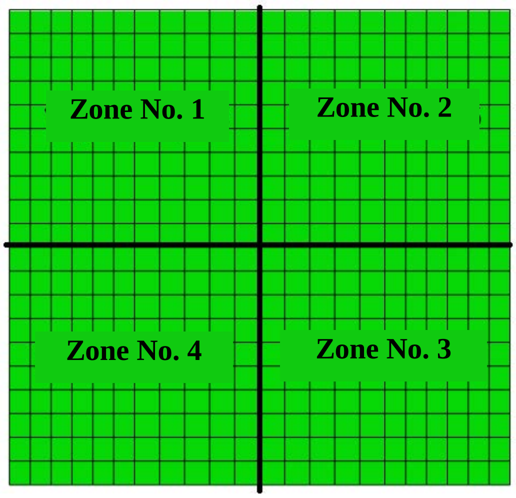


Figure 2. The model zoning

The plate was selected of type S4R. S represents elements of the conventional shell type; number 4 represents the number of joints with first-order function and, R shows the reduced integration for equations solution. The applied load on specimens is considered equal to $\frac{400\text{Kgf}}{\text{m}^2}$. The boundary conditions for two edges of the plate is assumed to be fixed.

5. Results

The effects of the height and number of longitudinal stiffeners in the models were taken into comparison. After loading models and their buckling, the location maximum displacement and its value along with the stress value were calculated and the results are presented in the following table.

Table 4. Shear wall with and without stiffener in the height of 0.1 m and mode 3

The results of group 1 in the height of 0.1 m			
Zone	Model	Stress (N/m^2)	Displacement (m)
No. 1	SW-00	1.8E+08	0.0222303
	SW-11	1.72736E+08	0.0258336
	SW-30	1.8E+08	0.0385135
	SW-03	1.8E+08	0.0471126
	SW-33	1.8E+08	0.0440288

No. 2	SW-00	1.8E+08	0.0407771
	SW-11	1.8E+08	0.0260355
	SW-30	1.78997E+08	0.0385888
	SW-03	1.8E+08	0.0472198
	SW-33	1.8E+08	0.0442216
No. 3	SW-00	1.24276E+08	0.0085801
	SW-11	1.8E+08	0.0192209
	SW-30	1.8E+08	0.0216862
	SW-03	1.8E+08	0.0228578
	SW-33	1.8E+08	0.0202117
No. 4	SW-00	1.8E+08	0.0308156
	SW-11	1.8E+08	0.0143805
	SW-30	1.8E+08	0.0209491
	SW-03	1.8E+08	0.0216949
	SW-33	1.8E+08	0.0198523

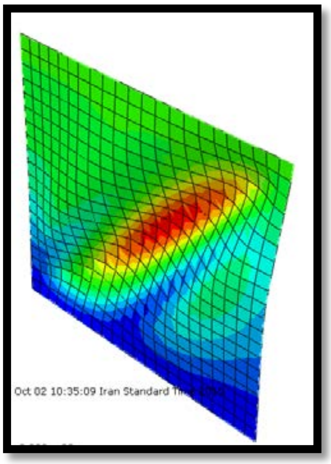


Figure 3. The deformation of shear wall model SW-00 in the mode 3.

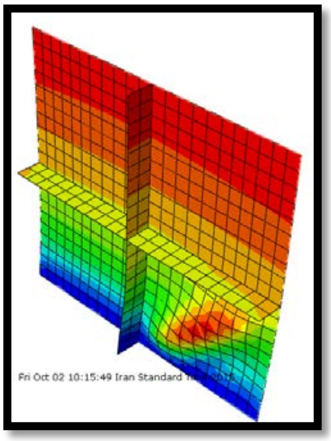


Figure 4. The deformation of shear wall model SW-11 in the mode 3.3

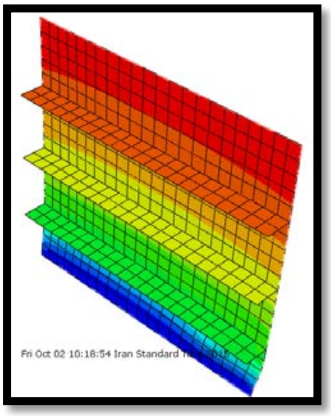


Figure 5. The deformation of shear wall model SW-30 in the mode 3.

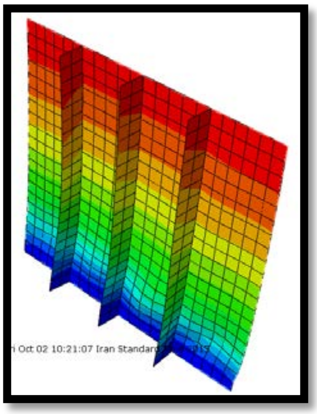


Figure 6. The deformation of shear wall model SW-03 in the mode 3.

