# Analysis, Design & Comparison of a Multi-Storied Building with and without Shear Wall in STADD-Pro

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*Abstract*— In modern world buildings with shear wall having a distinctive qualities in the modern multi-storey construction in urban India. So such typical construction is highly undesirable in high building built in seismically active areas. Here we study the importance of recognizing the presence of the shear wall in the analysis of building. Design of RCC elements will also be perform as per IS-456 2000 for the building with shear wall. A numerical study will perform using Staad pro Software will be used for multi storey 3D frames with shear wall and without shear wall to gain the knowledge and responses of the building structure under seismic and wind loads. Shear force, Bending moment, Axial force, inter storey drift, base shear, storey shear, storey moment will be computed for both the buildings with and without shear wall and comparing the results.
***Key words:*** STADD, RC Walls, RCC

## I. Introduction

Many high-rise multi-storey buildings have been build in different countries of the world. The trend of construction of large structures for both office & residential purposes is rapidly increasing. The main reasons for this trend are the increase in population densities due to urbanization, the growth of population and the high cost of land in urban areas. The economic prosperity and the technological advancement are also part responsible for the evolution of tall buildings. In many cases, tall buildings evolve as prestige symbols for commercial enterprises and organizations.

Although the construction of high-rise buildings has solved the problem of usable space in urban areas, it has caused many environmental and psychological social problems. The construction of high-rise buildings in the neighborhood of low-rise dwellings may spoil the urban aesthetics. It can also aggravate traffic problems if the location does not fit into the existing planning of the city. Closely spaced high-rise buildings may also cause pollution problems and obstruct sunlight, to the adjacent properties. A child brought up in high-rise buildings has less chance to explore and manipulate the environment. This may adversely affect the psychological development of the child in future years. The inhabitants of high-rise buildings often exhibit greater feelings of indifference and withdrawal towards neighbors. This is in contrast to dwellers of low-rise houses. The crime rate in high-rise buildings is higher compared to relatively low rise buildings. These are some of the problems for which the high-rise buildings are criticized in recent times.

Structural components such as walls, beams, columns and floor slabs form an integrated structural system of building. The structure and its components support the vertical and lateral loads applied to the building. The vertical load arises due to the self-weight of the components, the occupants and other objects broadly classified, as live loads. The lateral loads arise due to the action of wind, earthquake or blast effect. Different structural loads to be considered in the design of buildings are given in IS 1893-2002 and IS: 875-part 3. To design a structurally safe building, it is necessary to find the load taken by each component so that each component can be designed accordingly. For that reason a structural analysis is needed. The next step is proportion the components such that the criteria for stresses and deflections are satisfied. The Indian Structural Design Manual provides guidance in the design of structural components with steel, reinforced concrete, pre stressed concrete and other materials.

Complex interaction of the stiff floors with the walls increases the lateral stiffness of the structure. Besides acting as load bearing walls, these shear walls act as an internal partitions, acoustic barriers provide Fire divisions within the building. The arrangement of shear wall in a typical apartment building is shown in Figure 1. The shear walls are mainly located in both sides of corridor. The elevator shaft and stair well is also enclosed by shear walls.

In an office building, the arrangement of shear walls is different. The shear walls are located at the center; of the office building the arrangement of shear walls is different. Mainly to form a service core for the staircases and elevators. The central core is surrounded by columns which are interconnected to form different structural frames.

The arrangement of shear walls in a typical office building is shown in Figure 2.The present thesis is a study of these types of structures and their structural behavior when subjected to lateral loadings.

## II. Methodology

Generally, multi-story high rise buildings suffer higher lateral displacement in the presence of Wind and Earthquake loads. It becomes important to reduce such lateral movement within the acceptable limits. Larger the displacement, higher the induced moments, shear and discomfort.

1) It significantly reduces lateral displacement/story displacement /story drift.
2) Reduces the time period of vibration of the building.
3) Reduces moments and induced torsion during earthquakes.
4) Increases stiffness of the building.

