

# Analysis and Design of Prestressed Concrete Flat Slab

A.K.Kandale<sup>1</sup>, Prof Dr.S.S.Patil<sup>2</sup>P.G. Student, Department of Civil Engineering, WIT Engineering College, Ashok Chowk, Solapur, India<sup>1</sup>Associate Professor, Department of Civil Engineering, WIT Engineering College, Ashok Chowk, Solapur, India<sup>2</sup>

**ABSTRACT:** Beam less floor directly resting on support (column and/ wall) is known as flat slab. Because of this, Story height can be maintained uniform throughout. This provides us an ease of installation of mechanic and electric services. This also helps us in reducing the cost of formwork. Flat slab reduces the loads on foundation because of less height of structure. It gives us plain ceiling which gives an attractive appearance.

Flat slabs are subjected to gravity and lateral loads. Gravity load analysis of flat slab is carried out by Direct Design Method (DDM) and Equivalent Frame Method (EFM) as prescribed by different standards. On site some times because of site conditions or the owners requirements the column orientation may not get in an alignment this is known as staggered column conditions. In those conditions we have to use Equivalent Frame Method for analysis and design of flat slab.

IS 456-2000, BS 8110-1997 prescribed the coefficients for analysis of prestressed concrete flat slab as per DDM and EFM. Analysis and design of prestressed concrete flat slab is carried out with respective to the coefficients prescribed by different standards for distribution of moments along longitudinal and transverse directions. Slab is divided into column strip and middle strip. IS 456-2000, BS 8110-1997 specifying the fixed value of column strip and middle strip irrespective of interior span and mid-span.

The present study also incorporates the comparison of distribution of width of column strip and middle strip as per IS 456, BS 8110-1997 and as per Equivalent frame method for the staggered columns and the without the staggered column. And a comparison is made. The positive moment increases and negative moment decreases with Equivalent Frame Method. The negative and positive moments at exterior support increases for IS 456 compared to other.

Excel worksheet is also prepared for analysis and design of prestressed concrete flat slab (with staggered and without staggered columns) as per EFM. EFM includes analysis as per IS 456-2000 & BS 8110-1997 and using the distribution coefficients along longitudinal and transverse directions.

**KEYWORDS:** Prestressed concrete, flat slab Moment.

## I. INTRODUCTION

Common practice of design and construction is to support the slabs by beams and support the beams by columns. This may be called as beam – slab construction. The beams reduce the available net clear ceiling height. Hence in warehouses, offices and public halls sometimes beams are avoided and slabs are directly supported by columns are called Flat Slabs.

The increasing cost of structural steel and cement day by day in the World market directly affects many projects which are totally constructed by using cement and steel, especially industrial warehouses, offices and public halls and shopping malls structures which are constructed mostly using cement and steel.

Therefore, the main objective of a structural designer is to design the structures as light as possible without compromising the strength and stability of structures. These objectives can be safely achieved by varying the sections that is providing thin slabs and avoiding beams.

Bending moments and shear forces increases with increase in span, this leads to increase in the cross-section of members and amount of structural steel. Therefore, prismatic beams may become uneconomical. Moreover, with increase in depth there is a considerable reduction in head-room. Under such circumstances flat slabs may provide

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appealing solution. Flat slabs system of construction is one in which the beams used in the conventional methods of constructions are done away with. The slab directly rests on the column and load from the slab is directly transferred to the columns and then to the foundation. To support heavy loads the thickness of slab near the support with the column is increased and these are called drops, or columns are generally provided with enlarged heads called column heads or capitals.

Flat slabs with cross-section and/or material properties varying continuously or discontinuously along their length, are used in many structural applications to optimize the distribution of weight and strength and sometimes to satisfy architectural and functional requirements. Therefore, the analysis of flat slabs is of interest to many civil engineers.

Absence of beam gives a plain ceiling, thus giving better architectural appearance and also less vulnerability in case of fire than in usual cases where beams are used. Plain ceiling diffuses light better, easier to construct and requires cheaper form work.

