International Journal of Research
Available at https://edupediapublications.org/journals
e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 05 Issue 15
May 2018

Comparative study of principle stresses at the top and bottom of multistoried building with shear wall and without shear wall

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KEYWORDS: PRINCIPLE STRESSES

INTRODUCTION

1.1 FLAT SLAB:

A reinforced concrete flat slab, also called as beamless slab, is a slab supported directly by columns without beams. A part of the slab bounded on each of the four sides by centre line of column is called panel. The flat slab is often thickened closed to supporting columns to provide adequate strength in shear and to reduce the amount of negative reinforcement in the support regions. The thickened portion meets the floor slab or a drop panel, is enlarged so as to increase primarily the perimeter of the critical section, for shear and hence, increasing the capacity of the slab for resisting two-way shear and to reduce negative bending moment at the support. Slabs of constant thickness which do not have drop panels or column capitals are referred to as flat plates. The strength of the flat plate structure is often limited, and consequently they are used for light loads and relatively small spans. Behavior of flat slab and flat plates are identical to those of two way slab. Bands of slab in both directions along column lines are considered to act as beams. Such bands of slabs are referred as column strips which pass through the columns and middle strips, occur in the middle of two adjacent columns. The deflections are minimum at supports

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p-ISSN: 2348-795X
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and maximum at mid spans. The deflected flat slab at the center of panel shall have saucer shape. Where δx and δy is the deflection at mid span in X and Y direction and lx and ly is the span length in X and Y direction.

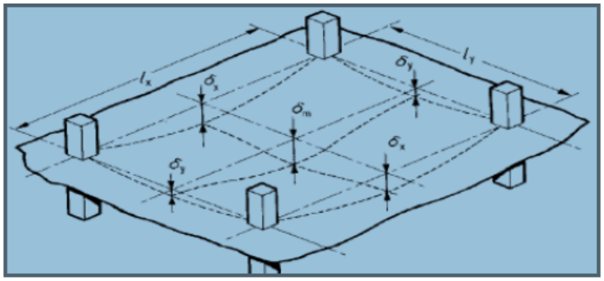

FIGURE 1: Deflection profile of flat slab

1.1.1 Method of analysis of Flat Slab :

1. The Finite Element Analysis

2. The Simplified Method

3. The Equivalent Frame Method

Finite Element Method: In the finite element modeling of a two dimensional shear wall and flat plate. The wall and plate is divided into smaller elements having finite size and number. These elements may be triangular, rectangular or quadrilateral. The most common plane stress element used for modeling shear walls is the two dimensional shell elements. It has three degrees of freedom at each node (two translations and one rotation). The finite element method is widely used not only in modelling multi-storey structures but also for all kinds of engineering problems.

International Journal of Research
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e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 05 Issue 15
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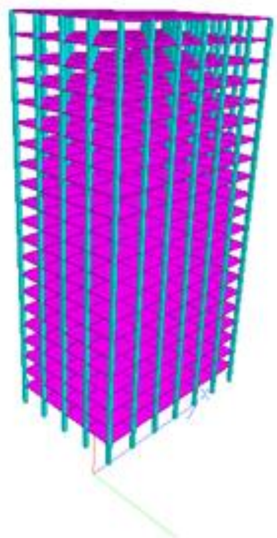

FIGURE 2: Flat slab in multistory building frame

1.2 SHEAR WALL:

A shear wall is a structural system composed of parallel walls that counter the effects of lateral load acting on a structure. Wind and Seismic loads are the most common loads that shear walls are designed to carry.

They are made of concrete and masonry and are used to resist lateral loads acting on building. They are continuous down to base to which they are rigidly attached and act as vertical cantilever in the form of separate planar walls. These walls are relatively thin and deep and subjected to axial forces.

Shear walls became an important part of mid and high-rise residential buildings. As part of an earthquake resistant building design, these walls are placed in building plans reducing lateral displacements under earthquake loads. So shear-wall frame structures are obtained.

The shear wall is in some ways a misnomer because the walls deform predominantly in flexure and therefore it is also known as flexure walls.

1.2.1 WHY WE NEED SHEAR WALLS CONSTRUCTION

Shea1r walls are not only designed to resist gravity / vertical loads (due to its self-weight and other living / moving loads), but they are also designed for lateral loads of earthquakes / wind. The walls are structurally integrated with roofs / floors and other lateral walls running across at right angles, thereby giving the three dimensional stability for the building. Shear walls have to resist the uplift forces caused by the pull of the wind. Walls have to resist the shear forces that try to push the walls over. Walls have to resist the lateral force of the wind that tries to push the walls in and pull them away from the building. Shear walls are quick in construction, as the method adopted to construct is concreting the members using formwork. Shear walls doesn't need any extra plastering or finishing as the wall itself gives such a high level of precision, that it doesn't require plastering.

1.2.2 SHAPES OF SHEAR WALLS

The shape and location of shear wall have significant effect on their structural behaviour under lateral loads. Lateral loads are distributed through the structure acting as a horizontal diaphragm, to the shear walls, parallel to the force of action. A core eccentrically located with respect to the building shapes has to carry torsion as well as bending and direct shear These shear wall resist

e-ISSN: 2348-6848
p-ISSN: 2348-795X
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horizontal forces because their high rigidity as deep beams, reacting to shear and flexure against overturning. However torsion may also develop in building symmetrical featuring of shear wall arrangements when wind acts on the faces of direct surface textures or when wind does not act through the centre of building's mass.

The shear wall sections are classified as six types.

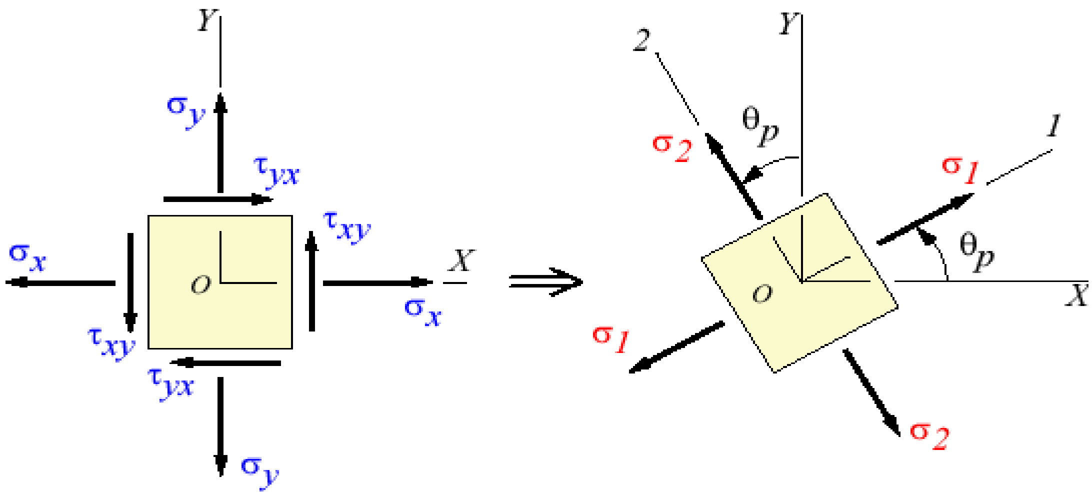
(a) Box Section (b) L – Section

(c) U - Section (d) W – Section

(e) H - Section (f) T – Section

1.3 PRINCIPAL STRESSES

A principal plane is any plane in which the shear stresses are zero. The normal stresses that are acting on this plane are therefore the principal stresses.



Stresses in given coordinate system

Principal stresses

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p-ISSN: 2348-795X
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FIGURE 3: Principal stresses

$$\sigma_1 = \frac{\sigma_x + \sigma_y}{2} + \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2}$$

$$\sigma_2 = \frac{\sigma_x + \sigma_y}{2} - \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2}$$

Principal stresses may be defined as“ The extreme values of the normal stresses possible in the material.” These are the maximum normal stress and the minimum normal stress. Maximum normal stress is called major principal stress while minimum normal stress is called minor principal stress.

- In the cases where more than two stresses are present(i.e. compound stress) the resultant stress at a point consists resultant of normal and shear stress. Both normal and shear stress at that point are the function of the inclination to horizontal. So study of this principal stress is done.
- If the material is brittle, the design is so done based on the normal stress. So to find that maximum normal stress we find the principal stress. Similarly in the materials where shear stress should be considered for design we find maximum shear stress and design accordingly.
- **MAXIMUM PRINCIPAL STRESS THEORY**
- The theory is associated with Rankine. This theory is approximately correct for cast iron and brittle materials generally. According to this theory, failure will occur when

the maximum principal stress in a system reaches the value of the maximum strength at elastic limit in simple tension. For the two dimensional stress case, this is obtained from the formula below-

- $\sigma_1 = 1/2(\sigma_x - \sigma_y) + 1/2\sqrt{(\sigma_x - \sigma_y)^2 + 4\tau_{xy}^2}$

OBJECTIVE OF STUDY AND METHODOLOGY

3.1 Objective :

The objective of the present work is to study and analysis of variation in Principal stresses on multistoried Buildings having flat slab and the effect of shear wall on the principal streeses of building under seismic forces. An investigation is done on principal stresses how the building react on lateral loads . In order to reduce lateral displacement shear walls have been provided throughout the height of the building at 4 corners near columns and in adjacent panels.

