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Proposition of Design Relations for Composite Steel Plate Shear Walls Containing an Opening

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Abstract:

Composite Steel Plate Shear Walls (CSPSW) are a developed type of steel shear walls that can be used in two ways to form the buckling due to the buckling in the steel sheet in these walls. One method is to use metal hardeners and the other is to use a concrete cover that is attached to the steel sheet through cutters. The second type is known as composite shear wall. In steel shear wall, the floor shear is transferred using the tensile field of the steel plate and after buckling due to diagonal pressure. In a composite cutting wall, the concrete wall preserves the steel plate and prevents it from buckling before yielding to pressure. As a result, the steel plate resists the sheer force of the floor due to shear yield. The shear yield capacity of a metal plate is clearly greater than the capacity it seeks to obtain with the help of a diagonal tensile field. In addition, the compacted concrete wall provides insulation against sound and temperature, and makes steel shear walls resistant and fire-retardant for steel sheets. However, due to architectural and installation reasons, these walls need to be opened. So with modeling as well as recommendations and criteria related to composite shear walls from different regulations to make a relationship for the case that we want to design the wall with opening with the given relations without opening, we have finally done the process of seismic design in composite shear wall systems, along with some design recommendations, it is stated about the design of composite shear wall components.

Keywords: Composite steel plate shear wall, Opening, Evolutionary algorithms, Multi-Expression Programming, Ultimate capacity.

Introduction

The main reason that composite steel shear wall has been proposed as a lateral load-resistant system is due to the low strength of steel shear walls before buckling of steel sheet. This early buckling of the steel sheet causes the phenomenon of pinching to be observed in the lateral load-displacement curves and reduces the energy dissipation. Therefore, if the premature buckling of the steel sheet can be prevented, both the large capacity of the steel sheet and the energy dissipation are used. According to studies and experiments, it was observed that the hardness of the composite shear wall is directly related to the thickness of the concrete cover, that is, as the thickness of the concrete cover increases, the stiffness of the composite shear wall increases. The researchers also based their research on a relationship for the optimal thickness of the concrete cover. One of these disadvantages is its high vulnerability to fire. In addition, off-plane buckling is another problem of steel sheet shear wall that significantly affects its energy dissipation capacity. Adding reinforced concrete panels to one or both sides of the steel sheet shear walls is a suggested method to eliminate the shortcomings. The concrete panel is attached to the steel plate using a series of shear studs.

The result is a new system called a composite steel sheet shear wall. Reinforced concrete panel (s) prevent premature buckling of the off-plate steel sheet and thus increase its load-bearing capacity. In addition, the concrete panel acts as a fire protection coating and also increases the lateral rigidity of the system. Various studies have been performed on different dimensions of steel and composite shear walls. For example, Metis et al. The study of metal shear walls made of low-yield steels as a method to improve the seismic performance of structures and has proposed various methods to prevent premature buckling of narrow steel plates [1,2]. Formisano et al. Used numerical and experimental results of steel sheet shear walls with circular openings to suggest predictive relationships for wall strength and stiffness [3]. Zhao and Astana first proposed a composite steel sheet shear wall system [4].

According to their studies, the gap between the concrete panel and the steel boundary elements reduces the damage to the concrete panel during high displacements under cyclic loads. The studies led to a design method presented in AISC341-10. In 1390. Arabzadeh et al. Investigating the effect of composite wall side openings on its capacity [6]. Smith et al. Investigated the buckling behavior of a reinforced steel sheet with a concrete panel using the Rayleigh-Ritz method [7]. Wright studied the effect of concrete panel contact with steel sheet and the allowable slimming limit of the plate [8]. Liang et al. Studied the post-buckling and localized buckling of a special type of composite wall made of two connected steel plates, the gap between which was filled with concrete [9]. Arabzadeh et al. Experimental study was performed on composite walls with only one side concrete slab and determined the buckling coefficient of steel sheet [10].In 2013, Ali et al. Investigation of cyclic performance of composite walls [11]. In this study, they developed three-dimensional numerical models in ABAQUS. In 2017, Epackachi et al.