6. Investigating Effect of the Number of 0.10-m-height Stiffeners in the Displacement in Mode 3.

Tables 5 to 8 are presented to show the comparison of the displacement of shear wall specimens with a 0.10-m-height stiffener in the mode 3 and in three directions of x, y, and z. A diagram is shown for each table in order to compare three parameters of x, y, z in the models with and without stiffeners.

6.1. Zone No. 1

Table 5. The displacement for zone No. 1, mode 3 and 0.10 m of height

Model	XX	YY	ZZ
SW-00	0.0212639	-0.0021019	0.00613328
SW-11	0.0258033	0.00123147	-0.000218108
SW-30	0.038409	0.00283448	1.27E-05
SW-03	0.0468943	0.00200071	-0.00406394
SW-33	0.0439902	0.00154784	-0.000999168

The displacement of the shear wall in zone 1 for mode 3 (joint 17) and stiffener height of 0.10 m were obtained. The maximum value of displacement is in XX direction in the model SW-03, which is equal to 0.0439902, and the minimum value of displacement is in the model SW-00, equaling to 0.0212639. The maximum value of displacement is in YY direction is also in the model SW-30, which is equal to 0.00283448, and the minimum value of displacement is in the model SW-00, which is equal to -0.0021019. And finally, the maximum value of displacement is in ZZ direction is in the model SW-00, which is equal to 0.00613328, and the minimum value of displacement is in the model SW-03, having a value of -0.00406394. Negative values in the YY and XX direction means the length reduction or displacement in the opposite direction of the axis and positive value indicates the enlargement or displacement in the direction of the axis. The negative value in ZZ direction also shows troughs or displacement in the opposite direction of the axis and positive value indicates bump or displacement in the direction of the axis.

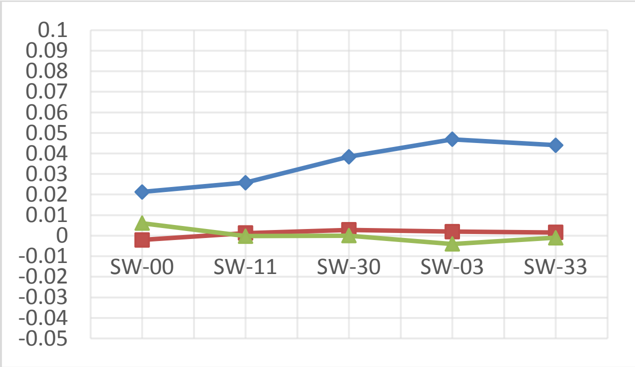


Figure 7. The displacement for zone No. 1, mode 3 and 0.10 m of height

6.2. Zone No. 2

Table 6. The displacement for zone No. 2, mode 3 and 0.10 m of height

Model	XX	YY	ZZ
SW-00	0.0182879	-0.00287459	-0.0363327
SW-11	0.025803	-0.00341893	-0.000599779
SW-30	0.0383843	-0.00396108	-0.000217765
SW-03	0.0469059	-0.00421396	0.00343319
SW-33	0.0441202	-0.00299158	-0.000111933

The displacement of the shear wall in zone 2 for mode 3 (joint 1) and stiffener height of 0.10 m has been calculated. The maximum value of displacement is in XX direction in the model SW-03, which is equal to 0.0469059, and the minimum value of displacement is in the model SW-00, equaling to 0.0182879. The maximum value of displacement is in YY direction is also in the model SW-00, which is equal to -0.002874598, and the minimum value of displacement is in the model SW-03, which is equal to -0.00421396. Finally, the maximum value of displacement is in ZZ direction is in the model SW-03, which is equal to 0.00343319, and the minimum value of displacement is in the model SW-00, having a value of -0.0363327. Negative values in the YY and XX direction means the length reduction or displacement in the opposite direction of the axis and positive value indicates the enlargement or displacement in the direction of the axis. The negative value in ZZ direction shows troughs or displacement in the opposite direction of the axis and positive value indicates bump or displacement in the direction of the axis.

