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Comparative Analysis of RCC Flat Slab with Post-Tensioned Flat Slab

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ABSTRACT

A floor system plays an important role in overall cost and service of the building. Flat plate/slabs are economical since they have no beams and hence can reduce the floor height by 10-15%. In this paper analysis of RC flat slab with drop and post-tensioned flat slab with drop is carried out. This analysis is done for ground floor slab level and G+2 slab level. A finite element based software ETABS (vr.2016) is used for analyzing parameters like strip wise bending moments, shear force and displacements. A comparative analysis is carried out for maximum values of bending moments, shear force and displacements found in RCC and PT flat slab. The present work provides reasonable information regarding the suitability of Post-tensioned flat slab over RC flat slab.

Keywords : Finite Element Analysis, Etabs, Post-Tensioned Flat Slab, Strip Moments, Displacement, Shear Force

I. INTRODUCTION

A slab is a flat two dimensional planar structural element having thickness small compared to its other two dimensions. A flat slab consists of a reinforced concrete slab that is directly supported by concrete columns. C.A.P. Turner constructed flat slabs in U.S.A. in 1906 mainly by conceptual ideas, which was the origin of this type of construction. Later in 1914, Nicholas proposed a method of analysis of flat slabs based on simple statics. This method is used even today for the design of flat slabs and flat plates and is known as the direct design method. In the present work performance of RC flat slab and Post-tensioned flat slab are studied for Ground and G+2 slab level. Flat slab panels with spans **5mx5m and 10mx10m** are studied.

OBJECTIVES

- To study the performance of RC flat slab and Post-tensioned flat slab
- To study the behavior of both the structures for parameters like maximum strip bending moment, maximum shear force and maximum displacement.
- Comparison of conventional flat slab and post-tensioned flat slab for above parameters.

II. MATERIAL PROPERTIES AND LOADS

This work has been analyzed using ETABS software. For the analysis the material properties like grade of concrete, steel, density, modulus of elasticity must be defined initially. And also the loads like dead and live load needs to be define earlier.

Design Parameters-

Dead load= 1.5kN/m²

Live load= 3kN/m²

Floor to Floor Height= 3m

Column Size for 5m span= 650mmx650mm

For 10m span= 800mmx800mm

Grade of Concrete M25

Grade of steel Fe 415

III. METHODS OF ANALYSIS FOR FLAT PLATES

For this IS 456-2000 Cl.no.31.3.1 permits use of any one of the following two methods:

(a) The Direct Design Method

(b) The Equivalent Frame Method

Both Direct Design Method and Equivalent Frame methods are approximate methods so values of bending moment and shear force differ significantly. So with the advent of sophisticated finite element analysis programs which are relatively easy to use and have significant economy can be used as an alternative for above two methods.

Direct Design Method

This method has the limitation that it can be used only if the following conditions are fulfilled:

(i) There shall be minimum of three continuous spans in each directions.

(ii) The panels shall be rectangular and the ratio of the longer span to the shorter span within a panel shall not be greater than 2.

(c) The successive span length in each direction shall not differ by more than one third of longer span.

(d) The design live load shall not exceed three times the design dead load.

(e) The end span must be shorter but not greater than the interior span.

(f) It shall be permissible to offset columns a maximum of 10 percent of the span in the direction of the offset not withstanding the provision in (b).

Total Design Moment

The absolute sum of the positive and negative moment in each direction is given by

$$M_0 = WL_n/8 \quad (1)$$

where,

M_0 = Total moment

W = Design load on the area L_2X L_n

L_n = Clear span extending from face to face of columns, capitals, brackets or walls but not less than 0.65 L_1

L_1 = Length of span in the direction of M_0

L_2 = Length of span transverse to L_1.

