The theoretical study and finite elements of effect in the height changes to threshold on the shear strength of steel shear walls

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Abstract: In this article, studying the theoretical behavior of steel shear walls by Veladi et al and comparing its experimental results clarified that the degree of theoretic resistance has difference with experimental results. This difference is originated from the lack of width to height effect (b/h) on the shear resistance. Thus, to remove the problem, using ABAQUS software has been carried out to calculate a coefficient which is b/h proportion function. After comparing the obtained results from modeling and experiment, the authenticity was confirmed. Also, to reach to the study's purpose, modeling of samples from steel shear and material except the height was carried out efficiently. Then, by the use of experimental results and computer based modeling's, the extraction of a relationship was carried out to achieve multiple functions to theoretic relations.

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Key words: Steel shear walls, theoretical relations, periodical behavior, experimental behavior, experimental studies, ABAQUS software.

1. Introduction

About two decades ago, serious and considerable studies have been carried out on the steel shear walls. Due to the similar behavior of these systems with decks and sheets in terms of shear resistance, the similar relations of the system were considered. Benefits such as being economical, lightweight and idea plasticity behavior justify the importance of studying these panels more. The steel shear walls are enough easy to be achieved than other similar systems being jointed or connected as two bolt and curve to their surrounding frame and because it does not have any tensions concentrate, therefore, no need to accurate control of the bolts. The first serious work of the panel shear strength after buckling was carried out by wanger in 1931.The experiments were done by wanger based on the thin layer of aluminum shear panels made him to present the theory of stretching field (8). After him, many scientists such as Cohen, Bussler, Rocky, Porter and others studied their researches on the stretching field of deck-sheets diameters and their final resistance calculations, the stiffness sided panels were gradually evaluated. The regular bases of these studies during 20 years were mostly subjected to the application of diametrical stretching field being made after steel shear buckling. During the limited years, the steel shear walls with strong pre-fabricated steel sheets to prevent its buckling were used in a few buildings with inspiration of sheeting industry. The planning of using steel shear walls with thin thickness was carried out based on some useful studies on sheets for the first time in 1980s in Alberta college, Canada by Koolak and et al. these researchers concentrated merely on the theoretical and experimental studies based on steel shear walls with thin-thickness replacing a series of flanked stretching bars.

2. The theoretical behavior

Now, the behavior of the plate is being divided into three sections and the shear and tension (buckling) resistance would be reviewed in each section:

1- Pre buckling behavior
2- Elasticity – plasticity after buckling to the delivery of plate (sheet) tension
3- Plasticity after delivery to plate (sheet) fault tension

Pre-buckling behavior

In this section, the shear force continues from zero up to the plate buckling begins. Also, in this section, the linear relations and plate regulations are completely accurate. Of course, the range here is much lower than other parts. If the thickness of the plate is much lower than other dimensions (lower than 500), this section can be ignored.

The critical stress using classical plate theory is:

$$(1) \quad \tau_{cr} = \frac{k\pi^2 E}{12(1-\upsilon^2)} \times (\frac{t}{h})^2$$

Grater or equal to one

$$k = 5.35 + 4(\frac{b}{h})^2$$

For b/h Smaller or equal to one

For b/h $k = 5.35(\frac{b}{h})^2 + 4$

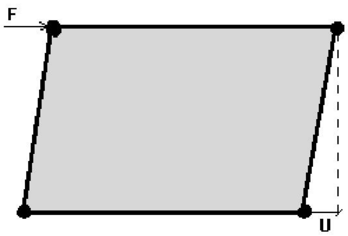


Figure 1. Plate of steel shear wall

b= the length of panel
h= the length of panel
t= the thickness of plate

(4) $F_{cr} = b \times t \times \tau_{cr}$

(5) $U_{cr} = \gamma_{cr} h = \frac{\tau_{cr}}{G} \times h$

The plasticity-elasticity behavior after buckling to plate delivery tension

The section can be considered the plate (sheet) as diametrical (diagonal) stripes with 45°. (1).