The objective can be brief under following heads

1. Study of variation of principal stresses in flat slab with increase in height of building.
2. Comparison of principal stresses in flat slab in 10 storied multi storied building with and without shear wall.
3. Comparison of principal stresses in flat slab in 20 storied multi storied building with and without shear wall.
4. Comparison of principal stresses in flat slab in 30 storied multi storied building with and without shear wall.

3.2 Methodology :

For this purpose of study and analysis, three cases of multi-storey buildings are considered.

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p-ISSN: 2348-795X
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Case I – 10 Storey buildings. Case II – 20 Storey buildings.

Case III – 30 Storey buildings.

The structural analysis of each case is done considering the building frame provided with shear wall and without shear wall.

These flat slab structure are subjected to the dead load, live load and seismic load.

The accuracy and the efficiency of the proposed models are tested by performing static lateral load analysis and time history analysis on flat slab system and shear wall-flat slab frame systems.

The structural analysis is carried out by the means of finite element modeling considering flat slab as plate element and shear wall as surface element on the software STAAD.PRO.

Then maximum value of both major and minor principal stresses produced on the top and bottom plane of flat slab on each storey due to applied load are found.

Then the principal stresses variation profiles for different case are compared and results are drawn out.

. General dimensions

FOR 10 STOREY BUILDING

Case I: Plan Area is 20m x 30m, shear wall is not provided.

Case II: Plan Area is 20m x 30m, shear wall of thickness 150mm is provided up to 10 storeys.

FOR 20 STOREY BUILDING

Case I: Plan Area is 20m x 30m, shear wall is not provided.

Case II: Plan Area is 20m x 30m, shear wall of thickness 250mm is provided up to 20 storeys

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FOR 30 STOREY BUILDING

Case I: Plan Area is 20m x 30m, shear wall is not provided.

Case II: Plan Area is 20m x 30m, shear wall of thickness 300mm is provided up to 30 storey.

4.2 Loads Considered:

4.2.1 Dead Load:

The loads considered are as follows:

In the present work, the self weight of the members is calculated by considering the density as 25 kN/m^3 for concrete. According to IS 456 minimum grade of concrete is M20 and grade of steel adopted is Fe415. The self weight of slab =0.2 x 1 x 1 x 25 = **5** kN/m^2

Load considered due to floor finish= **1** kN/m^2

4.2.2Live Load :

Live load adopted for floor slab and roof according to IS 875 part-II: **3** kN/m^2.

4.2.3 Earthquake Load:

Response Reduction Factor: Depends on the perceived seismic damage of structure, it is characterised by ductile or brittle deformation; was taken fromtable-7(clause 6.4.2) IS1893 Part-1:2002.

Importance Factor: Depends on the functional use of building characterised by hazardous consequences of its failure, it is taken from table-6(clause 6.4.2) of IS1893 Part-1 :2002.

Time Period of undammed free vibration.

Table-1

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p-ISSN: 2348-795X
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Size of structural elements of flat slab without shear wall in multistoried building

S.No	Description	No of stories	Column		Slab
			Width (mm)	Depth (mm)	Thickness (mm)
1	Flat Slab without Shear Wall	10	500	500	300
		20	500	500	300
		30	500	500	300

Table-2

Size of structural elements of flat slab with shear wall in multistoried building

S.No	Description	No. of Stories	Column		Slab	Shear wall
			Width (mm)	Depth (mm)	Thickness (mm)	Thickness (mm)
1	Flat Slab with Shear Wall	10	500	500	300	150
		20	500	500	300	200
		30	500	500	300	300

RESULTS

As mentioned in chapter 3 the objective of work was to study the principal stresses in flat slab and its variation along the height of a structure and effects due to action of shear wall. For these

e-ISSN: 2348-6848
p-ISSN: 2348-795X
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purpose analysis has been done and following results obtain for principal stresses for different case are shown by means of table and the variation graphs are being plotted.

Table – 3

Showing the major and minor principal stresses at top and bottom of flat slab
For 10 storied flat slab structure without shear wall

Storey	S max top	S max bottom	S min top	S min bottom
1	0.393	0.451	0.387	0.442
2	0.243	0.233	0.24	0.227
3	0.256	0.263	0.254	0.257
4	0.249	0.252	0.246	0.247
5	0.241	0.243	0.238	0.239
6	0.227	0.228	0.223	0.225
7	0.206	0.207	0.204	0.205
8	0.179	0.241	0.206	0.185
9	0.188	0.219	0.218	0.19
10	0.168	0.239	0.199	0.206

Table – 4

Showing the major and minor principal stresses at top and bottom of flat slab
For 10 storied flat slab structure with shear wall

Storey	S max top	S max bottom	S min top	S min bottom
1	0.13	0.154	0.115	0.15
2	0.108	0.16	0.13	0.127
3	0.135	0.212	0.177	0.168
4	0.271	0.33	0.329	0.263

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e-ISSN: 2348-6848
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5	0.243	0.277	0.257	0.262
6	0.239	0.3	0.284	0.235
7	0.239	0.322	0.307	0.252
8	0.256	0.343	0.329	0.268
9	0.274	0.36	0.353	0.28
10	0.25	0.395	0.325	0.304

Table – 5

Showing the major and minor principal stresses at top and bottom of flat slab
For 20 storied flat slab structure without shear wall

Storey	S max top	S max bottom	S min top	S min bottom
1	16.26	18.63	16.2	18.6
2	10.05	9.7	10	9.7
3	10.32	10.4	10.3	10.4
4	9.98	10	9.9	10
5	9.67	9.7	9.6	9.7
6	9.29	9.3	9.2	9.3
7	8.87	8.8	8.8	8.89
8	8.4	8.4	8.3	8.4
9	7.9	7.9	7.8	7.9
10	7.4	7.3	7.4	7.4
11	6.8	6.8	6.8	6.8
12	6.33	6.2	6.2	6.3
13	5.78	5.7	5.7	5.77
14	5.2	5.17	5.1	5.2
15	4.65	4.5	4.6	4.6
16	4.08	4	4	4

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17	3.5	3.4	3.4	3.5
18	2.97	2.9	2.9	2.9
19	2.4	2.6	2.7	2.4
20	2.17	2.7	2.6	2.28

Table – 6

Showing the major and minor principal stresses at top and bottom of flat slab
For 20 storied flat slab structure with shear wall

Storey	S max top	S max bottom	S min top	S min bottom
1	7.8	9.7	7.87	9.76
2	4.7	4.5	4.69	4.551
3	4.8	5	4.79	5.114
4	4.77	4.83	4.644	4.94
5	4.7	4.76	4.554	4.89
6	4.803	4.767	4.647	4.917
7	3.82	5.265	3.94	4.987
8	15.75	17.13	16.01	16.775
9	8.74	9.09	8.5	9.31
10	8.19	7.85	7.95	8.08
11	7.4	7.217	7.23	7.46
12	6.8	6.55	6.56	6.8
13	6.2	5.93	5.938	6.2
14	5.6	5.34	5.341	5.611
15	5.06	4.785	4.778	5.074
16	4.55	4.686	4.643	4.5
17	4.25	4.695	4.644	4.295
18	4.3	4.782	4.715	4.35
19	4.47	4.915	4.914	4.46

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20	4.13	5.35	4.547	4.88

Table – 7

Showing the major and minor principal stresses at top and bottom of flat slab
For 30 storied flat slab structure without shear wall

Storey	S max top	S max bottom	S min top	S min bottom
1	24.2	9.7	24.2	27.7
2	15.2	4.5	15.3	14.9
3	16.3	5	16	16.3
4	15.9	4.83	15.9	16
5	15.7	4.76	15.7	15.8
6	15.5	4.767	15.4	15.5
7	15.1	5.265	15.1	15.2
8	14.8	17.13	14.7	14.8
9	14.3	9.09	14.3	14.4
10	13.9	7.85	13.8	13.9
11	13.4	7.217	13.3	13.4
12	12.9	6.55	12.8	12.9
13	12.3	5.93	12.3	12.3
14	11.79	5.34	11.7	11.7
15	11.2	4.785	11.1	11.1
16	10.6	4.686	10.5	10.5
17	9.9	4.695	9.9	9.9
18	9.3	4.782	9.3	9.3
19	8.7	4.915	8.6	8.7
20	8.1	5.35	8	8.1
21	7.4	7.217	7.4	7.4

22	6.8	6.55	6.7	6.8
23	6.2	5.93	6.1	6.2
24	5.6	5.34	5.5	5.6
25	5	4.785	4.9	4.9
26	4.4	4.686	4.3	4.3
27	3.8	4.695	3.8	3.8
28	3.26	4.782	3.7	3.2
29	3.23	4.915	3.7	3.2
30	3.13	5.35	3.6	3.2