Distribution of bending Moments in to Negative and Positive moments:

The total design moment M_0 in a panel is to be distributed into –ve moment and +ve moment as specified below,

In an Interior span:
Negative Design Moment = 0.65 M_0
Positive Design Moment = 0.35 M_0
In an End span:

Interior negative design moment= $\left[0.75 - \frac{0.1}{1+\frac{1}{\alpha_C}}\right] M_0$ (2)

Positive design moment= $\left[0.68 - \frac{0.28}{1+\frac{1}{\alpha_C}}\right] M_o$ (3)

Exterior negative design moment= $\left[\frac{0.65}{1+\frac{1}{\alpha_C}}\right] M_0$ (4)

Where α_c is the ratio of flexural stiffness at the exterior columns to the flexural stiffness of the slab at a joint taken in the direction moments are being determined and is given by

$$\alpha_c = \frac{\Sigma k_c}{\Sigma k_s} \quad (5)$$

Where,

K_c = Sum of the flexural stiffness of the columns meeting at the joint; and

K_s = Flexural stiffness of the slab, expressed as moment per unit rotation

Distribution of Bending moments across panel width: The positive and negative moments found are to be distributed across the column strip in a panel as shown in Table 1 The moment in the middle strip shall be the difference between panel and the column strip moments.

Table 1 Distribution of Moments across the Panel Width in a Column Strip

Sr.No	Distributed Moment	Percent of Total Moment
1.	Negative BM at exterior support	100
2.	Negative BM at interior support	75
3.	Positive Bending moment	60

IV. FINITE ELEMENT ANALYSIS

The finite element method (FEM) is the dominant discretization technique in structural mechanics. The concept of FEM modeling is the division of mathematical model into non overlapping components of simple geometry. The response of each element is expressed in terms of a finite number of degrees of freedom characterized as the value of an unknown function. The finite element method is well suited for superimposition of material models for the constituent parts of a composite material. Advanced constitutive models implemented in the finite element system ETABS serve as rational tools to explain the RC and PT flat slab.