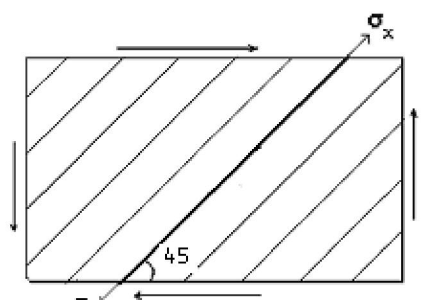


Figure 2. The hypothesis of stripes elements

The strain distribution on the stripes is not fixed in reaching to delivery tension based on Dr. Elghaiee experiments (2); but, it is variable as following form:

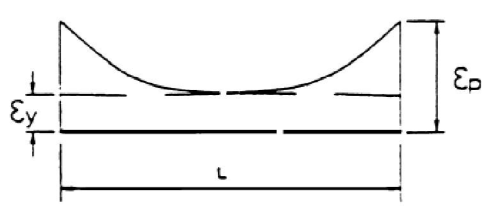


Figure 3. Strain distribution in stripes elements

(6) $\Delta_y = \varepsilon_y L + (\varepsilon_p - \varepsilon_y)\frac{L}{3} = (2+\alpha)\varepsilon_y \frac{L}{3}$

(7) $\varepsilon_p = \alpha \varepsilon_y$

(8) $\beta = \frac{2+\alpha}{3}$

(9) $\varepsilon = \frac{\beta \sigma_e}{E}$

Which α represents the coefficient of variation in the rage of 5 to 20. When the thin-layered plate and its limited members have enough stiffness, the degree of α would be about 20 while the thick-layered plate would be decreased to 5 due to their softness and flexibility elements.

$2.32 \le \beta \le 7.33 \qquad 5 \le \alpha \le 20$

Now, if the direction of X along with stripe and Y as vertical direction were considered, the strain distribution would be as following during the delivery strain:

(10) $\varepsilon_{xe} = \frac{(1+\upsilon)}{E} \times \tau_{cr} + \frac{\beta \sigma_e}{E}$

(11) $\varepsilon_{ye} = -\frac{(1+\upsilon)}{E} \times \tau_{cr} - \upsilon' \frac{\beta \sigma_e}{E}$

Which the position coefficient, v', in the plastic zone would be equal to 0.5 and plate delivery strain, σ_e based on "phone-misses" criteria could be obtained as following:

(12) $\sigma_e \cong F_y - \sqrt{3} \times \tau_{cr}$

The transformation of these strains in the direction of the panel, the shear strain would be governed during the delivery strain of the panel:

(13) $\varepsilon_{ye} = -\frac{(1+\upsilon)}{E} \times \tau_{cr} - \upsilon' \frac{\beta \sigma_e}{E}$

(14) $U_e = \left(\frac{\tau_{cr}}{G} + (1+\upsilon')(\frac{\beta \sigma_e}{E}) \right) \times h$

During the plate is reaching to delivery strain, total shear resistance can be obtained by balancing method. Then, we will have:

(13) $\gamma_E = \frac{2(1+\upsilon)}{E} \times \tau_{cr} + (1+\upsilon')(\frac{\beta \sigma_e}{E})$

(14) $U_e = \left(\frac{\tau_{cr}}{G} + (1+\upsilon')(\frac{\beta \sigma_e}{E}) \right) \times h$

(15) $F_e = (\tau_{cr} + 1/2\sigma_e \sin 2\theta) bt$

The angle Θ according to the Canadian regulations, it would be:

(16) $\tan^4 \theta = \frac{1 + \frac{tl}{2A_c}}{1 + th_s(\frac{1}{A_b} + \frac{h_s^3}{360 I_c L})}$

A_c = the area of columns section
I_c= the inertia of columns
H_c = the height of floor
A_b = the surface of the cross-section in a column
It must be noted that, the angle error effect on the ultimate strength must be very less than 0.10%.

The plasticity behavior after delivery to the fault of plate strain

In this step, the theoretical concepts of the plasticity are not effective but the plate can be considered as the stripe elements in this regard. The only difference with the latest step is the change of elasticity modulus which is decreased than elastic mood. Of course, the fixation hypothesis of the stripe section surface in the plasticity area due to the plate thinness is correct in the whole relations of the uniaxial strain for E from E_t was used.