A numerical study was performed on 98 samples of composite shear walls and based on the obtained results, proposed a relationship to predict the load displacement and maximum shear capacity of the wall [12].According to this study, the introduction of the span has a negative effect on the load carrying capacity and performance of the system under cyclic loading. The main purpose of this study is to develop numerical models using ABAQUS to investigate the effect of four different parameters including stud shear distance, steel sheet thickness, peripheral steel frame thickness and concrete compressive strength on final capacity. Sheet wall of composite steel sheet containing an opening. Experimental results reported by Meghdadian et al [13-18] are used to confirm the model. In addition, the effect of these parameters on the performance of the three proposed methods of Meghdadian et al to improve the behavior of composite walls with opening will be evaluated. These methods include adding a reinforcing steel frame around the opening, inserting 45-degree reinforcing rebars into the concrete panels at the corners of the opening, and combining the first two approaches [19].

Experimental verification of the developed model

In this section, we make Experimental samples for loading and check the results for validation with numerical samples. The samples reported in Tables (1) and (2), which was done according to the mixing plan of the concreting ACI362[20], and the samples were covered and kept by a wet hemp sack for four weeks. The experiment test set-up is demonstrated in Fig. 1.

Table 1- Material properties and dimensions of the steel members of the control specimens

Component	Profile	Yield stress (MPa)	Ultimate stress (MPa)	Modulus of elasticity (GPa)

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Columns	2IPE140	361	510	203
Beams	IPE140	361	510	203
Infill	t=6 mm	268	410	203
Bolts	Ø20	336	492	203
Rebar	Ø3	361	510	203

Table 2- Material properties and dimensions of the concrete components of the control specimens

Component	Concrete cover
Dimensions (mm)	t=80 mm
Compressive strength of the cylindrical specimens (mm)	45
Compressive strength of the cubic specimens (mm)	49
Modulus of elasticity (MPa)	30725

For lateral loading of laboratory models, the displacement control method was used according to ATC24[21] instructions. Result is shown in Figure 1

Fig. 1 . Hysteresis load-displacement curves and the damaged control specimens

Development of numerical models

In this research, a three-dimensional shell element (S4R) has been used to model the steel sheet in ABAQUS software. This element has the ability to study the behavior of both thick and thin shells. Among the capabilities of this element are plasticity, creep, swelling, strain stiffness, deformations and large strains. It is also suitable for problems described according to Kirchhoff or Mindlin's theory. The program's five default integration points for this element are sufficient for the elastoplastic response. For concrete coating, due to the desire to see the real cracks and deformations, three-dimensional brick elements (C3D8R) were used, in which longitudinal and transverse reinforcements are defined separately in a layer and then embedded in the desired locations by placing the element inside the concrete cover. . Each layer of rebar must have characteristics such as the cross section of each rebar, the free distance of the rebars, the type of rebar material and the angle of their extension. The S4R element has six degrees of freedom (three degrees of transition and three degrees of rotation) (u_x, u_y, u_z, θ_x, θ_y, θ_z), while the C3D8R element has three degrees of freedom (three degrees of transition) (u_x, u_y, u_z). Therefore, a contact element was used to match the middle layer of the steel sheet and the concrete wall. The middle layer between the steel sheet and the reinforced concrete panel was modeled by a frictionless contact element without allowing the steel sheet to penetrate the concrete.