In India a considerable number of buildings have reinforced concrete structural systems. This is due to economic reasons. Reinforced concrete building structures can be classified:

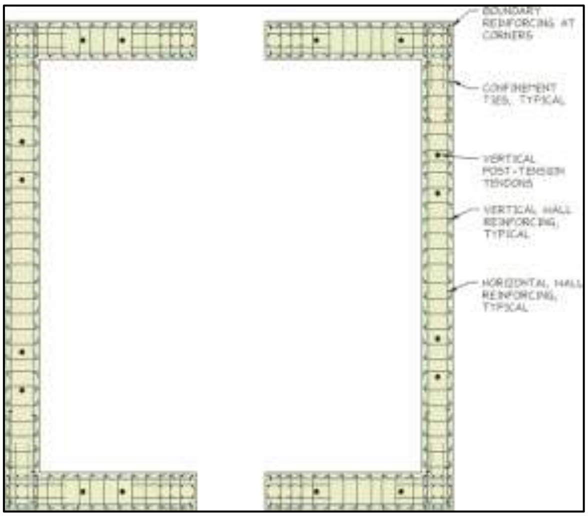
1) Structural Frame Systems: The structural system consists of frames. Floor slabs, beams and columns are the basic elements of the structural system. Such frames can carry gravity loads while providing adequate stiffness.
2) Structural Wall Systems: In this type of structures, all the vertical members are made of structural walls, generally called shear walls.

3) It consist of a reinforced concrete frames interacting with concrete shear wall.

## III. Reinforcement Bars in RC Walls

It depends - are we talking about a specific wall in timber, concrete, masonry, steel or what?

Steel bars embedded in concrete are one form of reinforcement. Deformation of the plan profile to form piers or columns makes up a second method of reinforcement. Using sheet plies over timber framing are a third form of wall reinforcement. Reinforcement to masonry walls usually takes the form of piers or pilasters and probably includes vertical and horizontally- embedded steel bars in grout fill. Basically wall reinforcements are methods of increasing resistance to shear, bending, torsion, tension or compression in an otherwise flat vertical surface. It can also take the form of thickening with depth, so that a wall becomes thicker toward the base, assuming the wall to be loaded from behind by water or soils.




### A. *One-way and two-way reinforced concrete slabs.*

One way slab is a slab which is supported by beams on the two opposite sides to carry the load along one direction .The ratio of longer span (l) to shorter span (b) is equal or greater than 2, considered as One way slab because this slab will bend in one direction i.e in the direction along its shorter span

Due to the huge difference in lengths, load is not transferred to the shorter beams. Main reinforcement is provided in shorter span and distribution reinforcement in longer span.

Two way slab is a slab supported by beams on all the four sides and the loads are carried by the supports along both directions, it is known as two way slab. In two way slab, the ratio of longer span (l) to shorter span (b) is less than 2.

In two way slabs, load will be carried in both the directions. So, main reinforcement is provided in both direction for two way slabs.

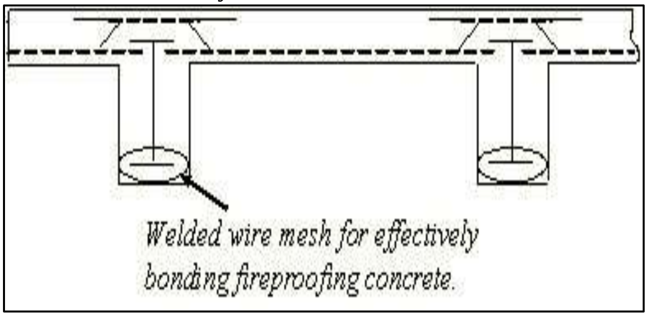



Fig. 3.5: Cross section of one-way slab floor

### B. *Braced frames:*

1) A column may be considered braced in a given plan if lateral stability of the structure as a whole is provided by walls or bracing.
2) These coulmn are not designed to resist lateral load
3) These coulmn have zero value of sway force
4) structural system having bracing is most used for the important structure