Table – 8

Showing the major and minor principal stresses at top and bottom of flat slab
For 30 storied flat slab structure with shear wall

Storey	S max top	S max bottom	S min top	S min bottom
1	14.18	17.06	14.1	17
2	8.7	8.485	8.68	8.5
3	8.9	5	8.8	9.1
4	8.6	4.83	8.5	8.8
5	8.6	4.76	8.4	8.8
6	8.6	4.767	8.4	8.8
7	8.6	5.265	8.3	8.8
8	8.6	17.13	8.4	8.8
9	8.7	9.09	8.4	8.9
10	9.1	7.85	8.8	9.2
11	7.9	7.217	8.2	9.7
12	27.9	6.55	27.5	25.7
13	14.4	5.93	14.2	15.1

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14	13.8	5.34	13.5	13.6
15	12.8	4.785	12.5	12.7
16	11.9	4.686	11.6	11.8
17	11.1	4.695	10.8	11
18	10.3	4.782	10.1	10.34
19	9.68	4.915	9.4	9.6
20	9	5.35	8.7	8.9
21	8.4	7.217	8.1	8.3
22	7.85	6.55	7.6	7.8
23	7.3	5.93	7.1	7.3
24	6.8	5.34	6.9	6.8
25	6.4	4.785	6.9	6.4
26	6.45	4.686	7	6.5
27	6.6	4.695	7.2	6.7
28	6.8	4.782	7.4	6.9
29	7.3	4.915	7.9	7.3
30	6.425	5.35	6.9	8

Graphs Are Plotted Showing The Comparison Of Principal Stresses Variation With Height For Flat Slab Structure Without & With Shear Wall

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p-ISSN: 2348-795X
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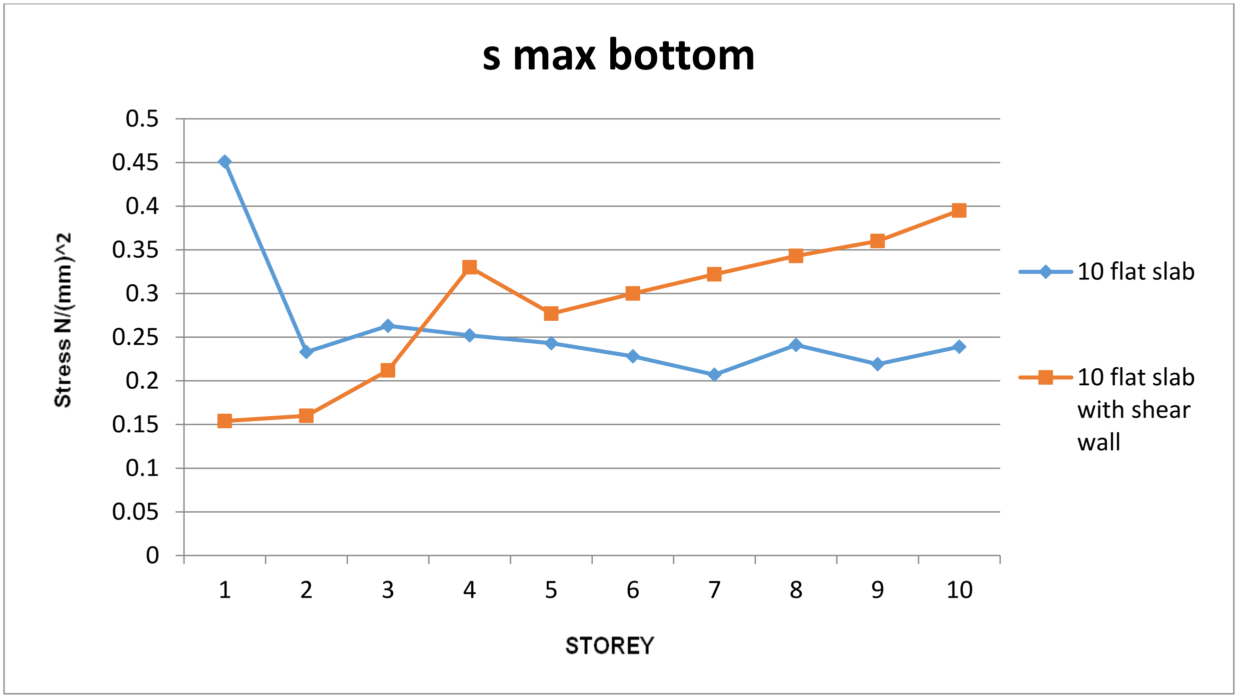

FIGURE 35: Max Bottom principal stresses variation with height for 10 storey flat slab structure without and with shear wall

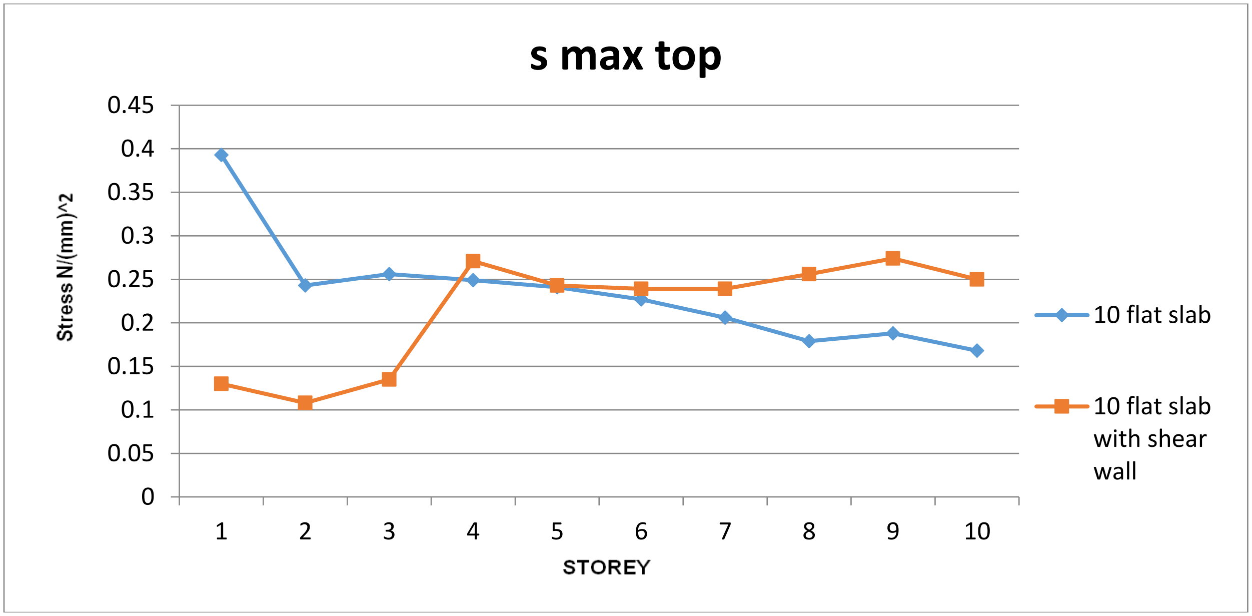

FIGURE 36: Max top principal stresses variation with height for 10 storey flat slab structure without and with shear wall

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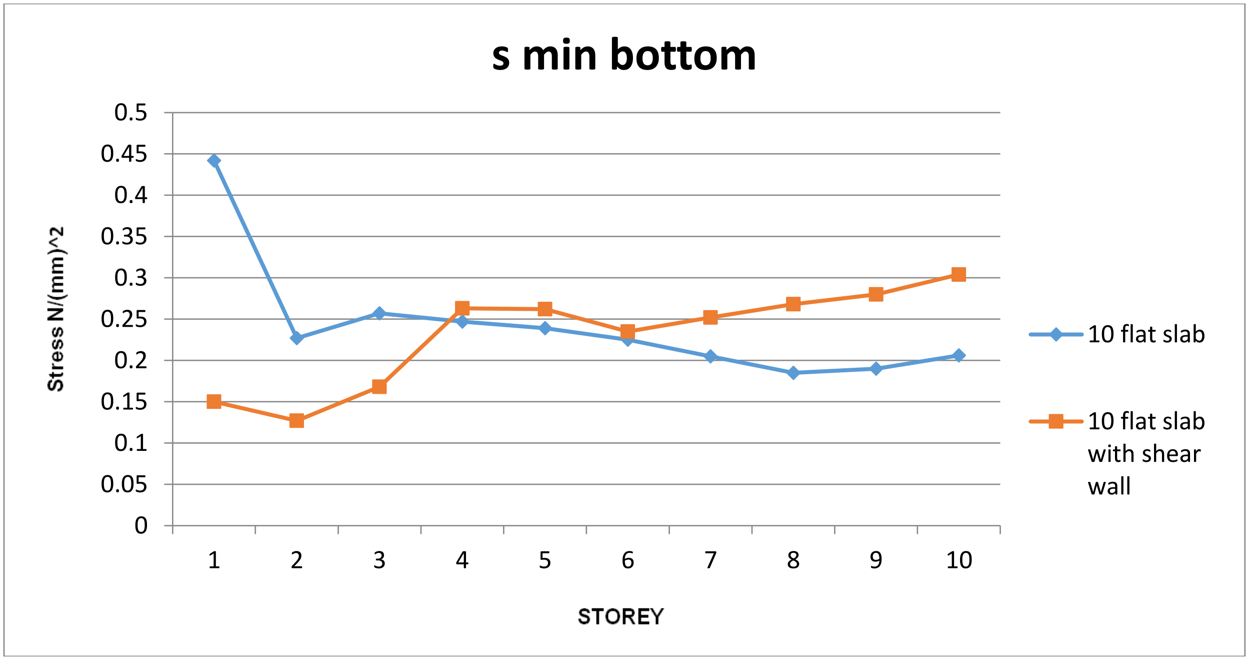