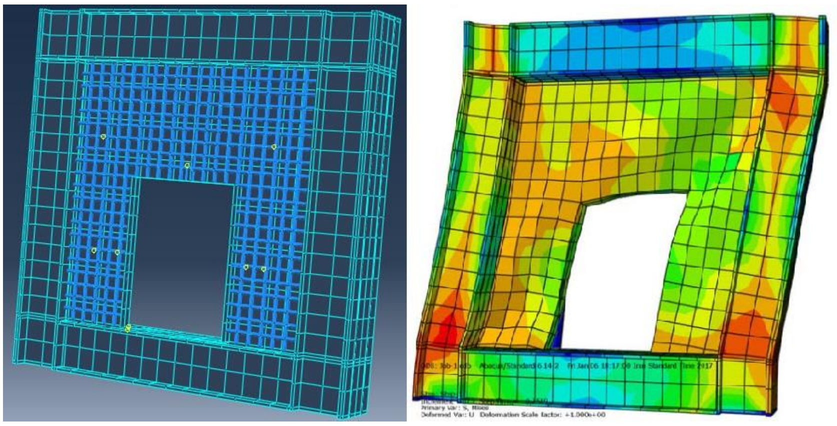

Fig. 2. Developed numerical model

In the present study, a three-dimensional beam element whose length is equal to the thickness of the concrete cover was used to model the bolts. In the beam element, the specifications of the cutting section can be entered into the software. In networking, the system operates in such a way that we have only two nodes at both ends of the cutters, which are connected to the corresponding nodes on the steel sheet and concrete cover. Also, steel sheet and concrete cover should have the same mesh; So that the knots are placed at the junction of these two walls with the cutters. Three-dimensional elements have been used to model the boundary elements in the above system.

These elements are able to more accurately estimate stresses and deformations compared to three-dimensional beam elements. There is an element to one-dimensional elements. It should be noted that the connecting sheets between the steel wall and the boundary elements were not modeled in the finite element analysis. In order to confirm the modeling, the laboratory samples were compared in the model software and the results were compared with the laboratory results. In order to be accurate in modeling and eliminate possible errors, first only the steel shear wall was modeled and analyzed, then after ensuring the accuracy of the results, the composite shear wall was modeled and reinforced concrete was modeled. The cross section of the bolts is designed so that all specimens can withstand the same cut. In modeling, Solid element (C3D8R) is used for beams and columns and concrete cover, Shell (S4R) is used for steel sheet and Beam (B31) is used for bolts. The reason for using the Solid element for concrete coating is the possibility of accurately modeling its contact with the surrounding frame and observing its true deformation at the end of the analysis. In order to model the base grip, the degrees of freedom of the lower end of the beam are taken in all directions. Figs. 3 compares the experimental and numerical hysteresis curves for control specimens.

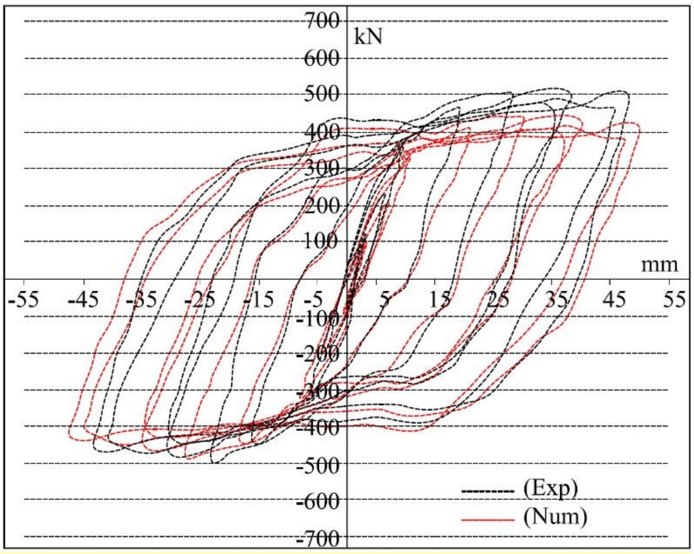

Fig. 3. Comparison of the experimental and numerical hysteresis curves of the control specimen

Proposition of the relation

In general, structural optimization problems can be based on mathematical planning problems in terms of design variables and quantities expressing the behavior of the structure. Mathematical programming methods are generally divided into two distinct groups. The first group includes gradient-based methods that use derivatives of the objective function and constraints along with the values of these functions to find the optimal design. In some structural engineering problems, optimization of functions is possible using methods based on the objective function gradient; But in some cases, either these methods cannot be used or it is simply not possible to use them. In some cases, the problem space is discrete, and sometimes due to the continuity of the search space, local optimizations prevent gradient methods from reaching the overall optimality. In these cases, direct search methods that are in the second group of mathematical programming methods are used.