V. FLOWCHART

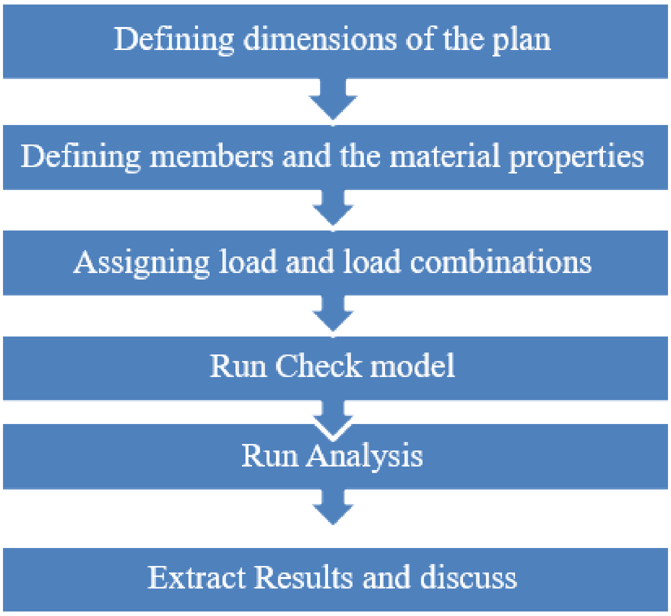

Fig.1 Steps in Analysis of Structure

VI. ANALYSIS OF CONVENTIONAL RC FLAT SLAB

i. RC Flat Slab 5mx5m Panel Dimensions

Ground Floor Slab

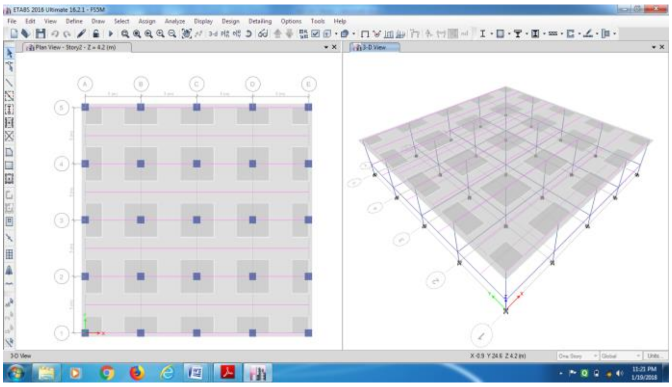

Fig.2 Plan and 3-D view RC flat slab with 5m span

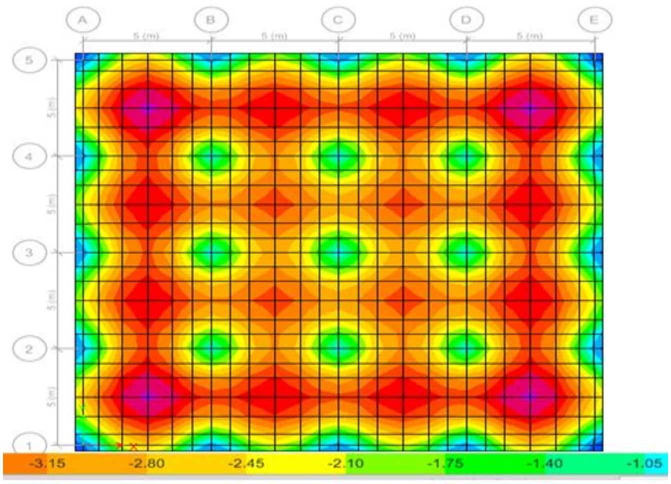

Fig.3 Panel wise displacement found in deformed shaped of 5m span RC flat slab

Table 2. Bending Moment in 5m RC Flat Slab With Drop

Sr.No.	Nature	Location	Strip Moment (kNm)
1	+ve	Outer CS	32.5774
2	-ve	Outer CS	171.0478
3	+ve	Outer MS	57.4626
4	-ve	Outer MS	56.7566
5	+ve	Middle CS	64.5975
6	-ve	**Middle CS**	**388.9677**
7	+ve	Middle MS	54.5946
8	-ve	Middle MS	60.0318
9	+ve	Central CS	62.2185
10	-ve	Central CS	351.4834

Table 3 Displacement in 5m RC Flat Slab with Drop

Sr.No.	Location	Displacement (in mm)
1	**Corner Panel**	**4.156**
2	Peripheral Panel	3.071
3	Central Panel	1.923

Table 4 Shear Force in 5m RC Flat Slab with Drop

Sr.No.	Location	Shear Force (kN)
1	Outer CS	211.4265
2	Outer MS	67.1391
3	**Middle CS**	**346.8148**
4	Middle MS	62.5782
5	Central CS	311.3988

a. G+2

Table 5 Bending Moment in 5m RC Flat Slab

Sr.No.	Nature	Location	Strip Moment (kNm)
1	+ve	Outer CS	26.5755
2	-ve	Outer CS	57.5777
3	+ve	Outer MS	45.889
4	-ve	Outer MS	25.169
5	+ve	Middle CS	57.123
6	-ve	**Middle CS**	**135.3368**
7	+ve	Middle MS	45.0819
8	-ve	Middle MS	28.3948
9	+ve	Central CS	55.3631
10	-ve	Central CS	128.8764

Table 6 Displacement in 5m RC Flat Slab

Sr.No.	Location	Displacement (in mm)
1	**Corner Panel**	**4.692**
2	Peripheral Panel	4.219
3	Central Panel	3.680

Table 7 Shear Force in 5m RC Flat Slab

Sr.No.	Location	Shear Force (kN)
1	Outer CS	85.0133
2	Outer MS	35.1553
3	**Middle CS**	**156.0378**
4	Middle MS	34.9299
5	Central CS	148.6625

ii. RC Flat Slab with Panel Dimensions 10mx10m

a. Ground Floor Slab with drop

Table 8. Bending Moment in 10m RC Flat Slab

Sr.No.	Nature	Location	Strip Moment (kNm)
1	+ve	Outer CS	49.5848
2	-ve	Outer CS	275.3177
3	+ve	Outer MS	87.4344
4	-ve	Outer MS	46.6132
5	+ve	Middle CS	98.7874
6	-ve	**Middle CS**	**565.9683**

7	+ve	Middle MS	83.6351
8	-ve	Middle MS	49.6603
9	+ve	Central CS	96.7342
10	-ve	Central CS	540.2578