FIGURE 37: Min Bottom principal stresses variation with height for 10 storey flat slab structure without and with shear wall

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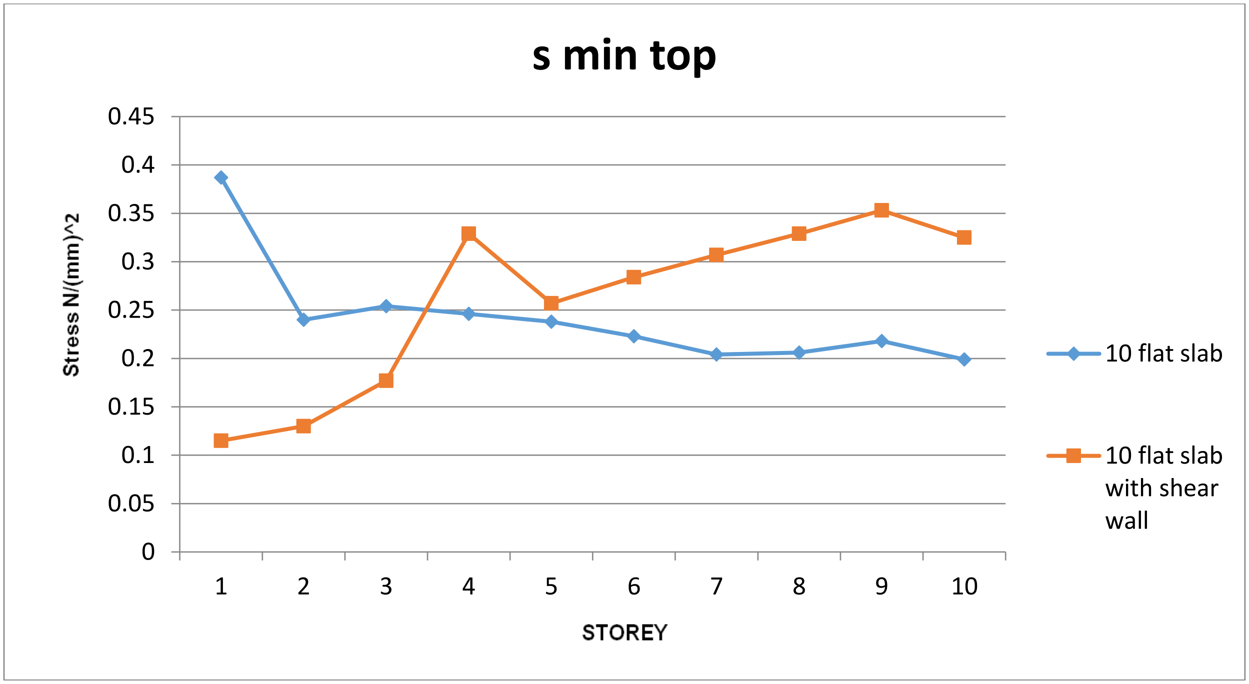

FIGURE 38: Min top principal stresses variation with height for 10 storey flat slab structure without and with shear wall

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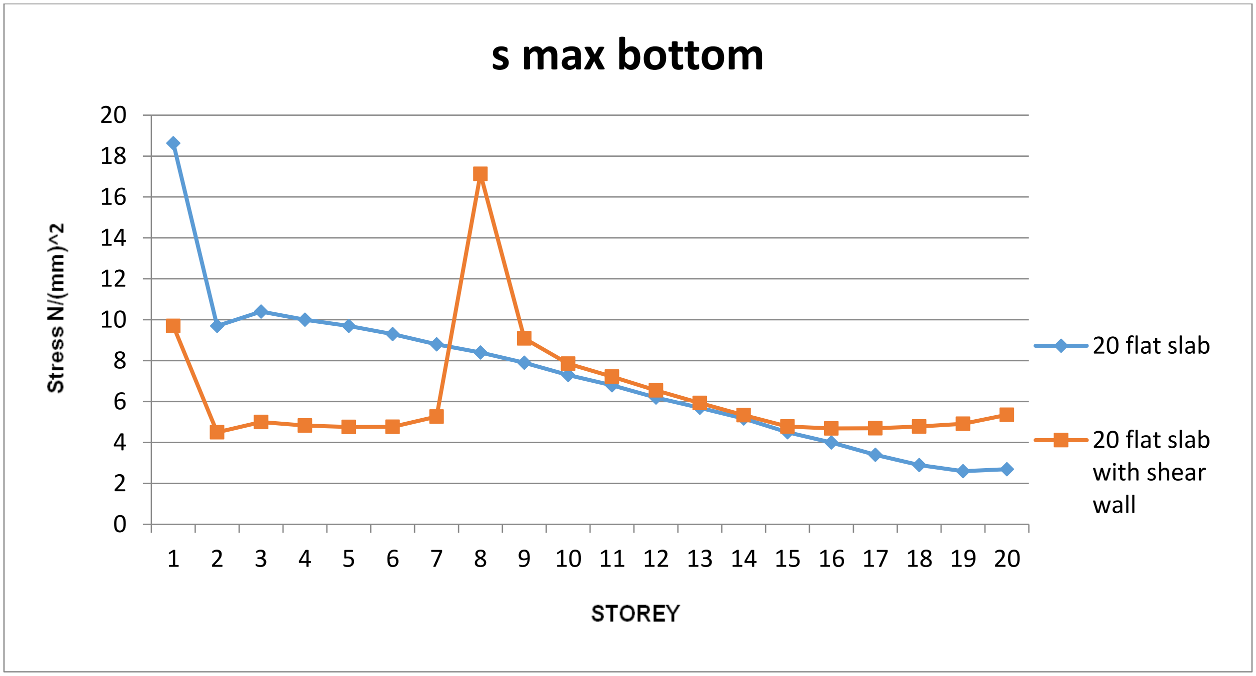

FIGURE 39: Max bottom principal stresses variation with height for 20 storey flat slab structure without and with shear wall

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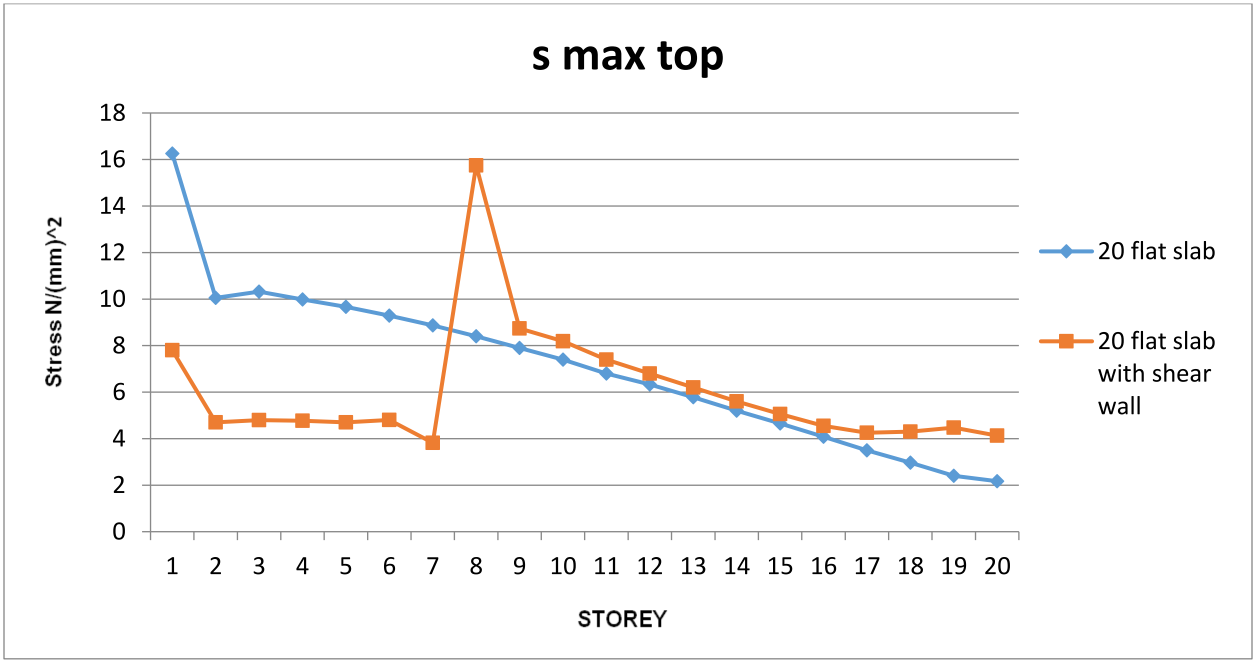