These methods are not based on gradients and only need to evaluate the values of the objective function and constraints for further searches. Since the first group methods use more information than the analysis at one point in the design, it can be expected that they are more efficient than the second group methods and require fewer consecutive analyzes. Linear and nonlinear programming also divide mathematical programming methods into two distinct groups. In linear programming, the objective function and constraints are considered as linear functions of design variables. In this method, there is no optimal local answer and the general answer is obtained accurately after a few limited steps. In practice, this method is used in a wide range of problems of optimal design of structures. The main group of optimal design problems of structures due to nonlinear relationship between structural behavior and design variables are in the framework of nonlinear planning problems. Given the non-linear nature of such issues, it is clear that they are not easy to solve and are fraught with difficulties. One of these difficulties is the existence of several relatively optimal responses. A local minimum point gives a smaller value for the objective function than its adjacent points; But this answer cannot be expected to be the least absolute value of the objective function in the acceptable region. Therefore, achieving a general optimal answer in nonlinear programming problems is questionable and the optimization process in many cases, converges to the local minimum response.

In cases where the design space is multi-constrained, the search operation can be started with several points; However, despite the use of this method, there is no guarantee to find the general optimal. From another point of view, mathematical programming methods can be placed in two groups of definite and random methods. Random methods are methods that, unlike methods They use random search space random sampling or objective function random models, which have attracted a lot of attention in recent years due to the provision of effective methods in solving optimization problems and the possibility of achieving general optimal points. However, in definite methods, there is a problem that as soon as it reaches the first local optimal point, it stops and is not able to leave this point and move to another optimal point and finally the absolute optimal point.

Therefore, studies on algorithms that can escape from local optimal points have been started for a long time, and different methods have been proposed and studied so far. Random algorithms, meanwhile, have received more attention due to their simpler operation and therefore ease of execution with the help of a computer.

In view of the above, in the process of searching for the optimal points, two things should be considered simultaneously; First, the overall optimization can be anywhere in the search space, and second, based on local strategy, the probability of finding new points that improve the value of the function is closer to a point with a better objective function value than a point with a worse function value. As stated, an effective optimization method should pursue two conflicting goals. Considering the overall strategy, the distribution of potential points should be uniform, and to meet the second strategy, the distribution of points should be centered around the best current points. For this reason, optimization methods should use both local and general search strategies to solve optimization problems, but most of these methods use general search strategies.

Among the optimization methods inspired by living nature, genetic algorithms are among the most evolved. In nature, people who win the race for limited resources, such as food and shelter, survive and reproduce. The superiority of these people is due to their individual characteristics, which are greatly influenced by their genes. The reproduction of successful individuals leads to the proliferation of these genes, resulting in better offspring. By successively selecting the best people in the population and reproducing them, the whole population will move towards greater adaptation to their environment, that is, access to better and more resources.

Genetic algorithms are search algorithms that are based on the mechanism (mechanism) of natural selection and natural genetics mentioned above. In each generation, a new set of strings is created using the best partitions of the previous rhetoric and a new random section to arrive at a suitable answer. Therefore, the genetic algorithm does not go through a simple process in selecting new data; They combine the idea of choosing new search points to achieve the desired progress. [22-59].

In widely used commercial software, because the opening of the composite shear wall does not open properly, and during the analysis, because we expect our results to be examined after the materials enter the nonlinear state, but the software due to the opening of this issue. Does not understand

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correctly and therefore makes mistakes in its analysis. Of course, this duality only exists for software that does not have the ability to analyze nonlinearly, because in software such as Abaqus, this opening is properly modeled, and therefore the results are in accordance with the experimental sample. In order to be able to reach acceptable results from software that does not have this analysis capability, it has been suggested that we make this modeling easier by considering relationships.