If the degree of strain is specified from the beginning plasticity to the plate fault with σ_p, the buckling is being introduced in the directions of X and Y as following:

(17) $$\sigma_u = \sigma_e + \sigma_p$$

(18) $$\varepsilon_{xp} = \frac{(1+\upsilon)}{E} \times \tau_{cr} + \frac{\beta \sigma_e}{E} + \frac{\sigma_p}{E_t}$$

(19) $$\varepsilon_{yp} = -\frac{(1+\upsilon)}{E} \times \tau_{cr} - \upsilon' \frac{\beta \sigma_e}{E} - \upsilon' \frac{\sigma_p}{E_t}$$

The negative sign in the buckling means the proportional length reduction.
The shear buckling and displacement reaching to the panel become to the fault tension or equal with the same tension:

(20) $$\gamma_P = \frac{2(1+\upsilon)}{E} \times \tau_{cr} + (1+\upsilon')\left(\frac{\beta \sigma_e}{E} + \frac{\sigma_p}{E_t}\right)$$

(21) $$U_p = \left(\frac{\tau_{cr}}{G} + (1+\upsilon')(\frac{\beta \sigma_e}{E} + \frac{\sigma_p}{E_t})\right) \times h$$

The panel degree resistance will be governed as following with the same yield point:

(22) $$F_p = \left(\tau_{cr} + 1/2\sigma_u \sin 2\theta\right) bt$$

Now, it can be determined the division of the ultimate shear resistance on displacement in the panel shear stiffness.

(23) $$K_E = \frac{bt\left(\tau_{cr} + 1/2\sigma_e \sin 2\theta\right)}{\left[\frac{\tau_{cr}}{G} + (1+\upsilon')\left(\frac{\beta \sigma_e}{E}\right)\right] \times h}$$

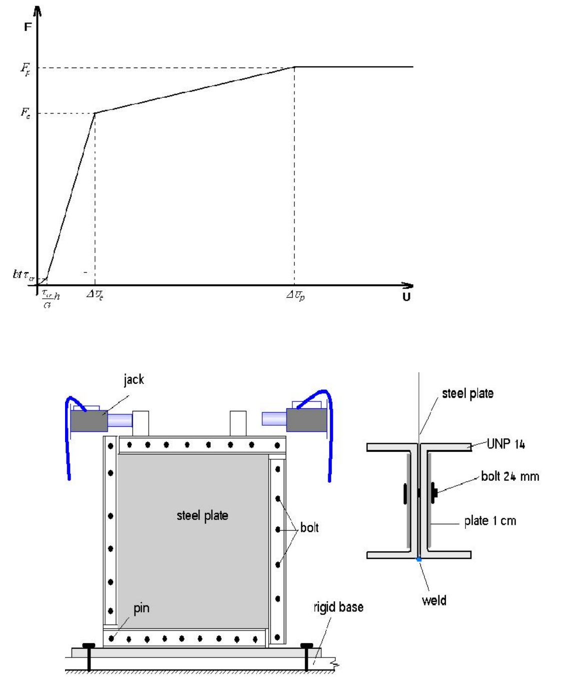


Figure 4. The behavior of steel shear wall panel

3. The study of theoretic discussion with experimental results

Six samples of steel joint shear walls with different dimensions and thickness were given in table 1. To study the seismic respond and its different effects, these samples were evaluated. The loading of these samples was achieved by jacks which are shown in figure "5".