FIGURE 41: Max top principal stresses variation with height for 20 storey flat slab structure without and with shear wall

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p-ISSN: 2348-795X
Volume 05 Issue 15
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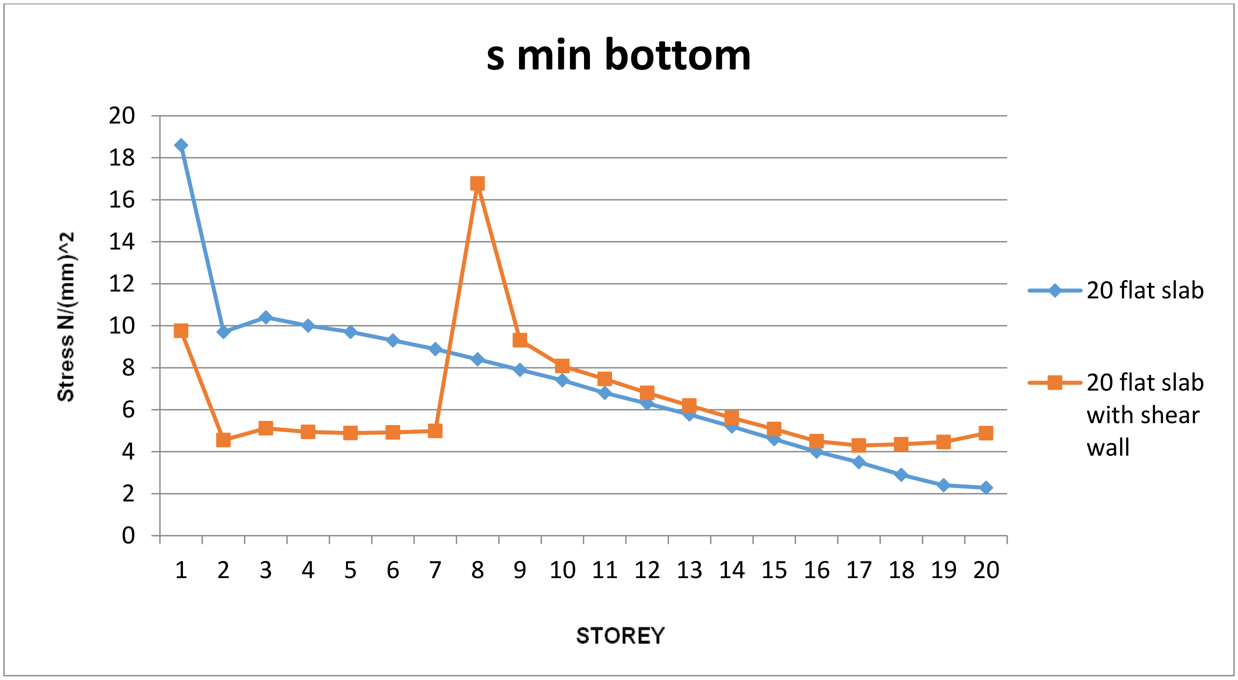

FIGURE 40: Min Bottom principal stresses variation with height for 20 storey flat slab structure without and with shear wall

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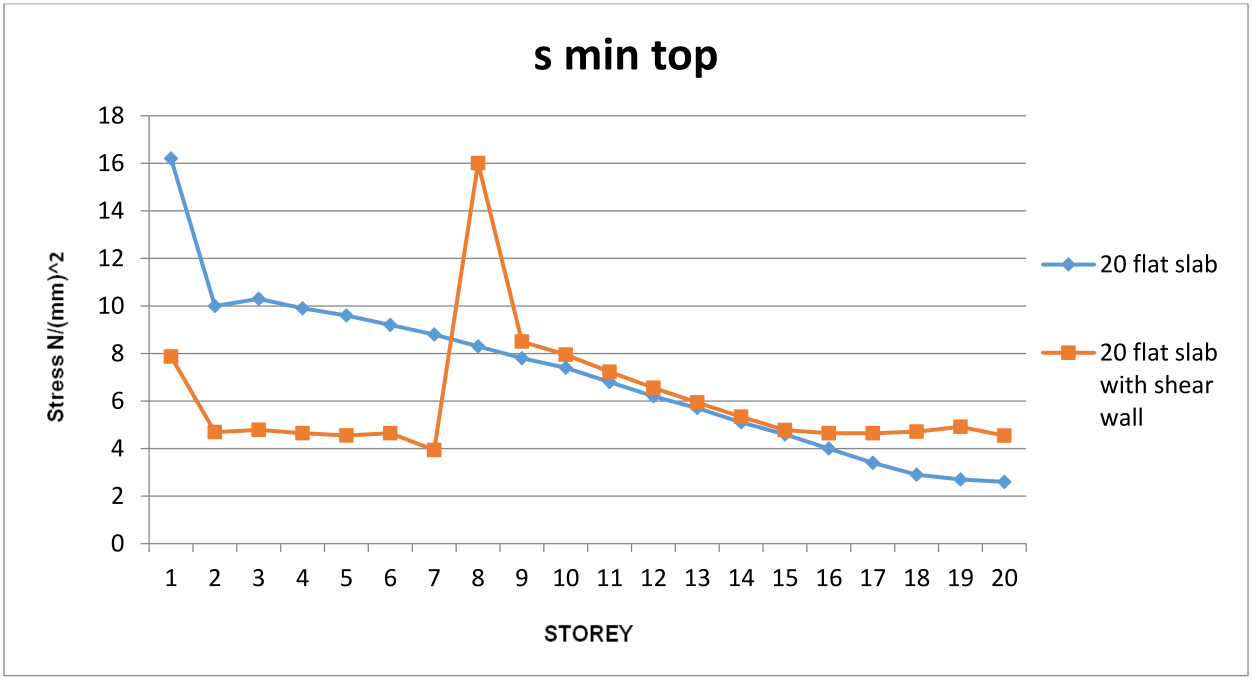

FIGURE 42: Min top principal stresses variation with height for 20 storey flat slab structure without and with shear wall

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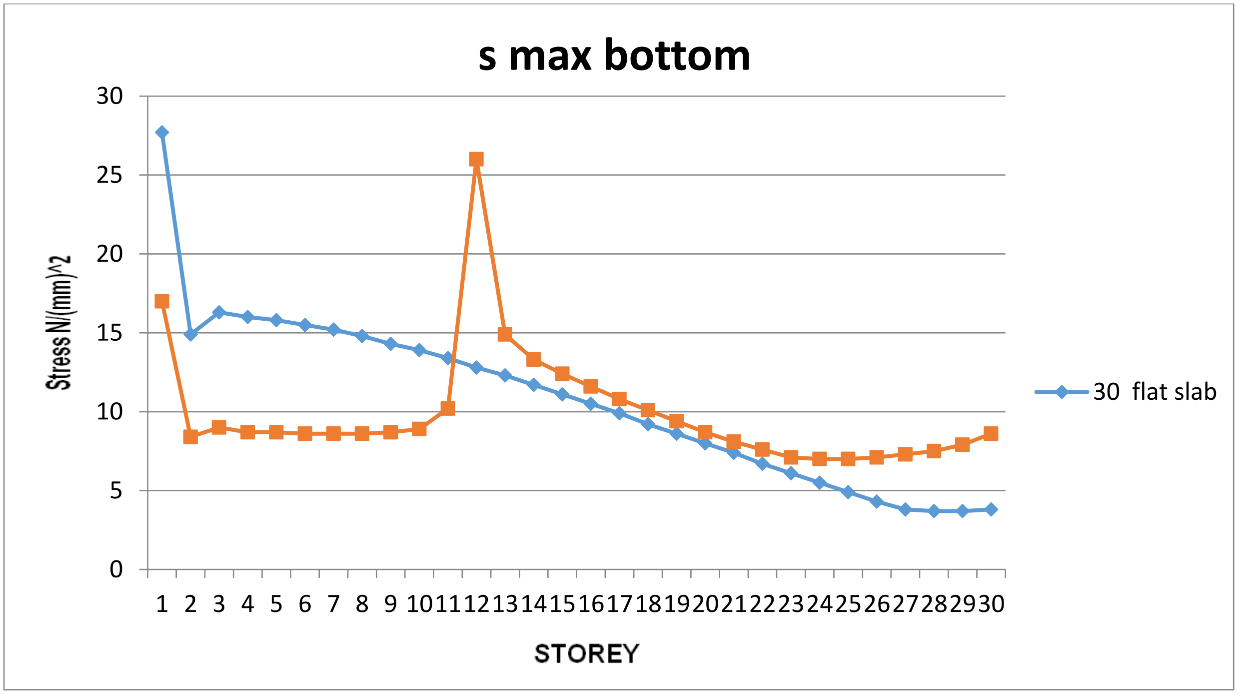