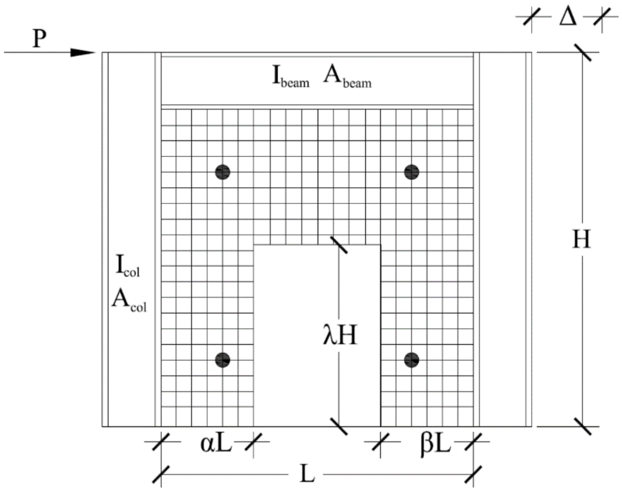

Fig. 4. The variable dimensions

For this reason, we have three relationships to calculate the wall stiffness(K), the amount of ultimate load(P), and the relationship to equate the composite shear wall with opening to the state of composite shear wall without opening(t_{seq}). For this reason, we used the genetic algorithm and having data from the output of Abaqus software, which had the parameters according to Figure 4. To achieve this, the collected numerical databases are used as input to the MEP program. The model parameters used to extract the mentioned models are presented in Table 3.

Table 3- Model parameters of MEP program used in derivation of the proposed relations

Model parameter	Value
Number of Subpopulations	30
Subpopulation size	200
Code length	60
Crossover probability	0.8
Crossover type	Uniform
Mutation probability	0.03
Tournament size	10
Probabilities of Operators	0.5
Probabilities of Variables	0.5
Probabilities of Constants	0.2
Number of generations	300

Number of Runs	200
Number of threads	30

and reached 3 relations for this purpose , which are given below:

(1)

$$t_{s_{eq}} = \frac{(\frac{H}{L})^{2.252\frac{H}{L}} \times \frac{0.77f'_c L}{H + 0.77f'_c} \times \frac{(E_s t_s + 2E_c t_c)^{1.024\frac{H}{L}}}{P^{1.318\frac{H}{L}-1}} \times \frac{(\alpha+\beta)^{\frac{H}{L}}}{\lambda^{1.897\frac{H}{L}}}}{10E_s + 20\frac{t_c}{t_s}E_c}$$

(2)

$$K = \frac{\alpha^{0.55}\beta^{0.59}H^{0.63}L^{1.31}{t_s}^{0.21}{t_c}^{0.37}{I_c}^{0.55}\ {I_b}^{1.13}{E_c}^{5.3}\ \ {E_s}^{2.9}}{1.3\lambda^{1.01}{f_c}^{0.24}{A_c}^{4.33}\ {A_b}^{6.14}}$$

(3)

$$P = P_U\frac{2.4 \times 0.53^{\lambda}}{\alpha^{0.27}\beta^{0.29}}$$

In these relations, $t_{s_{eq}}$ are the equivalent reduced thickness of the infill steel plate and covering concrete layers in cm, respectively. H, L are the height and span length in cm, respectively. α, β and λ are the dimension parameters of the wall and opening which are clearly defined in Fig. 4. E_s, E_c and f'_c are steel and concrete modulus of elasticity and compressive strength of concrete in kg/cm^2, respectively. P is the applied load in kg.

To validate the above three relationships, sample modeling can be used in other software.To do this, 50 random data are selected for the variables expressed in the above equations, and then we obtain the equivalent thickness, stiffness and load values by the given equations. are presented in Table 4.Then, according to the data we have for 50 samples, first they are modeled in Abaqus software and then using SAP software, modeling of the composite shear wall without opening is done with the values obtained from the above relations.