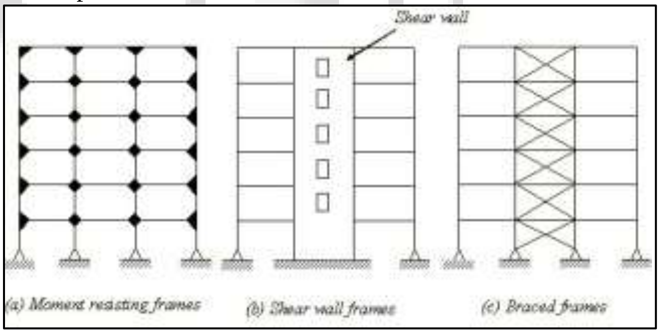



Fig. 3.6: Lateral load resisting systems

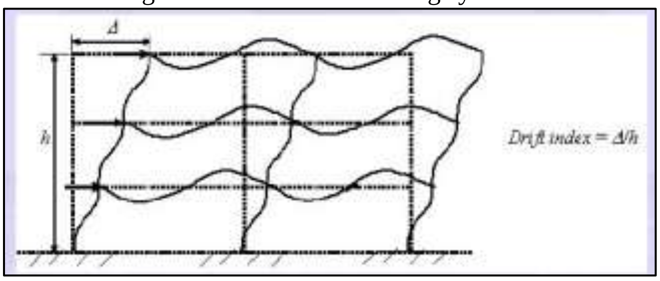



Fig. 3.7: Lateral drift

### C. *Loads Considered*:

Loads and properties of materials constitute the basic parameter of a R.C structures. Both of them are basically of a varying nature .For such a quality of varying nature, it is necessary to arrive of a single representative value. Such value is known as characteristic value. The value to be taken in design which provides appropriate or designed margin of safety is known as design values. The loads are taken as per IS-875 and the material properties like characteristic value are taken from IS: 456-2000.

*1) Dead loads:*

Dead load is the load from the self-weight of the structure and whatever is permanently attached to it and acts always. The dead load on a building is the weight of the building, its walls, beams and columns.

### D. *Imposed loads or live load:*

Live loads are either mobile or moving burdens with no increasing speed or effect. There are thought to be created by the expected utilize or inhabitance of the building including weights of versatile segments or furniture and so on. The floor sections must be intended to convey either consistently appropriated stacks or thought loads whichever deliver more noteworthy worries in the part under thought. Since it is improbable that any one specific time all floors won't be all the while conveying greatest stacking, the code allows some lessening in forced loads in planning segments, stack bearing dividers, wharfs backings and establishments.

### E. *Design Wind Speed (Vz):*

The essential breeze speed (Vz) for any site might be acquired from and should be adjusted to incorporate the accompanying impacts to get configuration twist speed at any stature (V,) for the picked from

1) Risk level;
2) Terrain roughness, height and size of structure; and
3) Local topography.

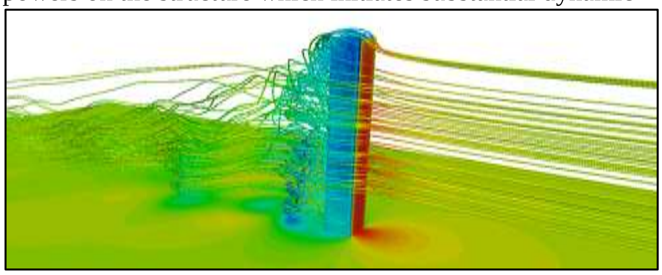
It can be mathematically expressed as follows:
Where:

$$V_z = V_b \times K_1 \times K_2 \times K^3$$

$V_b$ = design wind speed at any height z in m/s;
$K_1$ = probability factor (risk coefficient)
$K_2$= terrain, height and structure size factor and
$K_3$ = topography factor

*1) Wind pressures and forces on buildings / structures:*

Twist consequences for structures can be named Static and Dynamic. Static breeze impact essentially causes versatile bowing and winding of structure. What's more, for tall, long traverse and slim structures a dynamic examination of the structure is fundamental. Wind blasts cause fluctuating powers on the structure which initiates substantial dynamic



### F. *Pressure Coefficients -*

$$F = (C_{pe} – C_{pi})\ A\ P_d$$

Where,
$C_{pe}$ = external pressure coefficient,
$C_{pi}$ = internal pressure- coefficient,
A = surface area of structural or cladding unit, and
$P_d$ = design wind pressure element

3.5.4 Seismic load**:**

### G. *Design Lateral Force*

The design lateral force shall first be computed for the building as a whole. This plan parallel compel should then be circulated to the different floor levels We require a horizontal drive opposing framework to oppose tremor or wind strengths. For that we have solid shear dividers, minute edges, propped casings et cetera.

### H. *Design Seismic Base Shear*

$$V_b = A_h \text{ X } W$$

Where,
$A_h$ = horizontal acceleration spectrum
W = seismic weight of all the floors

### I. *Fundamental Natural Period*

Where,

$$T = \frac{0.09H}{\sqrt{D}}$$

Where,
h= Height of building
d= Base dimension of the building at the plinth level, in m, along the considered direction of the lateral force.

Distribution of Design Force (Storey Shear) :

$$Q_i = V_B \frac{W_i h_i^2}{\sum_{j=1}^{n} W_i h_i^2}$$

Qi=Design lateral force at floor i,
Wi=Seismic weight of floor i,
$h_i$=Height of floor i measured from base, and
n=Number of storeys in the building is the number of levels at which the masses are located.