FIGURE 43: Max bottom principal stresses variation with height for 30 storey flat slab structure without and with shear wall

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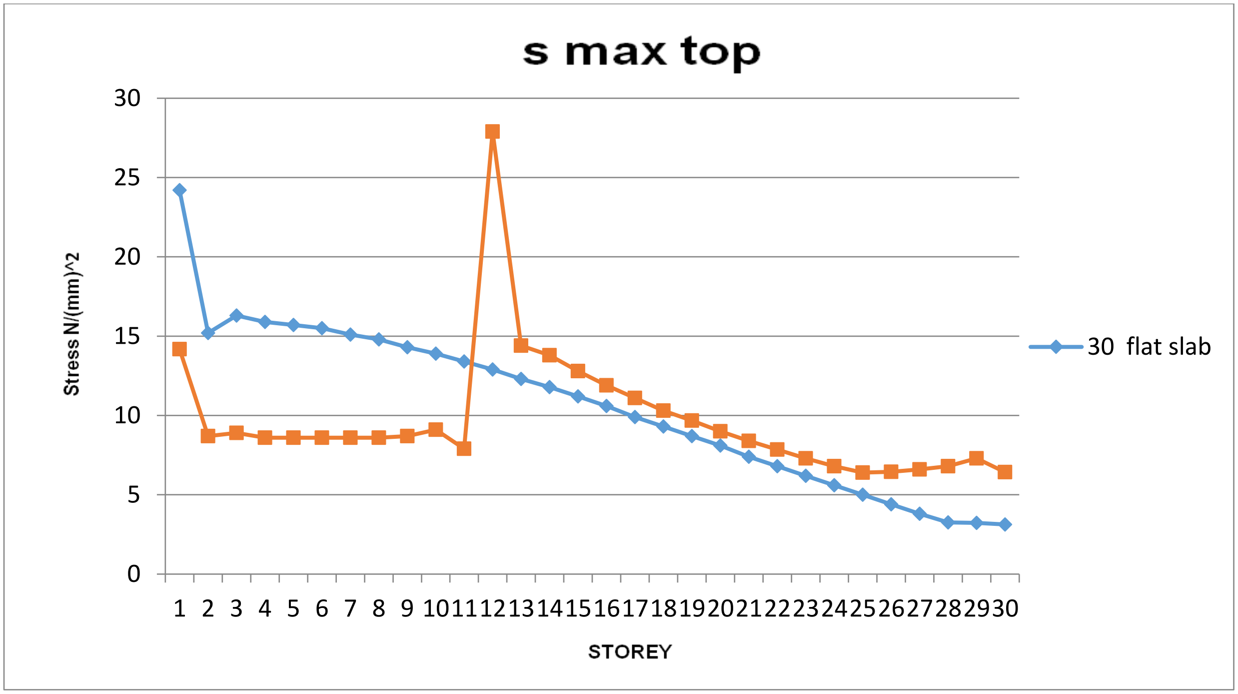

FIGURE 44: Max top principal stresses variation with height for 30 storey flat slab structure without and with shear wall

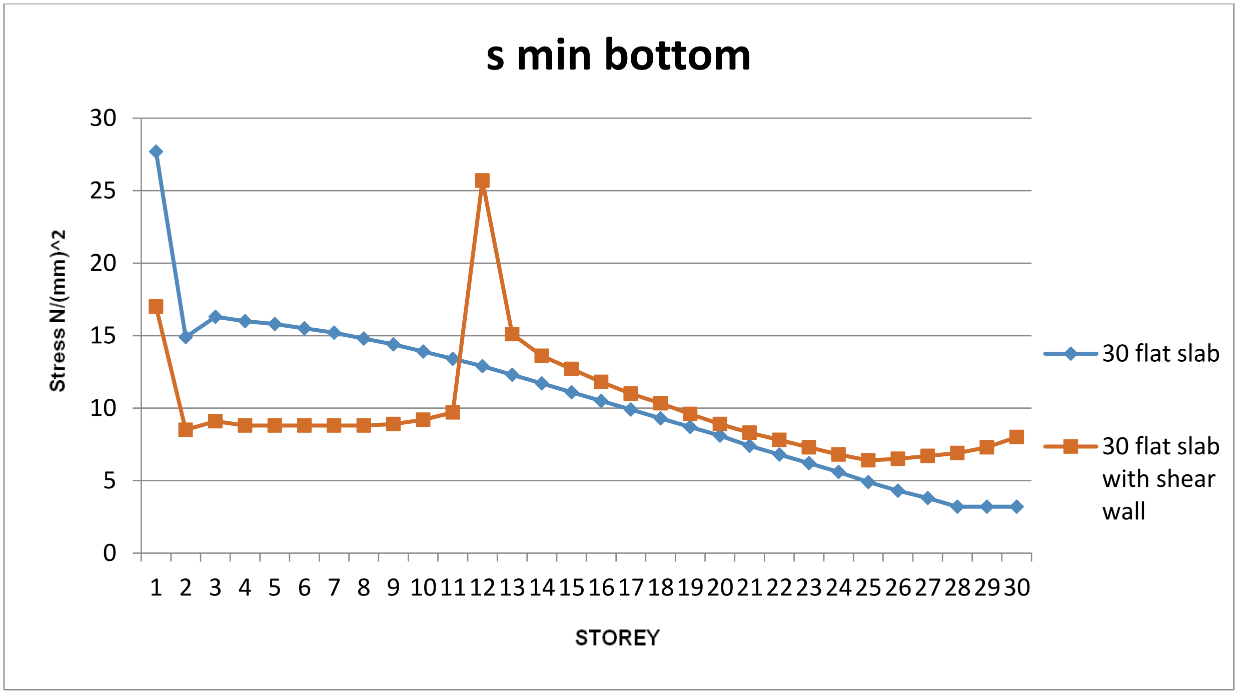

FIGURE 45: Min Bottom principal stresses variation with height for 30 storey flat slab structure without and with shear wall

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p-ISSN: 2348-795X
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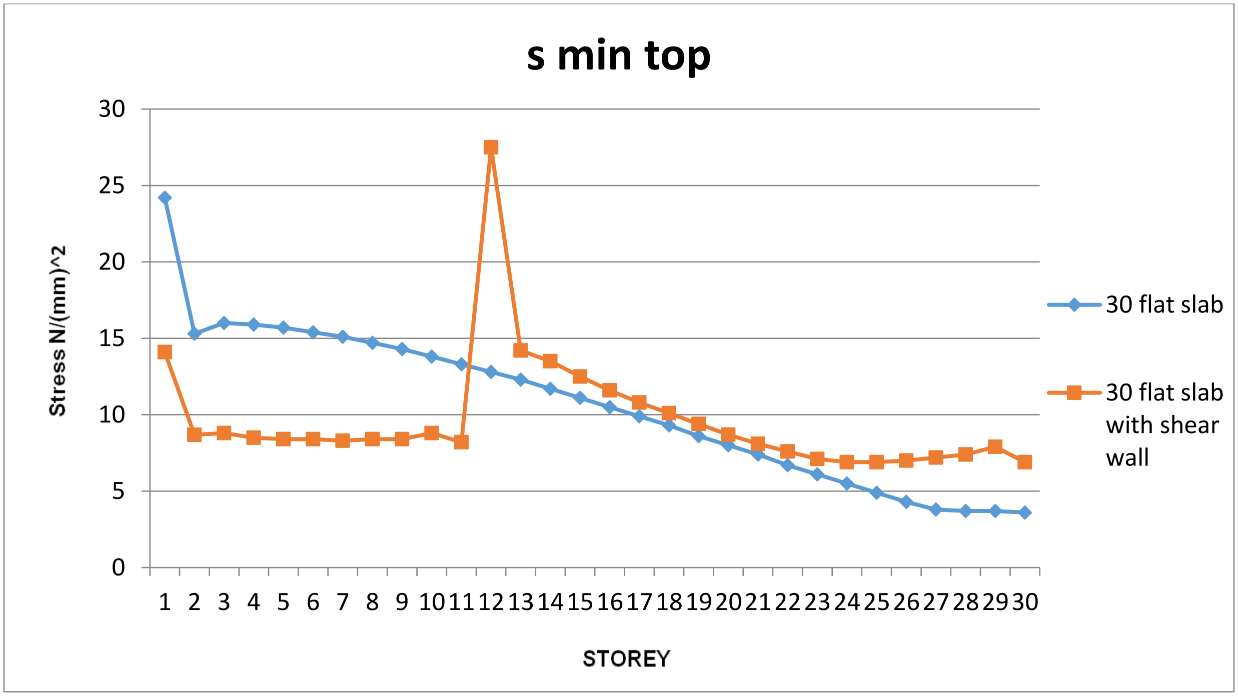

FIGURE 46: Min top principal stresses variation with height for 30 storey flat slab structure without and with shear wall