Table 4- Assumed parameters for modeling

NO	α(cm)	β(cm)	λ(cm)	H(cm)	L(cm)	t_s(cm)	t_c(cm)	E_s(kg/cm)	E_c(kg/cm)	F_c(kg/cm)	P_u(kg)	I_c(cm)	A_c(cm)	I_b(cm)	A_b(cm)	t_{seq}(cm)	K	P(kg)
1	0.30	0.35	0.62	71	78	0.55	10	2100000	246000	240	30000	1100	33	540	16	0.17	42327	91155
2	0.30	0.35	0.61	72	79	0.56	9	2200000	249000	230	35000	1000	31	490	15	0.18	87492	106748
3	0.30	0.35	0.59	73	71	0.57	8	1900000	248000	200	20000	1000	33	550	17	0.36	20446	61620
4	0.30	0.35	0.58	74	72	0.58	11	2200000	247000	210	30000	1200	34	540	16	0.34	49561	92780
5	0.31	0.36	0.55	75	73	0.59	12	2100000	248000	230	31000	1100	33	490	15	0.39	70591	97467
6	0.31	0.36	0.54	76	74	0.6	10	2000000	247000	220	22000	1000	33	530	15	0.47	62099	69478
7	0.31	0.36	0.52	77	75	0.61	9	2100000	246000	240	30000	1100	33	540	16	0.47	51056	95530
8	0.31	0.36	0.51	78	76	0.62	8	2200000	249000	230	35000	1000	31	490	15	0.48	106616	112472
9	0.31	0.30	0.49	79	77	0.63	11	1900000	248000	200	20000	1000	33	550	17	0.56	30680	68405
10	0.31	0.30	0.62	80	78	0.64	12	2200000	247000	210	30000	1200	34	540	16	0.32	52577	94101
11	0.31	0.30	0.61	81	79	0.65	10	2100000	248000	230	31000	1100	33	490	15	0.34	65178	97590
12	0.32	0.30	0.59	82	80	0.55	9	2000000	247000	220	22000	1000	33	530	15	0.35	57425	69952
13	0.32	0.31	0.58	83	81	0.56	8	2100000	246000	240	30000	1100	33	540	16	0.34	46236	95738
14	0.32	0.31	0.55	84	82	0.57	11	2200000	249000	230	35000	1000	31	490	15	0.37	115834	113536
15	0.32	0.35	0.54	85	83	0.58	12	1900000	248000	200	20000	1000	33	550	17	0.49	36170	62872
16	0.32	0.35	0.52	86	84	0.59	10	2200000	247000	210	30000	1200	34	540	16	0.47	73657	95093
17	0.32	0.35	0.51	87	85	0.6	9	2100000	248000	230	31000	1100	33	490	15	0.52	95375	99082
18	0.32	0.35	0.49	88	86	0.61	8	2000000	247000	220	22000	1000	33	530	15	0.63	86824	70903
19	0.33	0.36	0.62	89	87	0.62	11	2100000	246000	240	30000	1100	33	540	16	0.38	63244	88694
20	0.33	0.36	0.61	90	78	0.63	12	2200000	249000	230	35000	1000	31	490	15	0.68	119355	103880
21	0.33	0.36	0.59	71	79	0.64	10	1900000	248000	200	20000	1000	33	550	17	0.23	27175	59971
22	0.33	0.36	0.58	72	71	0.65	9	2200000	247000	210	30000	1200	34	540	16	0.37	47972	90383
23	0.33	0.30	0.55	73	72	0.55	8	2100000	248000	230	31000	1100	33	490	15	0.32	54603	100237
24	0.33	0.30	0.54	74	73	0.56	11	2000000	247000	220	22000	1000	33	530	15	0.38	57869	71444
