

Effects of Adding Structural Walls In The Bending Moments At The Columns

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ABSTRACT: This paper studied a case of reinforced concrete columns in an existing hospital building before and after applying earthquake loads and strengthening the building by adding RC Shear Walls (RCSW) and Steel Plate Shear Walls (SPSW). The objectives of this paper are to study the effects of using steel plate shear walls and RC shear walls with different thicknesses as retrofitting techniques and compare between the influences of the two approaches in reducing bending moments in the building columns. One typical model was selected from an existing RC hospital building, as a case study. The analysis of the building was carried out using SAP2000 FEA program and the 1997 Uniform Building Code (UBC 97). The retrofitting of the building was carried out by two techniques. Firstly, using SPSW with thicknesses of 5mm, 10mm, 15 mm, and 20mm. Secondly, using RCSW with thicknesses of 10 cm, 15 cm, and 20cm. The building was analyzed before and after the consideration of earthquake loads applied in two directions XX and YY. The 24 columns analyzed in this paper resulted in reducing the moments by 57%, 60% and 61% by using RC shear walls of 10 cm, 15 cm and 20 cm thick respectively. On the other hand, the moments were reduced by 16%, 25%, 31% and 36% when using steel plate shear walls of 5 cm, 10 cm, 15 cm and 20 cm thick respectively. It can be observed that SPSWs showed a good effect in reducing bending moments at the building columns.

KEYWORDS: RC shear wall; Retrofitting; Steel plate shear wall; Earthquake. UBC 1997

I. INTRODUCTION

Adding structural walls is one of the most common structure-level retrofitting methods to strengthen existing structures. This approach is effective for controlling global lateral drifts and for reducing damage in frame members. The main function of a steel plate shear wall (SPSW) is to resist horizontal storey shear and overturning moment due to lateral loads. In general, steel plate shear wall system consists of a steel plate wall, two boundary columns and horizontal floor beams.

II. ADVANTAGES AND DISADVANTAGES OF SPSW SYSTEMS

2.1 Advantages of SPSW

- 1- SPSW allows for less structural wall thickness in comparison to the thickness of concrete shear walls.
- 2- Compared to reinforced concrete shear walls, the steel shear wall is much lighter which can result in less weight to be carried by the columns and foundations as well as less seismic load due to reduced mass of the structure.
- 3- Compared to reinforced concrete shear walls, steel plate shear walls can be much easier and faster to construct when they are used in seismic retrofit of existing buildings.
- 4- By using shop-welded, field-bolted steel shear walls, one can speed-up the erection process and reduce the cost of construction, field inspection and quality control resulting in making these systems even more efficient.
- 5- Due to relatively small thickness of steel plate shear walls compared to reinforced concrete shear walls, from architectural point of view, steel plate shear walls occupy much less space than the equivalent reinforced concrete shear walls.
- 6- Steel plate shear wall systems that can be constructed with shop welded-field bolted elements can make the steel plate shear walls more efficient than the traditional systems. These systems can also be very practical and efficient for cold regions where concrete construction may not be economical under very low temperatures [1].

2.2 Disadvantages of SPSW

- 1- **Stiffness:** SPSW systems are usually more flexible in comparison with concrete shear walls.

2- Construction Sequence: Excessive initial compressive force in the steel plate panel may delay the development of the tension-field action. It is important that the construction sequence be designed to avoid excessive compression in the panel.

3- New System: Due to unfamiliarity with the system, a contractor will typically estimate a relatively high erected cost.

2.3 Features of metal shear panels materials [2]

- 1- High strength-to-weight ratio
- 2- Good ductility
- 3- Product availability
- 4- Ease of installation
- 5- Low maintenance cost
- 6-Reversibility

2.4 The construction of steel plate shear walls : SPSW systems that can be constructed with shop welded-field bolted elements can make the steel plate shear walls more efficient than the traditional systems. Figures 1. And 2 show strengthening of RC buildings using steel plate shear walls and the connections SPSWs with RC structure .