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p-ISSN: 2348-795X
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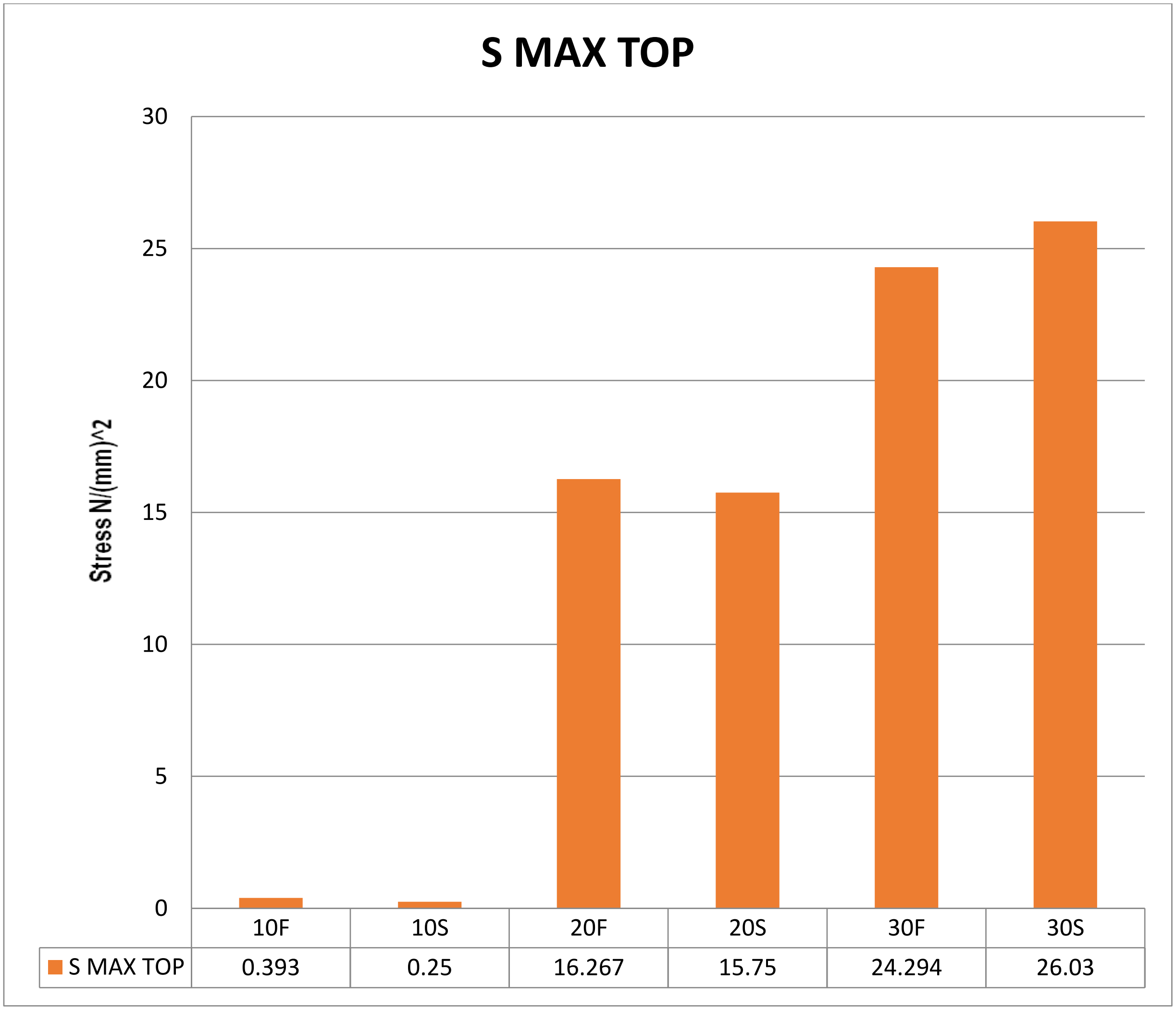

FIGURE 47: Comparison of principal stresses S Max top graph with and without shear wall for 10,20,30 stories

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p-ISSN: 2348-795X
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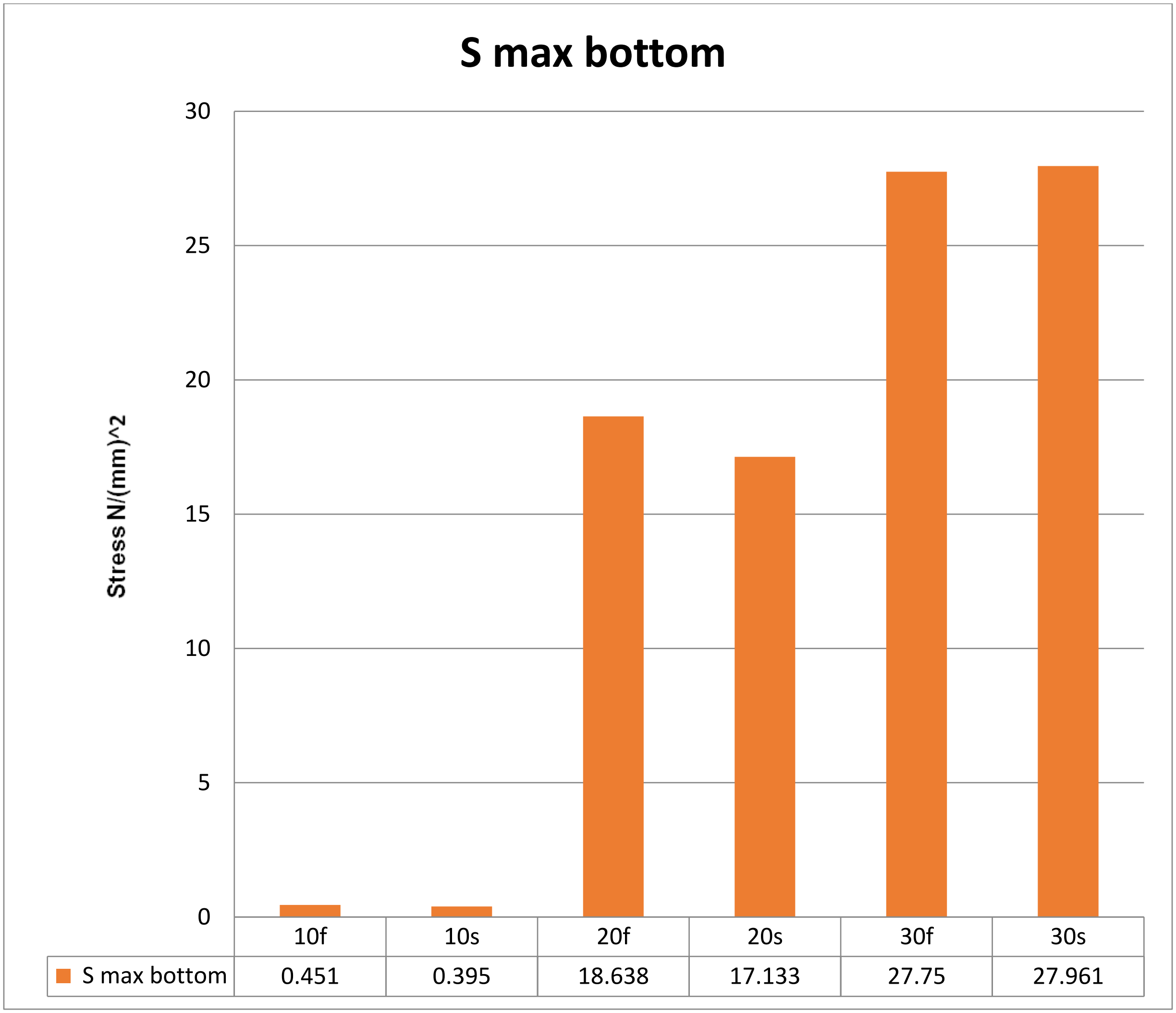

FIGURE 48: Comparison of principal stresses S Max bottom graph with and without shear wall for 10,20,30 storey