## III. RESULTS AND DISCUSSION

Beam results from Staad

BEANM NO. 3756 DESIGN RESULTS

M30 Fe415 (Main) Fe415 (Sec.)

LENGTH: 4390.0 mm SIZE: 300.0 mm X 450.0 mm COVER: 25.0 mm

STAAD SPACE -- PAGE NO. 129

SUMMARY OF REINF. AREA (Sq.mm)

| SECTION | 0.0 mm | 1097.5 mm | 2195.0 mm | 3292.5 mm | 4390.0 mm |
|---|---|---|---|---|---|
| TOP REINF. | 376.98 (Sq. mm) | 0.00 (Sq. mm) | 0.00 (Sq. mm) | 734.82 (Sq. mm) | 2164.15 (Sq. mm) |
| BOTTOM REINF. | 1483.36 (Sq. mm) | 841.94 (Sq. mm) | 257.46 (Sq. mm) | 257.46 (Sq. mm) | 412.00 (Sq. mm) |

SUMMARY OF PROVIDED REINF. AREA

| SECTION | 0.0 mm | 1097.5 mm | 2195.0 mm | 3292.5 mm | 4390.0 mm |
|---|---|---|---|---|---|
| TOP | 3-20í | 2-20í | 2-20í | 3-20í | 7-20í |
| REINF. | 1 layer(s) | 1 layer(s) | 1 layer(s) | 1 layer(s) | 2 layer(s) |
| BOTTOM | 5-20í | 3-20í | 3-20í | 3-20í | 3-20í |
| REINF. | 1 layer(s) | 1 layer(s) | 1 layer(s) | 1 layer(s) | 1 layer(s) |
| SHEAR | 2 legged 8í | 2 legged 8í | 2 legged 8í | 2 legged 8í | 2 legged 8í |
| REINF. | @ 150 mm c/c | @ 150 mm c/c | @ 150 mm c/c | @ 150 mm c/c | @ 150 mm c/c |

SHEAR DESIGN RESULTS AT DISTANCE d (EFFECTIVE DEPTH) FROM FACE OF THE SUPPORT

SHEAR DESIGN RESULTS AT 665.0 mm AWAY FROM START SUPPORT

VY = -65.85 MX = 0.13 LD= 118

Provide 2 Legged 12í @ 150 mm c/c

SHEAR DESIGN RESULTS AT 715.0 mm AWAY FROM END SUPPORT

VY = -146.02 MX = 0.31 LD= 109

Provide 2 Legged 12í @ 150 mm c/c

BEAM NO. 3763 DESIGN RESULTS

M30 Fe415 (Main) Fe415 (Sec.)

LENGTH: 1340.0 mm SIZE: 300.0 mm X 450.0 mm COVER: 25.0 mm

SUMMARY OF REINF. AREA (Sq.mm)

| SECTION | 0.0 mm | 335.0 mm | 670.0 mm | 1005.0 mm | 1340.0 mm |
|---|---|---|---|---|---|
| TOP | 1075.29 | 677.25 | 356.71 | 257.46 | 0.00 |
| REINF. | (Sq. mm) | (Sq. mm) | (Sq. mm) | (Sq. mm) | (Sq. mm) |
| BOTTOM | 0.00 | 256.23 | 256.23 | 256.23 | 393.68 |
| REINF. | (Sq. mm) | (Sq. mm) | (Sq. mm) | (Sq. mm) | (Sq. mm) |