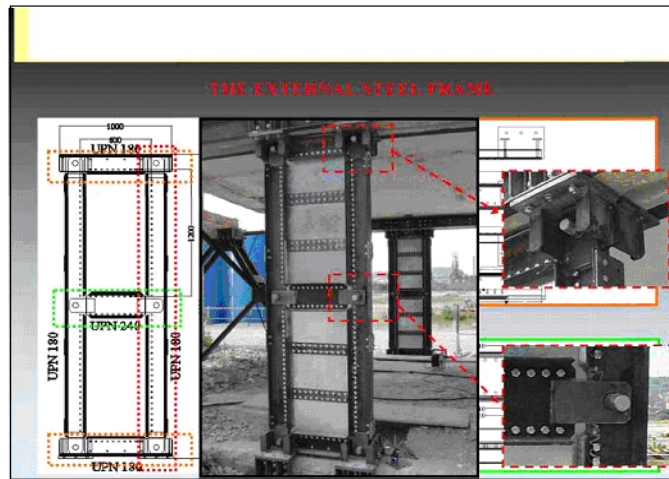
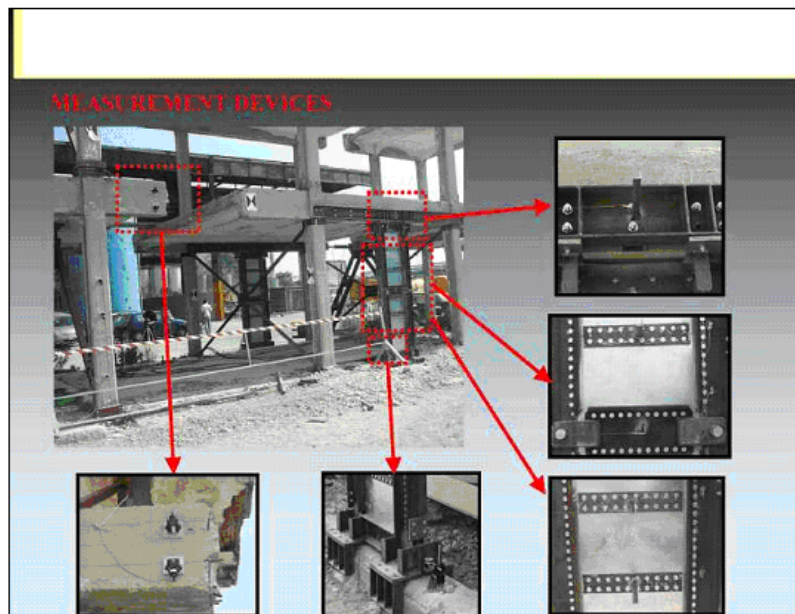
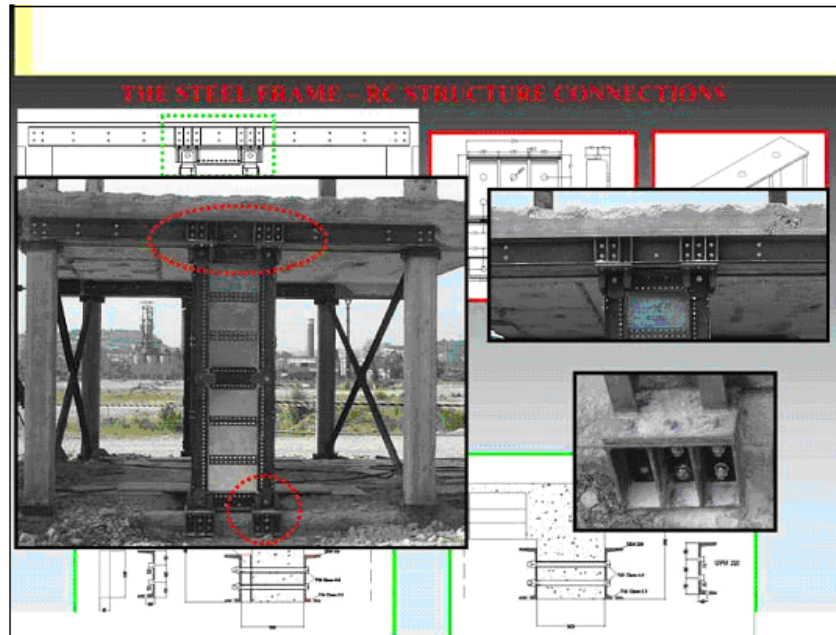