Figure 5. The establishment of the samples in a cyclic experiment completion

Table 1. The specifications of the samples in a cyclic experiment

ERROR(MM)	U_E(MM)	F_E KGF	(KG/CM^2) τ_{cr}	F_Y(KG/CM^2)	T(CM)	H	B(CM)	THE NAME OF SAMPLE
2.5	17.5	8583	10.27	2663	0.07	92	92	307
0.1	14.1	10524	20	2283	0.1	92	92	308
0.2	24.78	7836	7.34	2663	0.07	142	92	309
1.9	22	9619	15	2283	0.1	142	92	310
0	17.5	13894	6.55	2663	0.07	92	142	311
0	14.2	17031	13.4	2283	0.1	92	142	312

The figure 6 and 7 have given the placement-load coordination comparison and their theoretical relations. It's obvious that the degree of panel shear resistance in yield point (Fe) has difference with hysteresis coordination in relation 15. That is, in panels with equal threshold width (b) but different heights (h) are different before the buckling (T_{cr}) but equal after any bucklings. Of course, the relations do not have any impact but it does not seem logically that the panel with width 3^m and height 1^m have not any difference with the same panel dimensions. Hence, to verify the related degree, a correction coefficient, samples with b/h proportions were modeled in ABAQUS software.

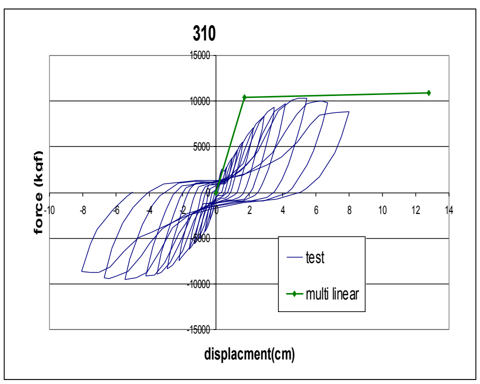


Figure 6. The comparison of placement-loading theory and sample hysteresis coordination 309

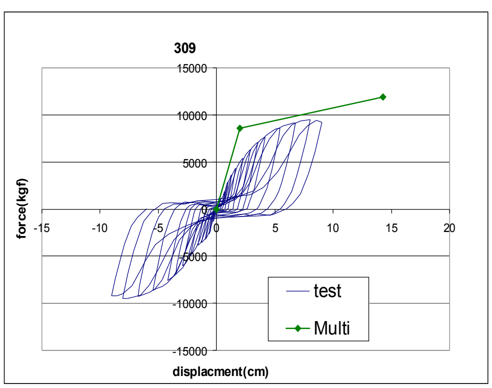


Figure 7. The comparison of placement-loading theory and sample hysteresis coordination 310

4 – The modeling of restricted elements in steel shear wall and accurate measurement with experimental results:

To study the behavior of steel shear wall wreckage, having a suitable mathematic model is required according to the engineering abilities with restricted element method which is mostly based on ABAQUS software.

Modeling hypothesis:

1) The thickness and width of the panel is fixed.
2) The lower column is completely motionless and shear is forced to the upper column.
3) The restricted elements of cross-sections are hardly to be observed and the connected points are completely joint and no bear any tensile anchorage.
4) The shear is not tolerated the plate
5) The lateral restricted elements buckling are negligible.
6) Meshing for every model is achieved up to the recovery results considerably.
7) To study the behavior after steel wall buckling, are-length method is used for solving non-linear equations.

Because the model is composed of Elastoplastic material, the tensile and buckling is considered as two linears. The analysis of each sample is consisted of two buckling linear and non-linear dimensions after buckling. Hence, sampling has two files. The first file including buckling analysis which is aimed to change the sample buckling formations for buckling moods, which is being used for the first imperfection of post-buckling. For the first buckling, the linear Static Buckle has been applied but for the second post-buckling, the non-linear static risk analysis has been used efficiently.

Since, the results of restricted element method should be confirmed to the experimental results, hence, the samples of 308,310, 312 given in table 1 were used. All these three samples were modeled with the same geometrical and material specification in ABAQUS software. The figures 8 to 10 have shown the comparison of the obtained results from the analysis of restricted element and experimental results. The comparison of placement-load coordination from restricted element modeling using ABAQUS software with hysteresis coordinations show that the restricted element modeling with ABAQUS software has an accurate precision due to an accurate modeling using ABAQUS software along with parametrical studies on the effect of height to threshold changes and steel shear wall resistance which is the main aim of the study in this regard.