25	0.33	0.30	0.52	75	74	0.57	12	2100000	246000	240	30000	1100	33	540	16	0.39	51138	98220
26	0.34	0.30	0.51	76	75	0.58	10	2200000	249000	230	35000	1000	31	490	15	0.40	104542	115528
27	0.34	0.31	0.49	77	76	0.59	9	1900000	248000	200	20000	1000	33	550	17	0.51	28734	66557
28	0.34	0.31	0.62	78	77	0.6	8	2200000	247000	210	30000	1200	34	540	16	0.29	45667	91570
29	0.34	0.35	0.61	79	78	0.61	11	2100000	248000	230	31000	1100	33	490	15	0.34	73301	91644
30	0.34	0.35	0.59	71	79	0.62	12	2000000	247000	220	22000	1000	33	530	15	0.22	66835	65709
31	0.34	0.35	0.58	72	80	0.63	10	2100000	246000	240	30000	1100	33	540	16	0.23	52562	89956
32	0.34	0.35	0.55	73	81	0.64	9	2200000	249000	230	35000	1000	31	490	15	0.25	112613	106709
33	0.35	0.36	0.54	74	82	0.65	8	1900000	248000	200	20000	1000	33	550	17	0.29	30324	61257
34	0.35	0.36	0.52	75	83	0.55	11	2200000	247000	210	30000	1200	34	540	16	0.24	71578	92661
35	0.35	0.36	0.51	76	78	0.56	12	2100000	248000	230	31000	1100	33	490	15	0.37	90428	96559
36	0.35	0.36	0.49	77	79	0.57	10	2000000	247000	220	22000	1000	33	530	15	0.45	80443	69160
37	0.35	0.30	0.62	78	71	0.58	9	2100000	246000	240	30000	1100	33	540	16	0.43	38469	91331
38	0.35	0.30	0.61	79	72	0.59	8	2200000	249000	230	35000	1000	31	490	15	0.41	79205	106954
39	0.35	0.30	0.59	80	73	0.6	11	1900000	248000	200	20000	1000	33	550	17	0.57	25450	61738
40	0.36	0.30	0.58	81	74	0.61	12	2200000	247000	210	30000	1200	34	540	16	0.52	56546	92957
41	0.36	0.31	0.62	82	75	0.55	10	2100000	248000	230	31000	1100	33	490	15	0.41	62902	93407
42	0.36	0.31	0.61	83	76	0.56	9	2000000	247000	220	22000	1000	33	530	15	0.49	56656	66541
43	0.36	0.34	0.59	84	77	0.57	8	2100000	246000	240	30000	1100	33	540	16	0.51	49296	88965
44	0.30	0.34	0.58	85	78	0.58	11	2200000	249000	230	35000	1000	31	490	15	0.46	107488	109585
45	0.30	0.35	0.55	86	79	0.59	12	1900000	248000	200	20000	1000	33	550	17	0.65	32283	63658
46	0.30	0.35	0.54	87	80	0.6	10	2200000	247000	210	30000	1200	34	540	16	0.59	65290	95708
47	0.30	0.35	0.52	88	81	0.61	9	2100000	248000	230	31000	1100	33	490	15	0.65	84517	99714
48	0.31	0.35	0.51	89	82	0.62	8	2000000	247000	220	22000	1000	33	530	15	0.80	76911	71350
49	0.31	0.35	0.49	90	83	0.63	11	2100000	246000	240	30000	1100	33	540	16	0.81	73915	98101
50	0.34	0.35	0.61	79	78	0.61	11	2200000	249000	230	35000	1000	31	490	15	0.32	106602	103469