Figure 1. Strengthening of RC buildings using steel plate shear walls [3] .



(A)



(B)

Figure 2. (A) and (B) are the connections SPSWs with RC structure [3].

III. CASE STUDY

3.1 Description of the Building : The studied building in this paper is a typical three-storey RC hospital building of both vertical and horizontal regular geometry. The structure members are made of in-situ reinforced concrete .The overall plan dimension is 21.5m x 13m. The height of the building is 9.6 m. The cross section of beams and columns are 300x500 mm. The structure system is a moment resisting RC frame (MRFS) with flat slab system, 200 mm thickness, situated in seismic zone one in the Sudan. The analysis of the building is carried out using SAP2000 FEA program [4] due to vertical static loading and computer generated earthquake loading per the 1997 Uniform Building Code (UBC 97) [5]. The building is modeled as 3-D frames with fixed supports at the foundation level. Figures 3 and 4 show the model of the 3 stories hospital building and the layout of columns.

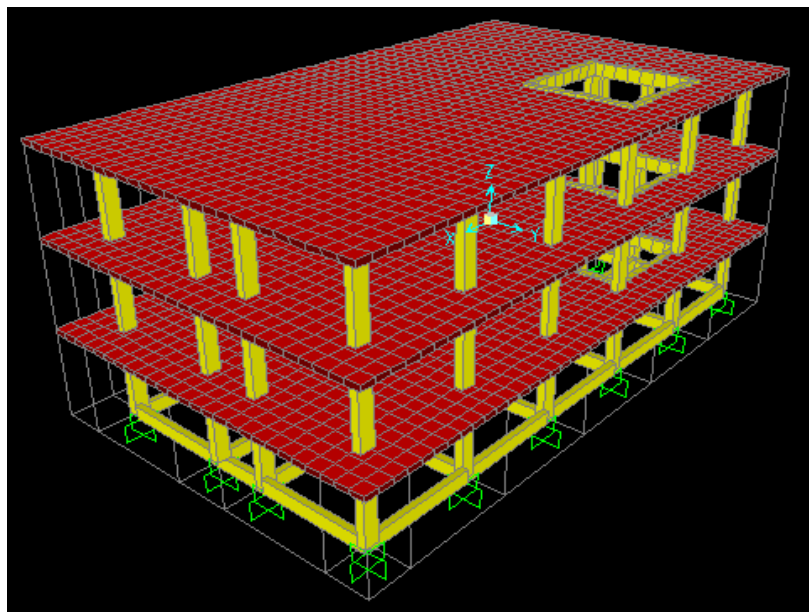