## II. LITERATURE SURVEY

**Anitha et al 2007 [8]** Illustrated the methods used for flat slab design using ACI-318, NZ-3101, and EC2 and IS: 456 design codes. For carrying out this project an interior panel of a flat slab with dimensions  $6.6 \times 5.6$  m and super imposed load  $7.75 \text{ kN/m}^2$  was designed using the codes given above. As per local conditions and availability of materials different countries have adopted different methods for design of flat slabs and given their guidelines in their respective codes.

**Kim and Lee 2005 [10]** Discussed merits and demerits of conventional methods of analysis of flat slabs such as Equivalent frame method and Finite Element Method. The author introduces the new and efficient method of analysis which is known as analysis of flat slabs by using super elements which is developed by using fictitious beams. This method significantly reduces the computational time and memory required for analysis as compared to conventional methods.

**Bharathet al.2004 [11]** Presented review and design of flat plate/slabs construction in India. They have described seismic design provisions per Indian Standard IS 1893 and Uniform Building Code UBC 2000 for the lateral force design of flat plate/slabs and also conclude by presenting two real world construction projects designed in Bangalore.

## III. COMPONENTS OF FLAT SLAB

- a) **Panel:-** Panel means the part of the slab bounded on each of its four sides by the center line of a column or center line of adjacent spans.
- b) **Drop:-** Moments in the slabs are large near to the column hence the slab is thickened near the columns by providing the drop. Drops when provided shall be rectangular in plan and have a length in each direction not less than one third of the panel length in that direction. For exterior panels, width of drops at right angles to the non-continuous edge and measured from center line of columns shall be equal to one half the width of drop for interior panels.
- c) **Column head:-** The column head is widened so as to reduce the punching shear in the slab. The widened portions are called column heads. The portion of a column head which lies within the largest right circular cone or pyramid that has a vertex angle of  $90^\circ$  and can be included entirely within the outlines of the column head, shall be considered for design purpose.
- d) **Column strip:-** Column strips means design strip having a width of  $0.25 l_2$ , but not greater than  $0.25 l_1$  on each side of a column centerline where  $l_1$  is the span in the span in the direction moments are being determined, measured center to center of support and  $l_2$  is the span transverse to  $l_1$  measured center to center of supports.
- e) **Middle Strip:-** A design strip bounded on each of its opposite sides by the column strip. Middle strip behaves as a continuous beam supported on column strip regions.

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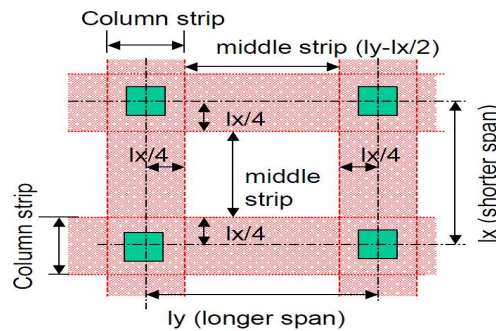


FIG No.1 COMPONENTS OF FLAT SLAB

## IV. TYPES OF FLAT SLAB

- Slabs without drop and column head.
- Slabs without drop and column with column head
- Slabs with drop and column without column head.
- Slabs with drop and column head.

## V. PRESTRESSED CONCRETE

Prestressed concrete is a concrete construction material which is placed under compression prior to it supporting any applied loads (i.e. it is "pre" stressed). A more technical definition is "Structural concrete in which internal stresses have been introduced to reduce potential tensile stresses in the concrete resulting from loads." This compression is produced by the tensioning of high-strength "tendons" located within or adjacent to the concrete volume, and is done to improve the performance of the concrete in service. Tendons may consist of single wires, multi-wire strands or threaded bars, and are most commonly made from high-tensile steels, carbon fiber or aramid fiber. The essence of prestressed concrete is that once the initial compression has been applied, the resulting material has the characteristics of high-strength concrete when subject to any subsequent compression forces, and of ductile high-strength steel when subject to tension forces. This can result in improved structural capacity and/or serviceability compared to conventionally reinforced concrete in many situations.

Prestressed concrete is used in a wide range of building and civil structures where its improved concrete performance can allow longer spans, reduced structural thicknesses, and material savings to be realized compared to reinforced concrete. Typical application range through high-rise buildings, residential slab, foundation systems, bridge and dam structures, and tanks, industrial pavements and nuclear containment structures.