Table 9. Displacement in 10m RC Flat Slab

Sr.No.	Location	Displacement (in mm)
1	**Corner Panel**	**27.041**
2	Peripheral Panel	21.541
3	Central Panel	16.121

Table 10. Shear Force in 10m RC Flat Slab

Sr.No.	Location	Shear Force (kN)
1	**Outer CS**	**320.3214**
2	Outer MS	39.6421
3	Middle CS	283.7137
4	Middle MS	39.690
5	Central CS	270.4404

b. G+2

Table 11. Bending Moment in 10m RC Flat Slab

Sr.No.	Nature	Location	Strip Moment (kNm)
1	+ve	Outer CS	214.9218
2	-ve	Outer CS	494.8471
3	+ve	Outer MS	367.1731
4	-ve	Outer MS	211.3807
5	+ve	Middle CS	453.9329
6	-ve	**Middle CS**	**1154.455**
7	+ve	Middle MS	358.7929
8	-ve	Middle MS	242.9806
9	+ve	Central CS	437.6356
10	-ve	Central CS	1079.9761

Table 12. Displacement in 10m RC Flat Slab

Sr.No.	Location	Displacement (in mm)
1	**Corner Panel**	**71.511**
2	Peripheral Panel	60.274
3	Central Panel	47.009

Table 13. Bending Moment in 10m RC Flat Slab

Sr.No.	Location	Shear Force (kN)
1	Outer CS	490.6827
2	Outer MS	139.4777
3	**Middle CS**	**724.5881**
4	Middle MS	143.2824
5	Central CS	678.4319

VII. POST-TENSIONED FLAT SLAB WITH DROP

i. Post-tensioned Flat Slab of 5mx5m Panel Dimensions

a. Ground Floor Slab

Table 14 Bending Moment in 5m span Post-tensioned Flat Slab

Sr.No.	Nature	Location	Strip Moment (kNm)
1	+ve	Outer CS	62.2712
2	-ve	Outer CS	16.3798
3	+ve	Outer MS	50.5583
4	-ve	Outer MS	35.2273
5	+ve	Middle CS	116.2862
6	-ve	Middle CS	27.0419
7	+ve	Middle MS	51.0171
8	-ve	Middle MS	37.3842
9	+ve	Central CS	**119.4608**
10	-ve	Central CS	26.6672

Table 15. Displacement in 5m span Post-tensioned Flat Slab

Sr.No.	Location	Displacement (in mm)
1	Corner Panel	1.046
2	Peripheral Panel	1.235
3	Central Panel	**1.360**

Table 16. Shear Force in 5m span Post-tensioned Flat Slab

Sr.No.	Location	Shear Force (kN)
1	Outer CS	41.3247
2	Outer MS	48.4149
3	Middle CS	71.3569
4	Middle MS	48.2796
5	Central CS	**72.2557**

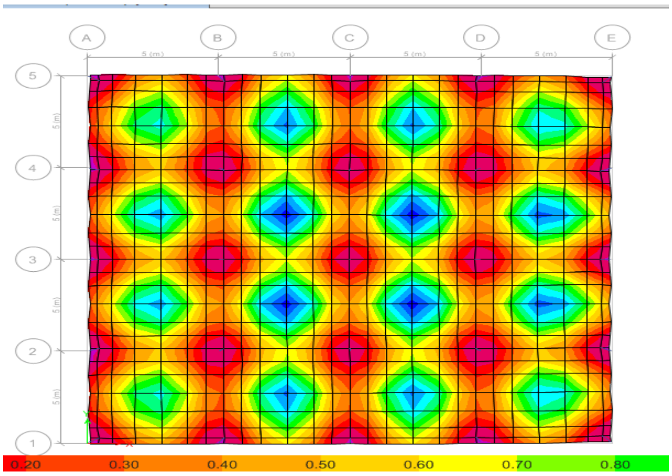

Fig 4. Displacements in 5m Span Post-tensioned Flat Slab

b. G+2

Table 17 Bending Moment in 5m span Post-tensioned Flat Slab

Sr.No.	Nature	Location	Strip Moment (kNm)
1	+ve	Outer CS	26.8759
2	-ve	Outer CS	20.995
3	+ve	Outer MS	43.8012
4	-ve	Outer MS	45.8353
5	+ve	Middle CS	51.7916
6	-ve	Middle CS	38.5587
7	+ve	Middle MS	43.0508
8	-ve	Middle MS	47.2273
9	+ve	Central CS	**54.1656**
10	-ve	Central CS	39.1335