Figure 3. Model of the 3 stories RC hospital building

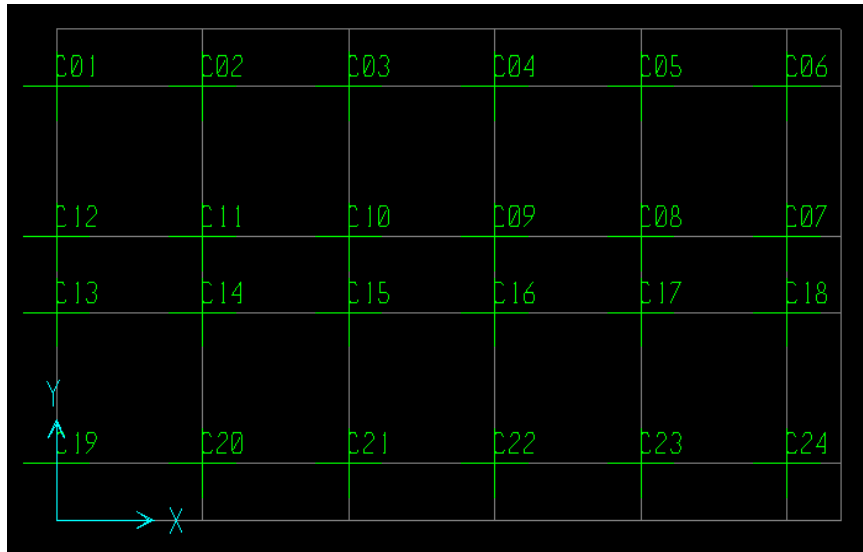


Figure 4. Label of columns

3.2 Structural Modeling :Numerical models for the case has been prepared using SAP2000 version 14 (Computers and Structures) [4]. Beams and columns are modeled as frame elements while walls and slabs are modeled as shell elements. In this paper the seismic performance of the considered building will be evaluated using the linear static analysis.

3.2.1 Modeling of steel shear walls in Analysis :The SPSWs can be modeled using full shell elements and isotropic material. It is suggested that the wall panel be modeled using at least 16 shell elements (4x4 mesh) per panel [2]. The lateral force resisting system consists of moment resisting frames with steel plate shear walls. The thickness of steel shear wall panels is taken as variable between 5mm to 20 mm. Figures 4and5 show the modeling of steel plate shear walls [6], while Figure 7 shows the type of seismic analysis.

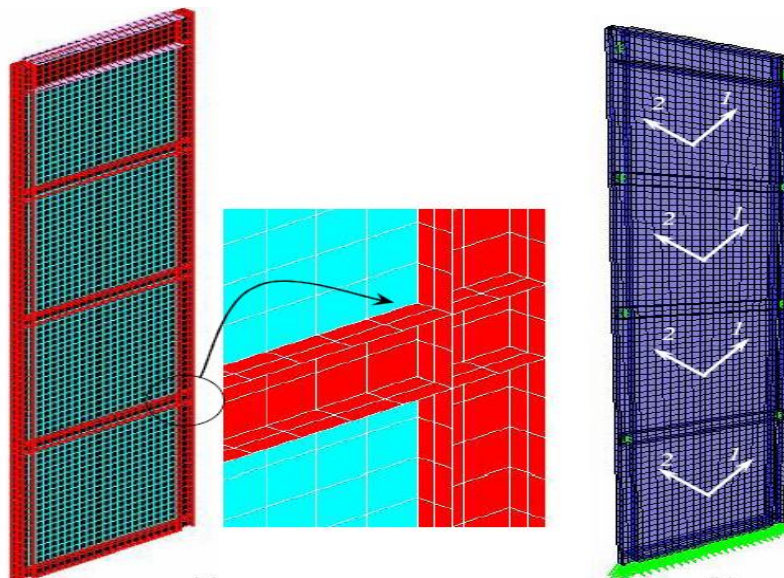


Figure 5. Finite element models of steel plate shear walls [6]