Then we compare the obtained results with the cases that can be used to validate the above relationships. Displacement can be mentioned. These differences are listed in Table 5.

Table 5- Comparison of lateral displacement of modeling in Abaquse with Sap

NO	Δ_{max} Abaquse	Δ_{max} Sap	Relative error (%)	NO	Δ_{max} Abaquse	Δ_{max} Sap	Relative error (%)
1	2.207	2.371	7.42	26	1.133	1.038	8.37
2	1.251	1.294	3.48	27	2.374	2.563	7.95
3	2.089	2.228	6.60	28	2.055	2.190	6.57
4	1.919	2.034	6.03	29	1.281	1.344	4.89
5	1.415	1.524	7.70	30	1.008	1.063	5.48
6	1.147	1.232	7.44	31	1.754	1.895	8.04
7	1.918	2.037	6.22	32	0.971	0.878	9.60
8	1.081	1.132	4.67	33	2.071	1.875	9.45
9	2.285	2.406	5.26	34	1.327	1.202	9.45
10	1.835	1.977	7.76	35	1.094	1.004	8.30
11	1.535	1.392	9.30	36	0.881	0.934	6.02
12	1.249	1.166	6.58	37	2.434	2.594	6.60
13	2.122	1.938	8.70	38	1.384	1.252	9.53
14	1.005	0.923	8.10	39	2.487	2.291	7.85
15	1.782	1.887	5.89	40	1.685	1.601	4.96
16	1.323	1.409	6.47	41	1.522	1.453	4.56
17	1.065	0.965	9.35	42	1.204	1.282	6.52
18	0.837	0.775	7.45	43	1.850	1.935	4.59
19	1.437	1.321	8.12	44	1.045	1.096	4.89
20	0.892	0.824	7.65	45	2.021	2.138	5.80
21	2.262	2.053	9.25	46	1.503	1.612	7.28
22	1.931	1.976	2.33	47	1.209	1.101	8.94
23	1.882	2.023	7.52	48	0.951	0.871	8.40
24	1.265	1.331	5.21	49	1.360	1.454	6.89
25	1.969	2.101	6.71	50	0.995	1.069	7.40

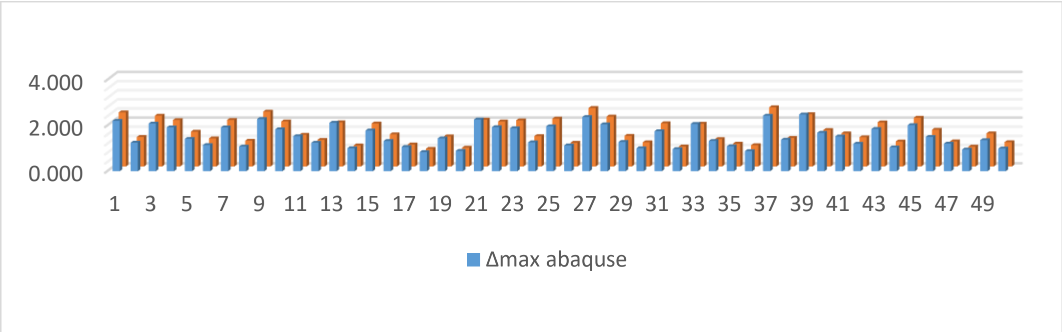

Fig. 5. The chart of Comparison of lateral displacement of modeling in Abaquse with Sap

According to the results obtained from the two modelings obtained in Abaqus and Sap and the comparison of the values given in Table 5. If we average this amount of errors, it will be seen that the average difference between the results of the two softwares is about 7%, which is a good number and indicates that these proposed relationships to an acceptable level require a designer to easily design and achieve Satisfied with more realistic results.

Conclusions:

In this paper, we have first tried to achieve a precise modeling of the composite shear wall by opening it in Abaqus software by validating a numerical sample with a experimental sample. Then, after confirming the validity and acceptance of the results obtained from Abaqus software. We have attempted to build Relations with MEP algorithm, Using this algorithm, we have obtained three equations to calculate the amount of stiffness, ultimate load and equivalent thickness in case we want to ignore this opening effect in the software. Then, by comparing different samples that have been modeled in Abaqus software and Sap software, using the suggested values, it was observed that these relationships, due to their very small error, can help designers to design safely. This type of system is one of the growing systems in the world. Experimental and numerical evaluations showed acceptable accuracy in the proposed relationship that can be used as a design tool for designers to facilitate numerical analysis and initial design of other structural members of CSPSW equipped structures in design software packages.

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