1) *Bending moment of beams with shear wall:*

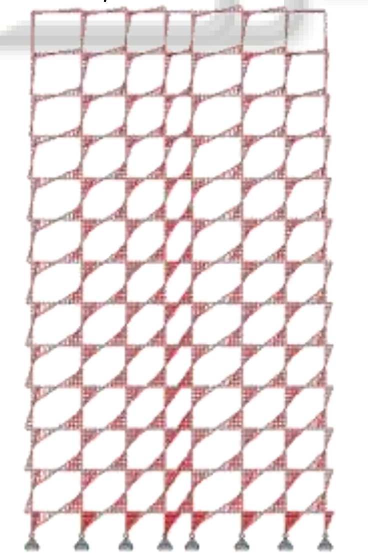


Fig. 5.5: Bending moment of beams with shear wall

J. *Bending moment of beams without shear wall:*

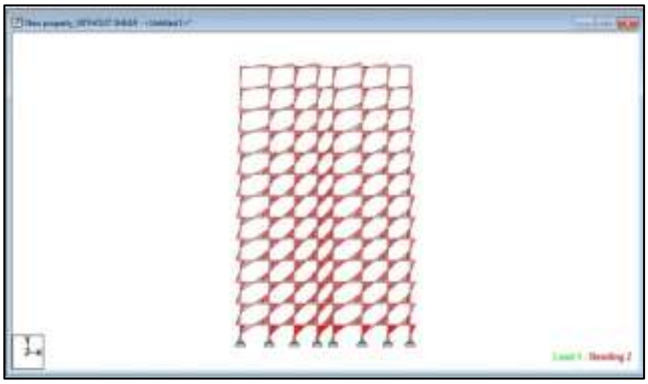


Fig. 5.6: Bending moment of beams without shear wall

1) *Shear force of beams with shear wall:*

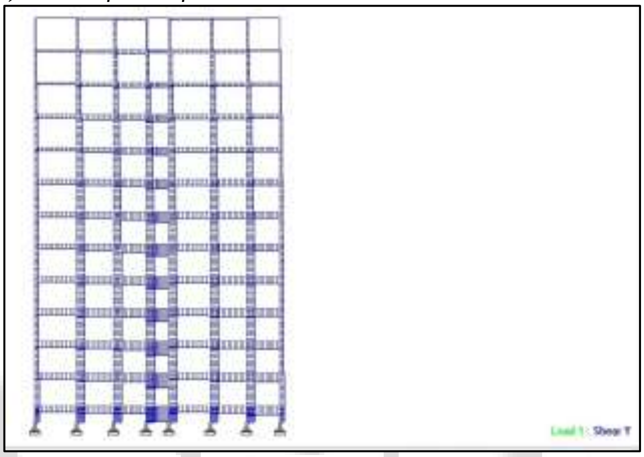


Fig. 5.7: Shear force of beams with shear wall

K. *Design of stair case:*

Design of Flight Slab

No of flights for each floor = 2

Height of the floor = 3.5m

Height of each flight = 3. 5 / 2 = 1.75m

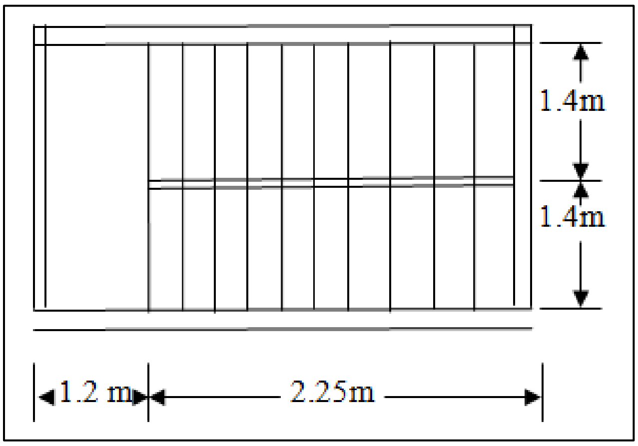
Assume Raise as 150mm and Tread as 250mm

No of Raisers = 1.75 / 0.15 = 11.66 (say 12)

Say Raise = 150mm

No of Treads = 12-1 = 11 Treads

Width of Stair = 1.2m




Effective Span = 3.425m

Span / Overall depth = 20 for deflection criteria

Let modification factor = 3425 / (20 x 1.20) = 142.7 mm (Say 150 mm)

Effective depth = 150-15-6 = 129mm (say 130 mm)
Loads:
Per meter width of stair case
Dead load of slab (On slope) = 0.150 x 1.00 x 25 = 3.75 KN/m
Finished load (On slope)
= 1.50 KN/m
5.25KN/m
Dead load of slab / horizontal meter run

$$5.25\left[\frac{\sqrt{250^2+150^2}}{250}\right] = 6.122\ KN/m^2$$

Dead load of one step = ½ x 0.150 x 0.23 x 19 = 0.33KN
Dead load of steps / horizontal meter run = 0.33/0.25 = 1.32KN/m
Imposed load 3KN/m$^2$ = 3.00 KN/m
Total working load = 10.442 KN/m
Factored Load = 1.50 x 10.442 = 15.663 KN/m
Bending Moment:
Maxi. BM = WL$^2$ / 8 = (15.663 x 3.425$^2$) / 8 = 22.96 KN-m
Effective depth of slab (For max.BM):
$M_u$ lim = 0.138 $f_{ck}$ bd$^2$

$$d = \sqrt{\frac{M_u\ lim}{0.138\ f_{ck}\ b}}$$

$$d = \sqrt{\frac{22.96 \times 10^6}{0.138 \times 25 \times 10^3}} = 81.57mm < \text{available depth 130mm}$$