## VI. ADVANTAGES OF PRESTRESSED CONCRETE

- The size or dimensions of structural members are reduced, which may increase the clearances or reduce storey heights.
- It permits the use of large spans (greater than 30 m) with shallow members, even when heavy load are encountered.
- In addition to general advantages, such as excellent fire resistance, low maintenance costs, elegance, high corrosion-resistance, adaptability etc, the prestressed concrete is found to sustain the effects of impact or shock and vibrations.
- Because of smaller loads due to smaller dimensions being used, there is considerable saving cost of supporting members and foundations.
- The prestressing technique has eliminated the weakness of concrete in tension and hence crack free members of structure are obtained.

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6. Because of better material (i.e. controlled concrete and high tension steel) being used and nullifying the effect of dead loads, smaller deflections are caused.

**Disadvantages of Prestressed Concrete:**

1. The unit cost of high strength materials being used is higher.
2. Extra initial cost is incurred due to use of prestressing equipment and its installation.
3. Extra labour cost for prestressing is also there.
4. Prestressing is uneconomical for short spans and light loads.

### VII. ANALYSIS OF PRESTRESSED FLAT SLAB

Design the prestressed concrete flat slab with staggered column shown in figure using equivalent frame method. it is subjected to live load of 3 kn/m<sup>2</sup> and floor finish of 1 kn/m<sup>2</sup>. use 12 wires of 5 mm diameter stressed at 1000 n/mm<sup>2</sup>. floor to floor height of column 3.5m.

Given:L.L: 1.1 = 3 kn/m<sup>2</sup> clear cover = 30 mm f<sub>ck</sub> =30 n/mm<sup>2</sup> column diameter = 350 mm floor to floor height of column = 3.5 m.

Column		Size in mm	Area mm <sup>2</sup>	I <sub>xx</sub>	I <sub>yy</sub>
Square	X Direction	350	122500	1250520833	1250520833
	Y direction	350			

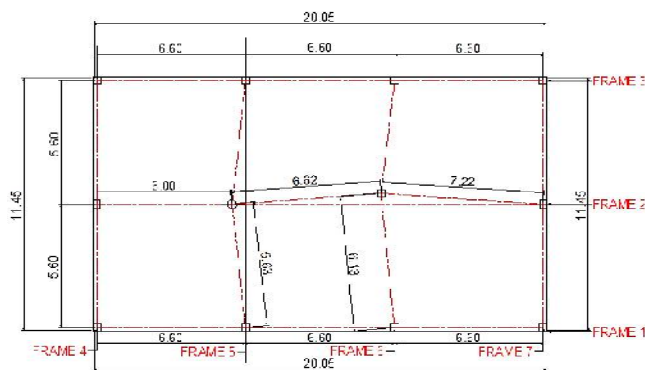


Fig No.2 Frame section

Solution:

Basic L/d ratio for continuous slab = 26, assume percentage of steel = 0.4

So modification factor a = 1.4

$$\text{Required } d = 6600 / (26 \times 1.4) = 181.318 \text{ mm}$$

$$\text{Required } d = 7217 / (26 \times 1.4) = 198.269 \text{ mm}$$

Provide total depth D = 225 mm

Effective depth provided = d = 225 - 30 - (5/2) = 193 mm

Effective depth in transverse direction = 193 - 5 = 188 mm

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Table 1: Span Length

Frame 1		
span A-B	X Direction	6.6
	Y direction	5.615
Span B-C	X Direction	6.6
	Y direction	5.88
Span C-D	X Direction	6.6
	Y direction	5.865

Load calculation:

Ultimate design load:  $Wud = 1.5 (25 \times 0.225 + 1) = 9.9375 \text{ kN/m}^2$

$WuL = 1.5 \times 3 = 4.5 \text{ kN/m}^2$

$Wu = Wud + WuL = 14.4375 \text{ kN/m}^2$

Check for requirement of direct design method:

- (1) Number of span is more than 3
- (2) long span/short span =  $7.217/5.13 < 2$
- (3) Columns are not staggered
- (4) Successive spans in each direction are equal.
- (5) Design LL should not be greater than three times of DL,  
Design live load =  $4.5 \text{ kN/m}^2 < 3 \times \text{D.L} (3 \times 9.9375 = 29.8125)$

The requirements (1), (3), (4) are not satisfied so direct design method cannot be used.