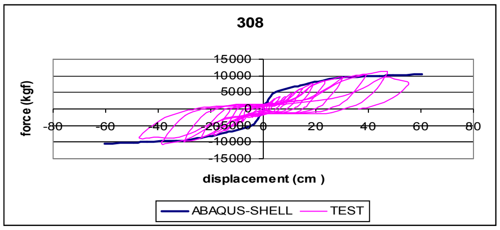


Figure 8. The comparison of experiment coordination and computer-based models in sample 308.

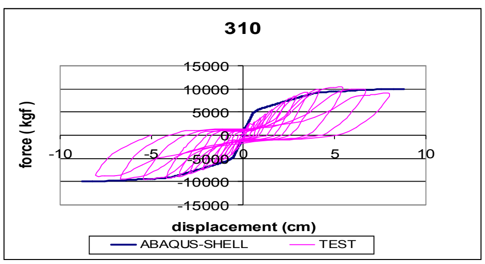


Figure 9. The comparison of experiment coordination and computer-based models in sample 310

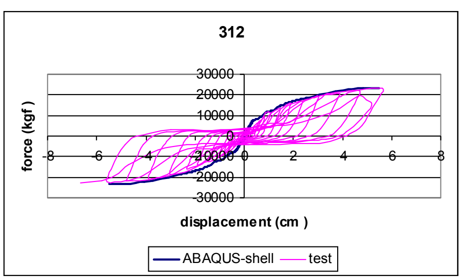


Figure 10. The comparison of experiment coordination and computer-based models in sample 312

5) The study of b/h proportion effect on the steel shear walls resistance:

In all samples, the geometrical can material specifications except the height are equal. The specifications have given in table 2.

Table 2. Geometrical specifications

Row	Sample	b(cm)	h(cm)	t(cm)
1	F	400	200	0.07
2	G	400	300	0.07
3	H	400	400	0.07
4	I	400	500	0.07
5	M	400	600	0.07

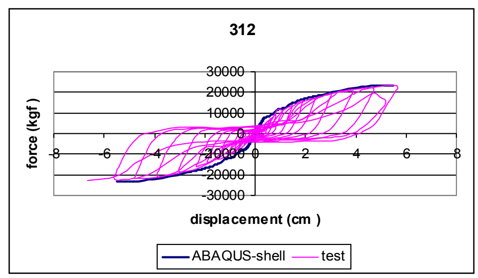
Also, the material specifications are as following:

$$E = 2\times10^{6}\frac{kg}{cm^{2}}$$

$$V = 0.29$$

$$F_{y} = 2400\frac{kg}{cm^{2}}$$

After modeling the samples by the use of placement-load coordination in figure 11, it seems that the degree of panel shear resistance in the yield point can be governed for each samples and then based on table 3, the K coefficients will be obtained for different b/h proportions.



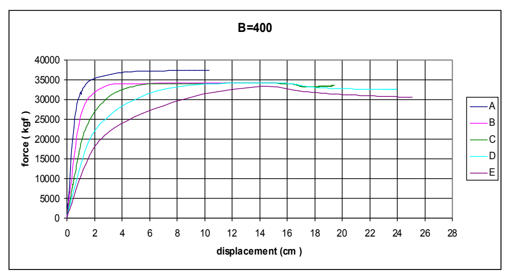


Figure 11. The coordination of placement-load in modeling

Table 3. The degree of K coefficient

Row	Sample	b/h	F	
1	A	2	21500	1.053
2	B	1.33	21000	1.028
3	C	1	20416	1
4	D	0.8	17500	0.857
5	E	0.66	15000	0.734

Note: the degree of (k) has been obtained by diving the shear resistance in each panel in panel shear resistance with b/h=1 proportion. Now, using the (b/h) proportion, and the measured degree of (k), the coordination b/h on k degree in figure 12 is being plotted.