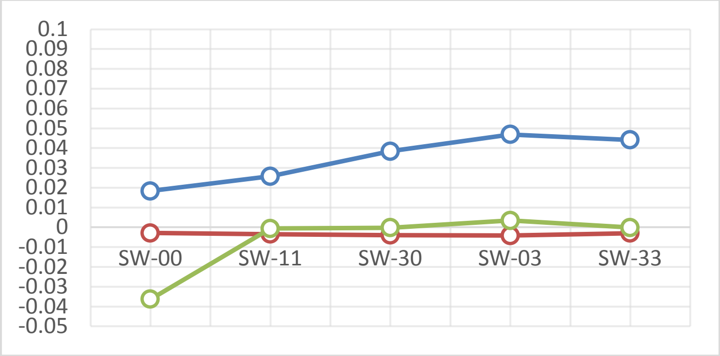


Figure 8. The displacement for zone No. 2, mode 3 and 0.10 m of height

6.3. Zone No. 3

Table 7. The displacement for zone No. 3, mode 3 and 0.10 m of height

Model	XX	YY	ZZ
SW-00	0.00137959	-5.04792E-05	0.00846832
SW-11	0.0124655	-0.00183077	0.0145156
SW-30	0.021365	-0.00348128	-0.00130805
SW-03	0.0224373	-0.00369603	0.00232066
SW-33	0.0200235	-0.00275067	-7.68631E-05

The displacement of the shear wall in zone 3 for mode 3 (joint 60) and stiffener height of 0.10 m were calculated. The maximum value of displacement is in XX direction in the model SW-03, which is equal to 0.0224373, and the minimum value of displacement is in the model SW-00, equaling to 0.00137959. The maximum value of displacement is in YY direction is also in the model SW-00, which is equal to -5.04792 E-05, and the minimum value of displacement is in the model SW-03, which is equal to -0.00369603. Consequently, the maximum value of displacement is in ZZ direction is in the model SW-00, which is equal to 0.00846832, and the minimum value of displacement is in the model SW-30, having a value of -0.00130805. Negative values in the YY and XX direction means the length reduction or displacement in the opposite direction of the axis and positive value indicates the enlargement or displacement in the direction of the axis. The negative value in ZZ direction shows troughs or displacement in the opposite direction of the axis and positive value indicates bump or displacement in the direction of the axis.

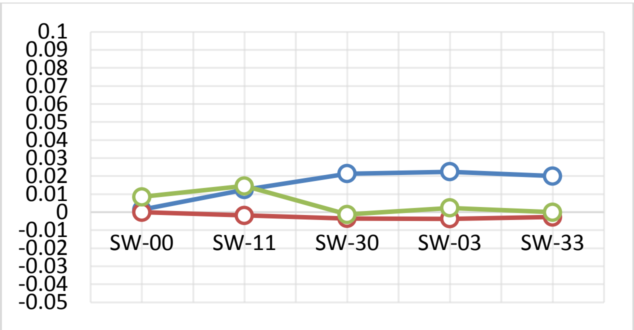


Figure 9. The displacement for zone No. 3, mode 3 and 0.10 m of height

6.4. Zone No. 4

Table 8. The displacement for zone No. 4, mode 3 and 0.10 m of height

Model	XX	YY	ZZ
SW-00	0.00523598	-0.000537988	-0.0303627
SW-11	0.0143532	0.00088296	7.1489E-05
SW-30	0.0208222	0.00194596	-0.00123072
SW-03	0.0208774	0.00114992	-0.00578635
SW-33	0.0197415	0.00162154	-0.00132623

The displacement of the shear wall in zone 4 for mode 3 (joint 11) and stiffener height of 0.10 m has been achieved. The maximum value of displacement is in XX direction in the model SW-03, which is equal to 0.0208774, and the minimum value of displacement is in the model SW-00, equaling to 0.00523598. The maximum value of displacement is in YY direction is also in the model SW-30, which is equal to 0.00194596, and the minimum value of displacement is in the model SW-00, which is equal to -0.000537988. Consequently, the maximum value of displacement is in ZZ direction is in the model SW-11, which is equal to 7.1489E-05, and the minimum value of displacement is in the model SW-30, having a value of -0.00123072. Negative values in the YY and XX direction means the length reduction or displacement in the opposite direction of the axis and positive value indicates the enlargement or displacement in the direction of the axis. The negative value in ZZ direction shows troughs or displacement in the opposite direction of the axis and positive value indicates bump or displacement in the direction of the axis.