Table 18 Displacement in 5m span Post-tensioned Flat Slab

Sr.No.	Location	Displacement (mm)
1	Corner Panel	1.783
2	Peripheral Panel	2.070
3	Central Panel	**2.265**

Table 19 Shear Force in 5m span Post-tensioned Flat Slab

Sr.No.	Location	Shear Force (kN)
1	Outer CS	30.215
2	Outer MS	64.9055
3	Middle CS	65.5558
4	Middle MS	66.0889
5	Central CS	**66.886**

ii. Post-tensioned Flat Slab with 10mx10m Panel Dimensions

a. Ground Floor Slab

Table 20. Bending Moment in 10m span PT flat slab

Sr.No.	Nature	Location	Strip Moment (kNm)
1	+ve	Outer CS	206.6588
2	-ve	Outer CS	68.0783
3	+ve	Outer MS	109.3594
4	-ve	Outer MS	128.0165
5	+ve	Middle CS	**320.6945**
6	-ve	Middle CS	88.533
7	+ve	Middle MS	108.0906
8	-ve	Middle MS	131.0058
9	+ve	Central CS	319.0434
10	-ve	Central CS	88.1937

Table 21 Displacement in 10m span PT flat slab

Sr.No.	Location	Displacement (mm)

1	Corner Panel	11.226
2	Peripheral Panel	**12.078**
3	Central Panel	12.002

Table 22 Shear Force in 10m span PT flat slab

Sr.No.	Location	Shear Force (kN)
1	Outer CS	84.5782
2	Outer MS	91.687
3	Middle CS	**111.4833**
4	Middle MS	92.9343
5	Central CS	111.2224

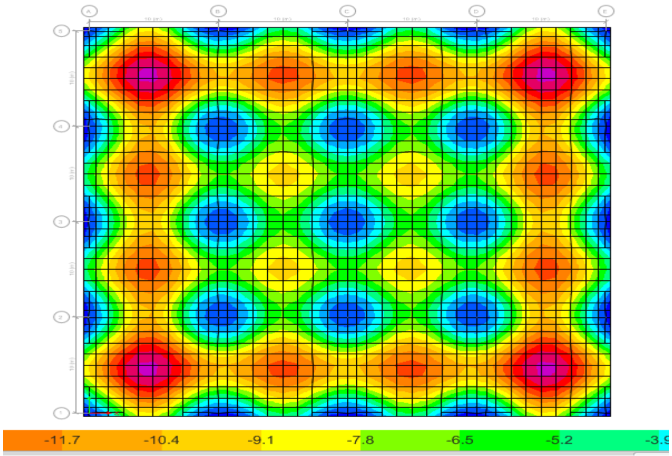

Fig 5. Displacement in post-tensioned GF slab with 10m span

b. **G+2**

Table 23 Bending Moment of Post-tensioned Flat Slab

Sr.No.	Nature	Location	Strip Moment (kNm)
1	+ve	Outer CS	98.2952
2	-ve	Outer CS	57.0241
3	+ve	Outer MS	148.6344
4	-ve	Outer MS	123.8696
5	+ve	Middle CS	176.705
6	-ve	Middle CS	92.8597
7	+ve	Middle MS	143.5427
8	-ve	Middle MS	127.3342
9	+ve	Central CS	**185.7348**
10	-ve	Central CS	94.0344

Table 24. Displacement of Post-tensioned Flat Slab

Sr.No.	Location	Displacement (mm)
1	Corner Panel	12.822
2	Peripheral Panel	14.304
3	Central Panel	**15.670**