Hence OK.
Calculation of Area of steel
$M_D$ = 22.96 KN-m

$$Ast = \frac{0.5\ fck}{fy}\left(1-\sqrt{1-\frac{4.6\ X\ M_D}{fckbd^2}}\right) X\ bd$$

$$Ast = \frac{0.5\ X\ 25}{415}\left(1-\sqrt{1-\frac{4.6\ X\ 22.96\ X\ 10^6}{25\ X\ 1000\ X 130^2}}\right) X\ 1000\ X\ 130$$

= 525 mm$^2$ > 120 mm$^2$ (Min.$A_{st}$ 0.12% of bD as per Clause26.5.2.1 of IS: 456-2000)

Provide 8 mm dia. Tor steel Ast = $\frac{\pi\ X\ 12^2}{4}$ = 113mm$^2$

Spacing of Steel:

$$= \frac{ast}{Ast}\ X\ 1000$$

$$\text{Spacing of Steel} = \frac{113}{525}\ X\ 1000$$

But maximum spacing of Tension Reinforcement as per Clause 26.3.3 b 1 from
IS: 456 – 2000 is 3d or 300 mm whichever is less.
3 x 130 = 390mm or 300 mm
Hence provide 12 mm dia. @ 200 mm C/C
Revised $A_{stx}$m = (1000 x 113) / 200 = 565 mm$^2$
Distribution Steel:
Area of steel = 0.12% of gross sectional area
= (0.12 x 1000 x 150) / 100 = 180 mm$^2$
Provide 8 mm dia. Tor steel ast = $\frac{\pi\ X\ 8^2}{4} = 50.26\ mm^2$

$$\text{Spacing of Steel} = \frac{ast}{Ast}\ X\ 1000$$

$$\text{Spacing of Steel} = \frac{50.26}{180}\ X\ 1000 = 279.22mm$$

But maximum spacing of Tension Reinforcement as per Clause 26.3.3 b 2 from
IS: 456 – 2000 is 5d or 450 mm whichever is less.
5 x 130= 650 mm or 450 mm
Hence provide 8mm dia. @ 270 mm C/C
Revised $A_{stx}$ m = (1000 x 50.2) / 270 = 186mm$^2$
Check for Shear:
Shear Force ($V_u$) = WL/2 = (15.663 x 3.425) / 2 = 27 KN
Nominal shear stress ($\tau_V$) = $V_u$ / bd = (27 x 10$^6$) / (1000 x 130) = 0.20 N/mm$^2$
Area of steel available $A_{st}$ = 565mm$^2$
$P_t$ % = (100 x 565/ 1000 x130) = 0.43 %
From Table 19 of IS: 456- 2000 $\tau_c$ = 0.397 N/ mm$^2$
$\tau_c > \tau_V$ Hence shear stress is within limits
Check for Bond:
Development length $L_d$ for 12 mm ǿ = (ǿ x 0.87$f_y$) / 4 $\tau_{bd}$
= (12 x 0.87 x 415) / 4 x 1.20 = 902mm
From 26.2.1.1 of IS: 456 – 2000
$\tau_{bd}$ = 1.20
Tension bars crossing at bends should be extended by 902mm beyond crossing point.
Check for Serviceability:
Basic l/d Ratio = 20
$P_t$ = 0.43% Service stress = (0.58 x 415 x 525) / 565 = 223N/mm$^2$
Modification factor = 1.20
Modified value of l/d ratio = 20 x 1.20 = 24
Actual l/d ratio = 3425/130= 26.34 > 24
Actual l/d ratio is > modified value of l/d ratio
Hence the thickness of the slab to be increased.

## IV. CONCLUSIONS

The behaviour of multi-storey building with and without shear wall is studied under zone-II. The linear static method has been used. A 3D model has been developed to study the behaviour of multi-story frame using Staad Pro. Software. The results obtained are presented in the form of tables and graphs. The analyses of frames are studied under wind and seismic loads. It is concluded that with seismic and wind loads, the storey shear, Columns forces without shear wall, increases when compared to the columns with shear wall.

Comparing the results of storey drifts, storey moment and displacements of both models, structures with shear wall behaves well than the structure without shear wall.

From results and discussion it can be concluded that the structure with shear wall is more preferable than that of structure without shear wall in seismic and wind prone areas.

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