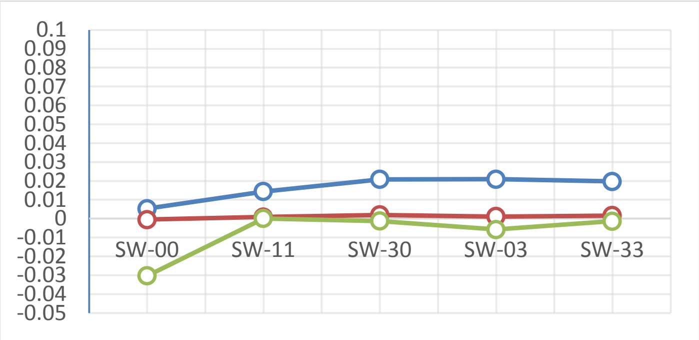


Figure 10. The displacement for zone 4, mode 3 and 0.10 m of height

7. Conclusions

The assumptions of the study is that the shear wall frame includes column and bema element added by shear steel panel. The investigated models were analyzed and designed by using finite element method in ABAQUS software and the obtained results were studied. The stiffeners cause to decrease out-of-plane displacements of the shear wall and change the buckling mode from general buckling to under-plane buckling. This change will increase the stiffness of the steel shear wall and finally increases the buckling load of the wall. Applying the stiffeners in the middles of the wall causes the maximum buckling load. The values of shear wall displacement with a stiffener height of 0.10 m are in mode 3. The maximum value in the direction of X-axis is in the zone No. 2 in model SW-03 equals to 0.046905; and the minimum value in the direction of X-axis is in the zone No. 3 in model SW-00 that is equal to 0.00137959. Moreover, the maximum value in the direction of Y-axis is in the zone No. 1 in model SW-30 equals to 0.00283448; and the minimum value in the direction of Y-axis is in the zone No. 3 in model SW-03 that is equal to -0.00421396. Consequently, the maximum value in the direction of Z-axis is in the zone No. 3 in model SW-00 equals to 0.00846832; and the minimum value in the direction of Z-axis is in the zone No. 2 in model SW-00 that is equal to -0.0363327.

REFERENCES

Batdorf, S. B. and Houbolt, J. C. (1946). "Critical combinations of shear and transverse direct stress for an infinitely long flat plate with edges elastically restrained against rotation.", *NACA Rep. 847*, 8-12.

Batdorf, S. B. and Stein, M. (1947). "Critical combinations of shear and direct stress for simply supported rectangular flat plates.", *NACA TN.* 1223.

Betten, J. and Shin, C. H. (2000). "Elastic-plastic buckling analysis of rectangular plates subjected to biaxial loads." *Forschung Im Ingenieurwesen-Engineering Research.* **65**, 90-94

Bijlaard, P. P. (1949) "Theory and tests on the plastic stability of plates and shells." *Journal of the Aeronautical Sciences*, September**.** 529-541.

Bui H, Cuong. (2013). "Buckling of thin-walled members analyzed by Mindlin-Reissner finite strip.", *Structural Engineering and Mechanics, An International Journal.* **48,** No.1, 77-91.

Chen, Y. (2003). Ultimate strength analysis of stiffened panels using a beamcolumn method, PhD. dissertation, Department of Aerospace and Ocean Engineering, Virginia Polytechnic Institute and State University, Blacksburg, VA, January.

Gabriela R. Fernandes and Joao R. Neto. (2015). "Analysis of stiffened plates composed by different materials by the boundary element method.", *Structural Engineering and Mechanics, An International Journal.* **56,** No.4, 605-623**.**

Ghosh B. (2003). Consequences of Simultaneous Local and Overall Buckling in Stiffened Panels, PhD.

Khayat,M., Poorveis,D., Moradi,SH. and Hemmati,M.(2016)."Buckling of thick deep laminated composite shell of revolution under follower forces.", *Structural Engineering and Mechanics An International Journal.* **58,** Number 1, 59-91.

Lee, S. G., Kim, S. C. and Song, J. G. (2001). "Critical loads of square plates under different inplane load configurations on opposite edges.", *International Journal of Structural Stability and Dynamics.* **1**, 283-291.

Pala M. (2006). "A new formulation for distortional buckling stress in cold formed steel members", *Journal of Constructional Steel Research*; **62**:716–22.

Schardt R. (1994). Generalized beam theory an adequate method for coupled stability problems. *Journal Thin-Walled Structures*,**1**, 161–80.

Suyai Fernández, Rossana C. Jaca and Luis A. Godoy. (2015). "Behavior of wall panels in industrial buildings caused by differential settlements", *Structural Engineering and Mechanics, An International Journal.***56**, No.3,443-460

Wang, C. M., Xiang, Y. and Chakrabarty, J. (2001). "Elastic/plastic buckling of thick plates.", *International Journal Solids and Structures***, 38**, 8617-8640.

Wang, C.M., Chen, Y. and Xiang, Y. (2002). "Exact buckling solutions for simply supported, rectangular plates under intermediate and end uniaxial loads.", Proceedings of the 2nd International Conference on Structural Stability and Dynamics, edited by C.M. Wang, G.R. Liu and K.K. Ang, World Scientific, 16-18 December 2002, Singapore, 424-429.

Xiang, Y., Wang, C. M. and Wang, C. Y. (2001). "Buckling of rectangular plates with internal hinge." *International Journal of Structural Stability and Dynamics*, **1**, 169-179.

Xiang, Y., Wang, C. M., Wang, C. Y. and Su G. H. (2003). "Ritz buckling of rectangular plates with internal hinge." *Journal of Engineering Mechanics, ASCE*. **129, No. 6**,683-688.