Table 25. Shear Force of Post-tensioned Flat Slab

Sr.No.	Location	Shear Force (kN)
1	Outer CS	60.544
2	Outer MS	93.7809
3	Middle CS	94.1821
4	Middle MS	93.2193
5	Central CS	**98.1662**

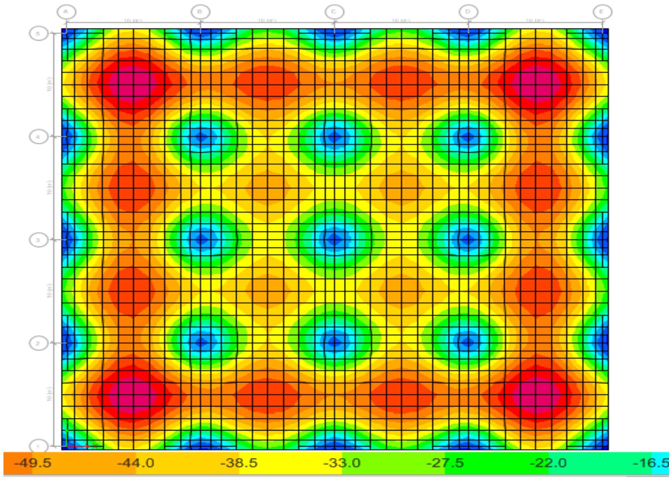

Fig 6. Displacement in post-tensioned G+2 slab with 10m span

VIII. RESULTS AND DISCUSSION

- **Comparison of bending moment for 5m RC and PT flat slab**

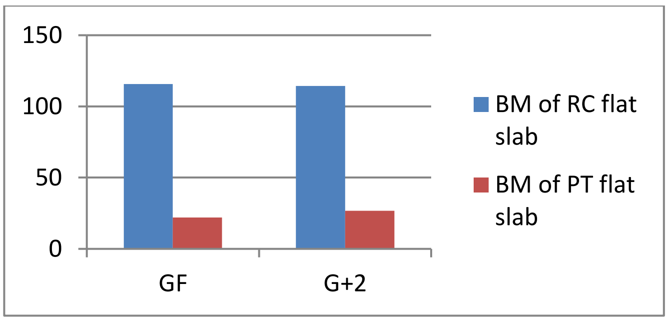

Figure 7 Graph of Storey wise Bending Moment for RCC and PT Flat Slab

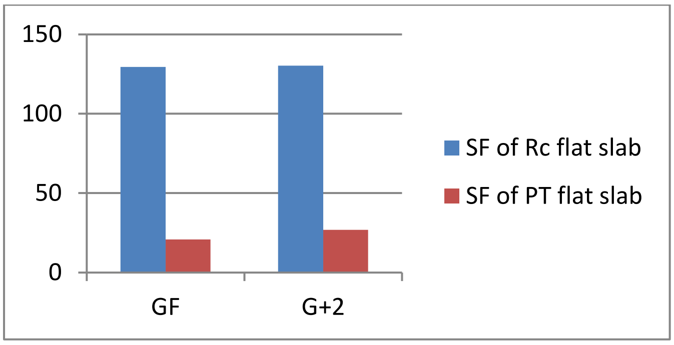

Figure 8 Graph of Storey wise Shear Force for RCC and PT Flat Slab

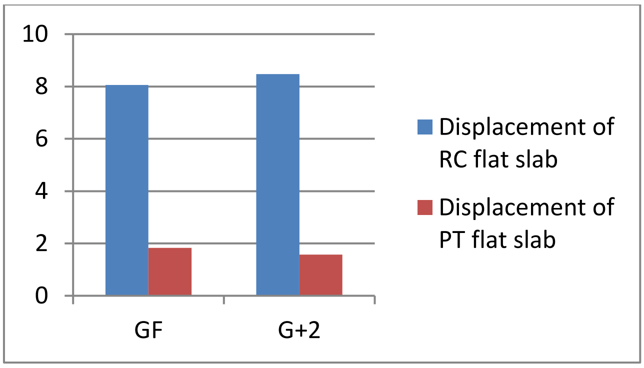

Figure 9 Graph of Storey wise Displacement for RCC and PT Flat Slab

- **Comparison of bending moment for 10m RC and PT flat slab**

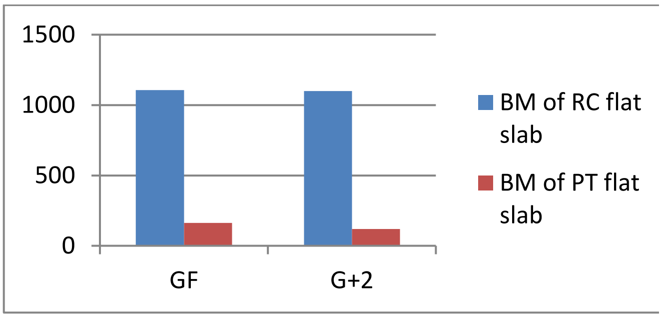

Figure 10 Graph of Storey wise Bending Moment for RCC and PT Flat Slab

- **Comparison of Shear force for 10m span RC and PT flat slab**

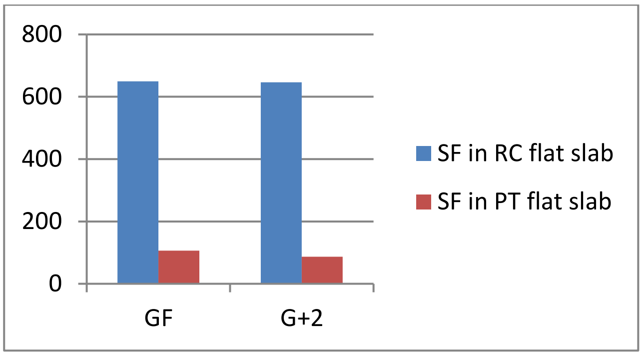

Figure 11 Graph of Storey wise Shear Force for RCC and PT Flat Slab

- **Comparison of Displacement for 10m span RC and PT flat slab**

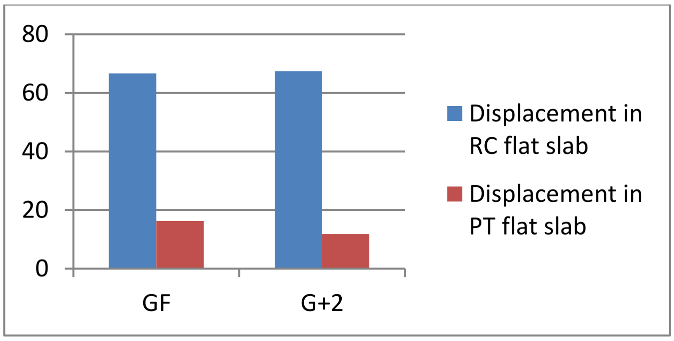

Figure 12 Graph of Storey wise Displacement for RCC and PT Flat Slab

a. 5m span

- The drop in bending moment in post-tensioned flat slab as compared to RC flat slab is in between 76-80%
- The percentage variation of shear force in Post-tensioned and RC slab is between 79-83%
- There is 77-81% drop in displacement of Post-tensioned flat slab as compared to RC flat slab

b. 10m span

- The drop in bending moment in Post-tensioned flat slab as compared to RC flat slab is in between 75-82%
- The percentage variation of shear force in Post-tensioned and RC slab is between 83-86%
- There is 75-82% drop in displacement of Post-tensioned flat slab as compared to RC flat slab in ground floor and G+2 slab level

IX. CONCLUSION

- Conventional RC and Post-tensioned flat slab are analyzed in this dissertation with drop. Analysis is done for spans 5m and 10m for storey starting from Ground floor and G+2.
- Bending moment, shear force and displacements are presented in tabular formats which will be helpful for comparative analysis. Span wise conclusions are summarized below.
- Maximum bending moment values decreases for Post-tensioned flat slab for Ground floor and G+2 top level slab for spans 5m and 10m
- Maximum shear force and displacement values are considerably less in PT flat slab as compared to RC flat slab for both the spans.
- The bending moment, shear force and displacements decreases in post-tensioned flat slab as compared to RC flat slab, therefore more slender sections are possible in post-tensioned flat slab.

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