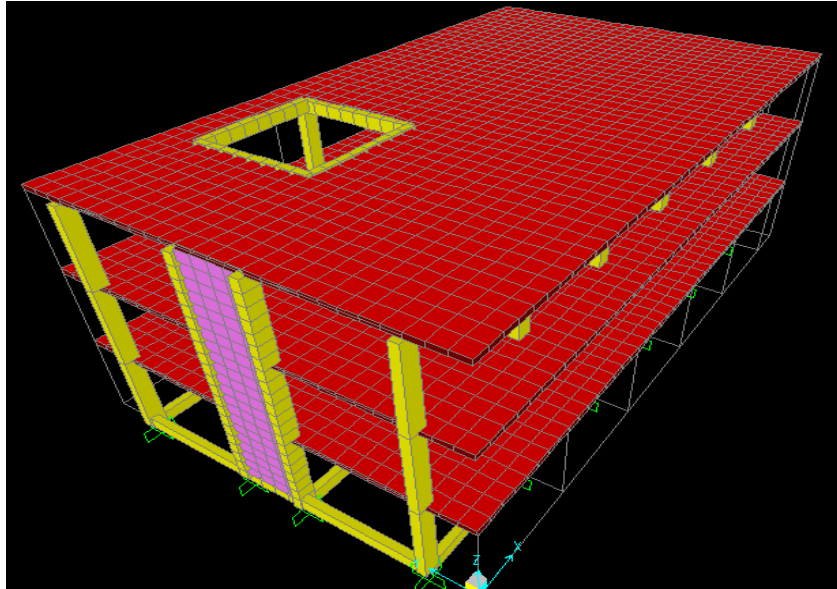


Figure 6. Modeling of shear wall in y directions

3.2.2 Types of seismic analysis

There are different methods of analysis which provides different degree of accuracy based on the type of external action and behavior of structure .Figure 6 shows the types of seismic analysis.

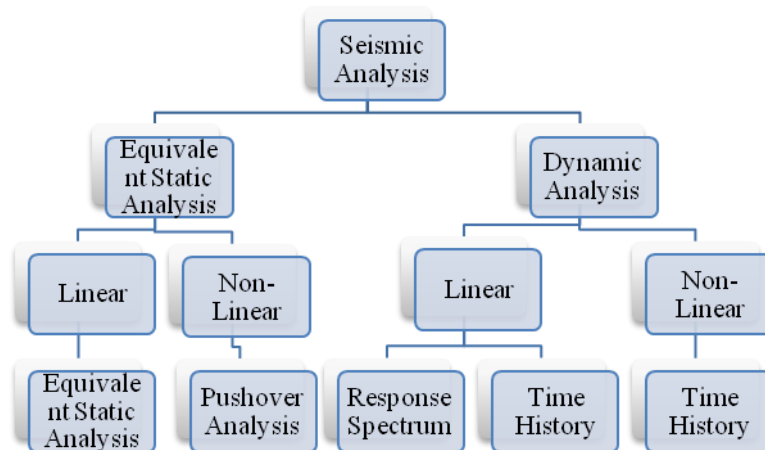


Figure 6. Type of seismic analysis

3.2.3 Load combinations : Based on section 1.6.1.2 of UBC 97 [5], structures are to resist the most critical effects from the following combinations of factored loads:

$$1.40 \text{ DL} + 1.70 \text{ LL} \dots\dots\dots(1)$$

$$1.32 \text{ DL} + 0.55\text{LL}+1.10 \text{ EQ} \dots\dots\dots(2)$$

$$0.99 \text{ DL} + 1.10 \text{ EQ} \dots\dots\dots(3)$$

ENVEQ-X is envelope of:

$$1.40 \text{ DL} + 1.70 \text{ LL} \dots\dots\dots(4)$$

$$1.32 \text{ DL} + 0.55\text{LL}+1.10 \text{ EQX} \dots\dots\dots(5)$$

$$0.99 DL + 1.10 EQX \dots\dots\dots(6)$$

ENVEQ-Y is envelope of:

$$1.40 DL + 1.70 LL \dots\dots\dots(7)$$

$$1.32 DL + 0.55LL+1.10 EQY \dots\dots\dots(8)$$

$$0.99 DL + 1.10 EQY \dots\dots\dots(9)$$

Where *DL* is the dead load, *LL* is the live load and *EQX*, *EQY* are the earthquake loads in direction *XX* and direction *YY*.

N: is the axialload in the column.

Mx: is the bending moment in x- direction.

My: is the bending moment at the column in y- direction.