## VIII. COMPARATIVE STUDY

1. With Staggered Column

Table No.1.1 Frame comparison (C.S moment)

DISTRIBUTION OF MOMENT TO COLUMN STRIP																
FRAME		Exterior span A-B					Interior span B-C					Exterior span C-D				
		Mul-	Mu+	Mur-	e	P	Mul-	Mu+	Mur-	e	P	Mul-	Mu+	Mur-	e	P
1	I	52.41	60.36	110.9	10	11	102.5	41.21	105.3	9	11	114.8	63.81	53.60	10	11
	S	04	7	7	0	15	1	05	6	4	15	42	65	1	3	15
1	B	38.32	53.94	108.1	10	10	99.93	36.82	102.7	9	10	111.9	57.02	39.19	10	10
	S	08	74	87	0	87	17	78	15	4	87	59	97	12	3	87
2	I	75.66	99.44	188.8	74	25	181.7	80.89	229.3	9	25	261.7	148.4	143.9	10	25
	S	14	1	7	74	41	4	9	96	0	41	45	32	6	3	41
2	B	55.64	89.17	182.7	76	24	174.9	70.62	217.2	9	24	248.9	128.8	105.7	10	24
	S	5	6	2	76	17	8	83	68	0	17	13	44	9	3	17

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Table No.1.2 Frame comparison (M.S moment)

DISTRIBUTIONN OF MOMENT TO MIDDLE STRIP																
FRAM E		Exterior span A-B					Interior span B-C					Exterior span C-D				
		Mul-	Mu+	Mur-	e	P	Mul-	Mu+	Mur-	e	P	Mul-	Mu+	Mur-	e	P
1	IS	0	73.39	68.47	82	893	64.46	54.44	73.35	82	893	81.9	92.02	0	103	893
	B S	22.05	80.62	66.52	84	965	62.47	59.03	70.45	73	965	78.81	99.37	30.7	103	965
2	IS	0	73.9	67.42	87	854	62.73	51.65	69.76	82	854	78.31	87.93	0	103	854
	B S	22.38	81.18	65.58	88	921	60.79	55.96	66.95	73	921	75.38	94.88	30.34	103	921

### 2. Without Staggered Column

Table No.2.1 Frame Comparison (C.S moment)

DISTRIBUTION OF MOMENT TO COLUMN STRIP																
FRAM E		Exterior span A-B					Interior span B-C					Exterior span C-D				
		Mul-	Mu+	Mur-	e	P	Mul-	Mu+	Mur-	e	P	Mul-	Mu+	Mur-	e	P
1	IS	52.9	60.58	109	103	1058	99.48	38.85	99.48	94	1058	109	60.58	52.9	103	1058
	B S	38.68	54.14	106.3	103	1032	96.98	34.72	96.98	94	1032	106.3	54.14	38.68	103	1032
2	IS	105.8	121.2	218	103	2117	199	77.7	199	94	2117	218	121.2	105.8	103	2117
	B S	77.36	108.3	212.6	103	2064	194	69.44	194	94	2064	212.6	108.3	77.36	103	2064

Table No.2.2 Frame Comparison (M.S moment)

DISTRIBUTIONN OF MOMENT TO MIDDLE STRIP																
FRA ME		Exterior span A-B					Interior span B-C					Exterior span C-D				
		Mul-	Mu+	Mur-	e	P	Mul-	Mu+	Mur-	e	P	Mul-	Mu+	Mur-	e	P
1	IS	0	80.7748	72.674	103	784	66.319	51.8	66.3186	85	784	72.6737	80.775	0	103	784
	B S	25.7873	88.5901	70.849	103	860	64.6535	56.8122	64.6535	75	860	70.849	88.5901	25.7873	103	860
2	IS	0	80.7748	72.674	103	784	66.319	51.8	66.3186	85	784	72.6737	80.775	0	103	784
	B S	25.7873	88.5901	70.849	103	860	64.6535	56.8122	64.6535	75	860	70.849	88.5901	25.7873	103	860

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## IX. CONCLUSION

Based on the work carried out in this dissertation on 'analysis and design of Prestressed concrete flat slab by using IS code and BS code provisions' the following conclusions were drawn.