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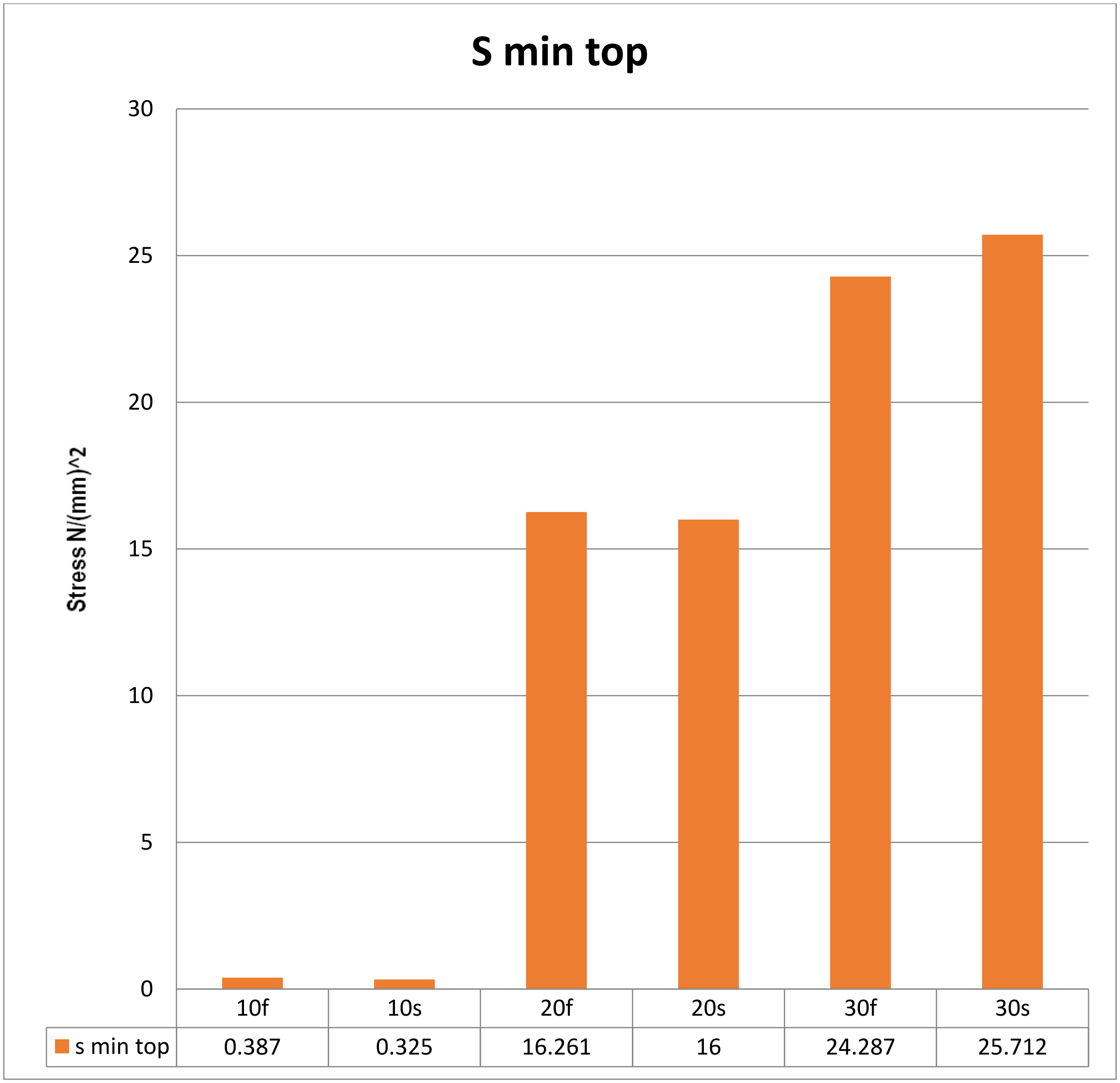

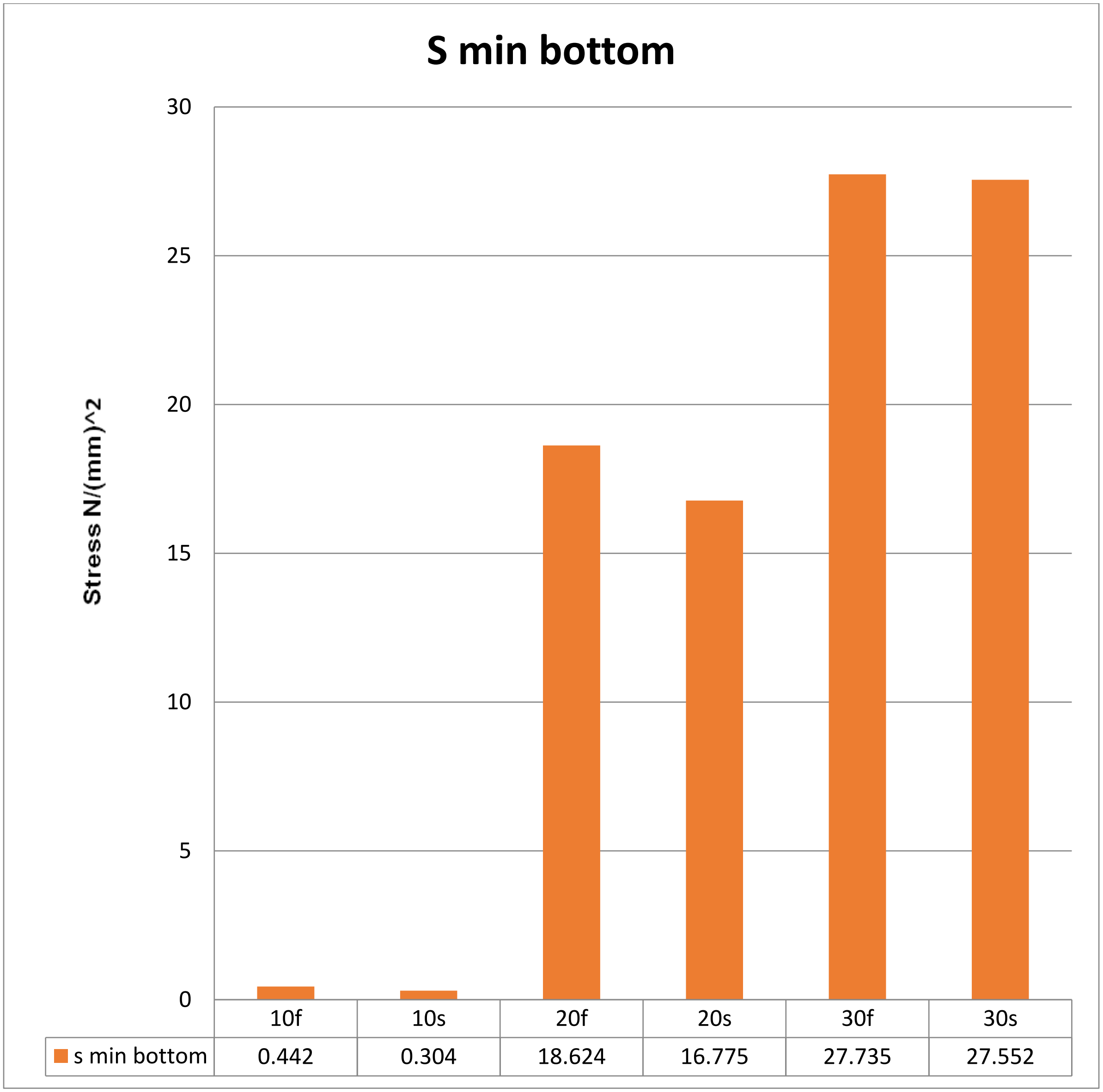
S min bottom
Stress N/(mm)^2
30
25
20
15
10
5
0
10f
10s
20f
20s
30f
30s
s min bottom
0.442
0.304
18.624
16.775
27.735
27.552

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FIGURE 50: comparison of principal stresses S Min bottom graph with and without shear wall for 10,20,30 storey

CONCLUSION

Considering the results of the analysis for the principal stresses in flat slab of 10,20, 30 storied flat slab multi- storied building with and without shear wall under the action of seismic load we reached the following conclusions.

1. The principal stresses are maximum on flat slab at lowest height and we obtain a sudden step down in stresses at adjacent upper storey then the stresses decreases linearly with increase in height for a multi-storied building without shear wall
2. We obtain a sudden hike or peak in the principal stresses in the flat slab at a height of 40 % of the total height of the multi-storied building with shear wall
3. The value principal stresses in flat slab increases with increase of number of storey's in multi-storied building
4. The graphs plotted for the variation of Max top principal stresses, Max bottom principal stresses, Min top principal stresses, Min bottom principal stresses along the height of a flat slab structure with and without shear wall shows similar variation profile for all four type of stresses.
5. We found that the maximum value of bottom principal stresses are more than the maximum value of top principal stresses for 10, 20 and 30 storied flat slab building with and without shear wall.

6. The Principal top stress varied by 16.02% and bottom stress varied by 12.41% for 10 storied building (without and with shear wall) building.
7. The Principal top stress varied by 3.18 % and bottom stress varied by 8.07% for 20 storied building (without and with shear wall) building.
8. The Principal top stress varied by -7.14% and bottom stress varied by -0.76% for 30 storied building (without and with shear wall) building.

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p-ISSN: 2348-795X
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FUTURE SCOPE OF WORK :

The review has shown that in the previous decade, much progress has been made in developing and understanding practical structural Flat Slab with Shear Wall structures in multi-storied building frames. An appraisal of these recommendations indicates that further work is needed in the following areas:

1. Identical building of (5 bay x 5 bay) is taken in problem for simplicity, but commercial and residential building are irregular shape in plan can also be taken up for further work.
2. The problem building is only symmetric square building, one can take rectangle, L-shape, C-shape building with eccentricity.
3. Shape of shear wall is taken in this building is rectangular; one can take different shapes such as L,U,C for further work.
4. The structure can be analysed for different seismic zones.
5. The dynamic analysis of structure can also be carried out.