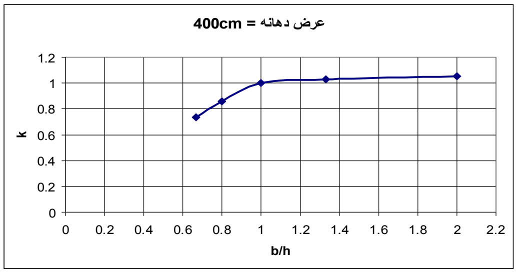


Figure 12. The coordination of b/h proportion with k

According to above coordination, the two linear equation can be measured: one for b/h ≤ 1 and the other b/h ≥equal to one and it can be neglected, too.

(24) If b/h ≥ 1, then k equals to K= 0.053 x + 0.947
(25) But, if b/h ≤ 1, then K= 0.79x+ 0.2
Note, in above-mentioned relations, the degree of x=b/h.
By using equations 24, 25, the degree of K can be measured and (Fe) relation is verified as well.
The equation 26 is the verified (Fe).

(26) $F_e = (\tau_{cr} + 1/2\sigma_t k \sin 2\theta)bt$

6. the study of equation precision

To be ensure of measured K equation precision and Fe for samples 309 and 310, again the K coefficient and without it will calculated.

Table 4. The study of K coefficient functions in theoretical relations

Sample	b (cm)	h (cm)	t (cm)	b/h	k	Fe* k (kgf)	Fe (kgf)	Ue (cm)	Fp (kgf)	Up (cm)
309	92	142	0.07	0.64	0.71	6097	8565	1.99	11914	14.3
310	92	142	0.1	0.64	0.71	7384	10400	1.7	10891	12.78

By using the degrees of table 4, the placement-load coordination will be plotted for each of these samples with K coefficient and without coefficient again. The figures 13 and 14, the comparison of experiment hysteresis with placement-load theory with and without coefficients were shown in samples 309 and 301.

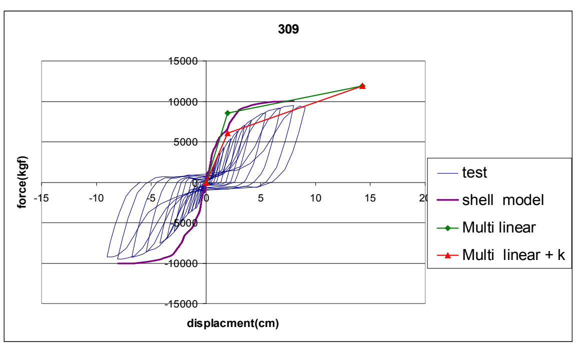


Figure 13. The comparison of experiment hysteresis coordination with placement-load theory with and without K coefficients in sample 309

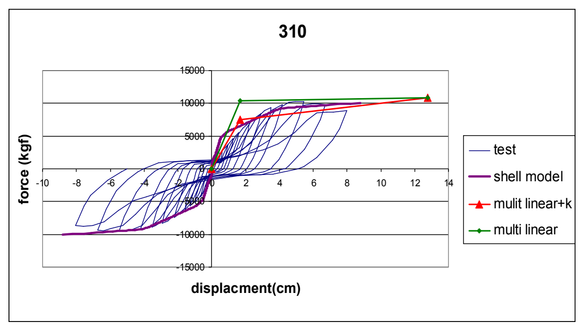


Figure 14. The comparison of experiment hysteresis coordination with placement-load theory with and without K coefficients in sample 310.

Summery and conclusion:

1) Generally, the achieved modeling by shell element had a suitable convergence with the real behavior of steel sheets in experimental samples which are a simple mood of steel shear wall of one floor and one threshold.
2) One of the most important obtained results as the main purpose of the study is the study of the extraction of a relationship for coefficient functions to given theoric relations considering the (b/h) effect which is the same height to width proportion on the resistance as following:
If b/h ≥1 = K and b/h ≤ 1=K then, the above-mentioned theoric behavior and experimental behavior will get closer

together considerably ensuring the obtained results of theoric relations.

3) In this research, it seems that if the (b/h) proportion is lower than 1, the panel resistance will be considerably decreased which is not favorable behavior in this regard. For example, in the modeling sample with b/h=0.66, the resistance decrease will be 27%. As a result, is seems that achieving this system with b/h > 1 will be suitable according to the planes dimensions.

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