- 1) The width of column strip and middle strip determined by IS and BS code are same.
- 2) The hogging bending moment obtained at two intermediate staggered columns by IS code provision are 5 % and 15% more than those obtained by BS code at same location.
- 3) The moments obtained by using IS code provisions are compared with the moments obtained by BS code. Their variations are discussed below.
  - The moment variation for without staggered columns:-
    - A) Column strip moments [Table No 4.21]:-
      - a) The external negative moments of flat slab along the longer and shorter span obtained by BS code provision are lesser from 23% to 28% in comparison with IS code provision.
      - b) The internal negative moments of flat slab along the longer and shorter span obtained by BS code provision are lesser from 2% to 8% in comparison with IS code provision.
      - c) The middle positive moments of flat slab along the longer and shorter span obtained by BS code provision are lesser from 9% to 12% in comparison with IS code provision.
    - B) Middle strip moments [Table No 4.22]:-
      - a) The external negative moments of flat slab along the longer and shorter span is zero by IS code and negligible moments with BS code is obtained.
      - b) The internal negative moments of flat slab along the longer and shorter span obtained by BS code provision are lesser from 0% to 5% in comparison with IS code provision.
      - c) The middle positive moments of flat slab along the longer and shorter span obtained by BS code provision are lesser from 5% to 10% in comparison with IS code provision.
  - The moment variation for staggered columns:-
    - A) Column strip moments [Table No 4.18]:-
      - a) The external negative moments of flat slab along the longer and shorter span obtained by BS code provision are lesser from 25% to 30% in comparison with IS code provision.
      - b) The interior negative moments of flat slab along the longer and shorter span obtained by BS code provision are lesser from 1% to 5% in comparison with IS code provision.
      - c) The middle positive moments of flat slab along the longer and shorter span obtained by BS code provision are lesser from 10% to 13% in comparison with IS code provision.
    - B) Middle strip moments [Table No 4.19]:-
      - a) The external negative moments of flat slab along the longer and shorter span is zero by IS code and negligible moments with BS code is obtained.
      - b) The internal negative moments of flat slab along the longer and shorter span obtained by BS code provision are lesser from 1% to 5% in comparison with IS code provision.
      - d) The middle positive moments of flat slab along the longer and shorter span obtained by BS code provision are higher from 5% to 10% in comparison with IS code provision.
  - The moment variation of the frame with staggered columns and without staggered columns by IS code:-
    - A) Column strip moments:-
      - a) The external negative moment of staggered columns decreases by 5% to 10% of the without staggered columns.
      - b) The interior negative moment of staggered columns increases by 5% to 15% of the without staggered columns.
      - c) The middle positive moment of staggered columns decreases by 5% to 15% of the without staggered columns.
    - B) Middle strip moments:-
      - a) The external negative moment of staggered columns and without staggered column are zero.
      - b) The internal negative moment of staggered columns increases by 5% to 15% of the without staggered

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- columns.
- c) The middle positive moment of staggered columns decreases by 5% to 10% of the without staggered columns.
- 4) The prestressing force obtained by using IS code provisions are compared with the prestressing force obtained by BS code. Their variations are discussed below.
- a) The prestressing force obtained in column strip for staggered column condition using the IS code provision is 5% more as compared to the BS code provision.
- b) The prestressing force obtained in middle strip for staggered column condition using the IS code provision is 8% more as compared to the BS code provision.
- c) The prestressing force obtained in column strip for without staggered column condition using the IS code provision is 6% more as compared to the BS code provision.
- d) The prestressing force obtained in middle strip for without staggered column condition using the IS code provision is 9% more as compared to the BS code provision.
- 5) The prestressing force obtained for staggered column condition using the IS code provision is 10% to 12% more as compared to the without staggered column.

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