3.3 The results and discussion of analysis:

3.3.1 Check of moments in the columns considering gravity and earthquake loads:

The moments in the columns obtained from gravity and earthquake loads in directions *XX* and *YY* are shown in Tables 1 to 3. It has been found that there are no effects of seismic loads in direction *-XX* because the bending moments in the columns due to earthquake in this direction are similar to bending moments due to gravity loads. Table 4 shows moments in the building columns with and without using reinforced concrete shear walls (RCSW), from which there are no significant difference in *Mx* values due to the thicknesses of RCSW because the inertias of these walls are approximately same. From Table 5, it can be seen that the values of *Mx* are inversely proportional to the thickness of SPSW. By comparing Tables 5 and 6 it has been shown that the use of RCSW scheme resulted in a better reduction of bending moments in the building columns which is thought to be due to material properties of the RCSW.

Table 1. The moments and axial forces in seven critical columns due to gravity loads

Column No.	Output Case	Case Type	N (kN)	Mx (kN-m)	My (kN-m)
C21	1.4DL+1.7LL	Combination	1020.20	26.03	-2.42
C22	1.4DL+1.7LL	Combination	1021.47	26.05	-2.65
C23	1.4DL+1.7LL	Combination	1025.54	25.98	-2.40
C05	1.4DL+1.7LL	Combination	1026.87	-25.46	-2.54
C04	1.4DL+1.7LL	Combination	1038.74	-26.03	-3.14
C20	1.4DL+1.7LL	Combination	1068.02	26.02	-4.00

Where C04,C05,C20,C21,C22 and C23 are selected columns

Table 2. The moments and axial forces in seven critical columns due to seismic loads in direction *-XX*

Column No.	Output Case	Case Type	Step Type	N (kN)	Mx (kN-m)	My (kN-m)
C21	ENVEQ-X	Combination	Max	1020.20	26.03	-2.42
C22	ENVEQ-X	Combination	Max	1021.47	26.05	-2.65
C23	ENVEQ-X	Combination	Max	1025.54	25.98	-2.40
C05	ENVEQ-X	Combination	Max	1026.87	-19.07	-2.54
C04	ENVEQ-X	Combination	Max	1038.74	-18.58	-3.14
C20	ENVEQ-X	Combination	Max	1068.02	26.02	-4.00

Table 3.The moments and axial forces in seven critical columns due to seismic loads in direction –YY

Column No.	Output Case	Case Type	Step Type	N (kN)	Mx (kN-m)	My (kN-m)
C21	ENVEQ-Y	Combination	Max	1020.20	60.56	-2.42
C22	ENVEQ-Y	Combination	Max	1021.47	64.26	-2.65
C23	ENVEQ-Y	Combination	Max	1025.54	67.87	-2.40
C05	ENVEQ-Y	Combination	Max	1026.87	25.43	9.84
C04	ENVEQ-Y	Combination	Max	1038.74	21.52	9.41
C20	ENVEQ-Y	Combination	Max	1068.02	56.82	-4.00

Table 4.Comparison between the moments in the building columns with and without RCSW using different thicknesses

Column No.	10 cm thick RCSW	15 cm thick RCSW	20 cm thick RCSW	Without RCSW
	Mx	Mx	Mx	Mx
C21	32.05	30.99	30.35	60.56
C22	32.66	31.51	30.82	64.26
C23	33.39	32.17	31.43	67.87
C05	-9.09	-10.33	-11.08	25.43
C04	-10.05	-11.20	-11.89	21.52
C20	31.54	30.58	30.00	56.82

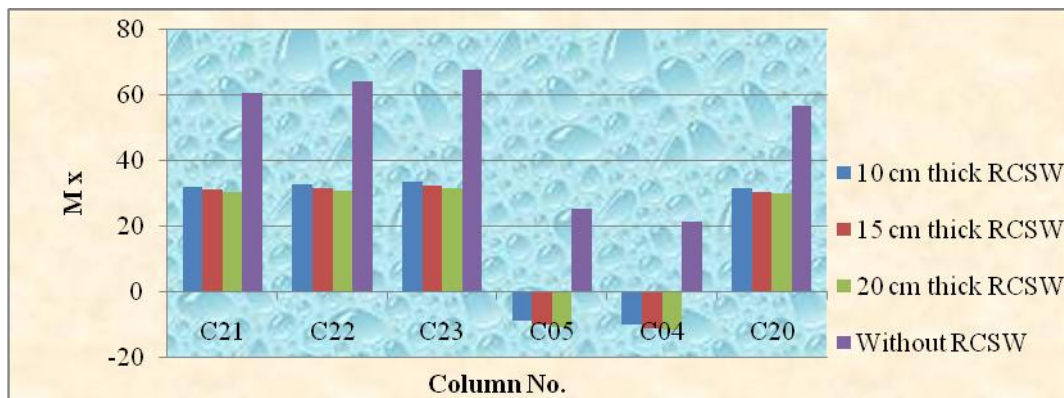


Figure 7. Comparison between the moments in the building columns with and without RCSW using different thicknesses

Table 5.Comparison between the moments in the building columns with and without SPSW using different thicknesses

Column No.	SPSW 5 mm	SPSW 10 mm	SPSW 15 mm	SPSW20 mm	Without SPSW
	Mx	Mx	Mx	Mx	Mx
C21	49.67	44.79	41.90	39.98	60.56
C22	51.96	46.55	43.38	41.27	64.26
C23	54.26	48.36	44.92	42.63	67.87
C05	11.82	5.93	2.49	0.20	25.43
C04	9.23	3.83	0.66	-1.45	21.52
C20	47.39	43.06	40.48	38.74	56.82

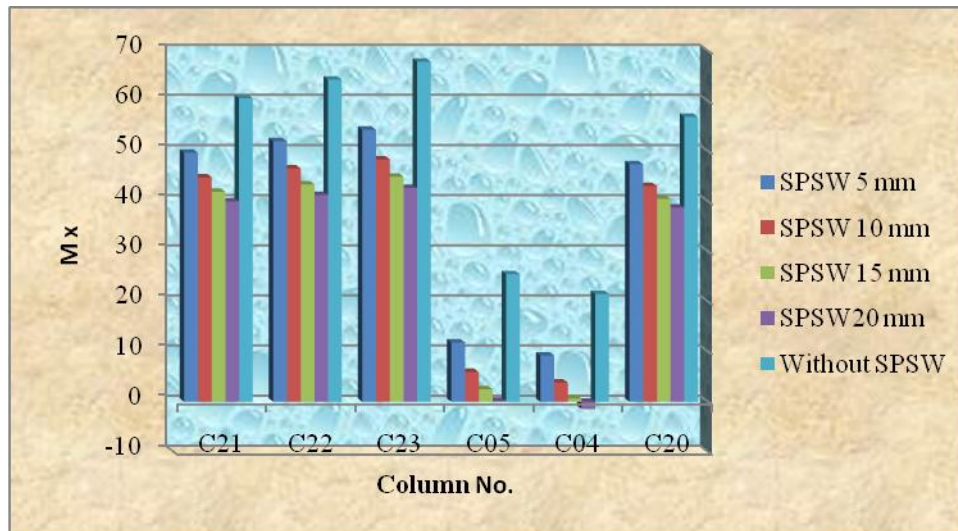


Figure 8. Comparison between the moments in the building columns with and without SPSW using different thicknesses

IV. CONCLUSION

The paper provides set of seismic analysis results of retrofitting RC hospital building. The building was analyzed before and after considering earthquake loads applied in two directions; XX and YY. From the results obtained it can be clearly seen that:

1. There are no changes in the values of M_x in the direction-XX due to gravity load and seismic loads, which is true for M_y in this direction. In the direction-YY, the values of M_x due to seismic loads are nearly double that due to gravity loads.
2. The different thicknesses of RCSW show approximately the same values of M_x which are approximately equal to half the values of M_x without using RCSW. Meanwhile, there are significant differences of the M_x values due to the thicknesses of SPSW.
3. It can be observed that SPSWs resulted in a good effect in reducing bending moments in the building columns.

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