COMPARATIVE STUDY OF FLAT SLAB DESIGN USING VARIOUS INTERNATIONAL CODES

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ABSTRACT

The structural function of beamless floor system is to collect the gravity load and other load such as wind load etc. and to transfer to the vertical structural elements i.e. column through the combined capacity in flexure and shear. In Flat slab, the slab is directly supported on the columns. Moments and shear values are usually the largest over the columns. However, when spans are relatively small and imposed load is low, the thickness of slab can be increased to reduce the stresses at slab-column joint which would result in providing greater effective depth for negative moments occurring near the column. With increasing span and live load intensity, the thickness requirement increases which does not give economical solution. So, to tackle this problem flaring of the column at top is done such that the plan geometry at the column head is similar to that of the column. The column capital is intended primarily to increase the capacity of the slab to resist punching shear. The column capital stiffens the slab, which help in controlling the floor deflection. Thus, the floor span can be increased to some extent. Beyond a certain range of span, further stiffening of the slab is required which is achieved by increasing the slab thickness of the slab panel around the column capital. This portion of the slab is known as drop panel. For flat slabs and flat plates supported directly by columns, shear may be the critical factor in design. In almost all tests of such structures, failures have been due to shear or perhaps shear and torsion. These conditions are particularly serious around the exterior columns. In the present study, attempt has been made to understand different methods of analysis of flat slab and parameters, which governs the design parameters of the flat slab. Attempts have been made to study the provisions of flat slab in well-known international standards such as ACI 318, EC-2 and IS 456:2000.

Keywords: *Flat slab, drop panel, Column head, IS 456:2000, ACI 318, EC-2*

1. INTRODUCTION

1.1 General

This Part provides an introduction to the concept of flat slabs along with the details of its types, components, etc. 1.2 Relevance Flat slabs include two-way reinforced slabs with capitals, drop panels, or both. These slabs are very satisfactory for heavy loads and long spans. Although the form work is more expensive than for flat plates, flat slabs will require less concrete and reinforcing that would be required for flat plates with same loads and spans. They are particularly economical for warehouses, parking and industrial buildings and similar structures where, exposed drop panels or capitals are acceptable. Flat slab systems are popular for use in office and residential buildings, hospitals, schools and hotels. They are quick and easy to formwork and build. The architectural finish can be directly applied to the underside of the slab. Absence of beams allows lower storey heights and as a result, cost saving in vertical cladding, partition walls, mechanical systems, plumbing and a large number of other items of construction especially for medium and high rise buildings. They provide flexibility for partition location and allow passing and fixing services easily. Windows can be extended up to the underside of the ceiling. The absence of sharp corners gives better fire resistance and less danger of concrete spalling and exposing the reinforcement. Moreover, a flat slab can result in more storeys being accommodated within a restricted height of the building. The flat slab system has been adopted in many buildings constructed recently due to the advantage of reduced floor heights to meet the economical and architectural demands. Flat slabs are favored by both architects and clients because of their aesthetic appeal and economic advantage. However, from the structural engineering point of view, flat slab has a major weakness, namely they are vulnerable to punching shear failure at the junctions of slabs and columns. A flat slab floor system is often the choice when it comes to heavier loads such as multi storey car parks, libraries and multi-story buildings where larger spans are also required. Flat slabs can be supported by a column capital or a drop panel in order to provide a good resistance to punching shear around the column. However, in some cases, column capitals and drop panels cannot be used for architectural reasons or to save space between the floors. If this is the case, alternative forms of shear reinforcement must be provided for the junctions. In flat slabs, shear failure due to punching shear is the most serious type of failure that may occur at a column-slab junction. A typical punching shear failure is characterized by diagonal cracks starting from the bottom of the slab and making their way to the top at an angle of 20-45° to the horizontal, leading to the separation of the slab around the column in a truncated pyramid shape. Punching shear failure is characterized as a one-way reaction that will lead to the progressive collapse of a structure. Punching failure of only one internal junction can be catastrophic, as the shear at the neighboring columns can be increased by 25%, leading to failure of all columns. Once triggered, it can easily spread horizontally and when the debris falls, subsequent floors will be overloaded and a vertical failure process will lead to complete collapse of a structure. The punching shear capacity of a slab without shear reinforcement depends on the strength of concrete, the area of tension reinforcement, the depth of the slab and the column size. Additionally, the shear capacity may be reduced by any openings close to the column’s perimeter, which are required for services for multi-storey buildings. In flat slab, all loads supported by the slab converge to the columns. Moments are usually the largest over the column and shear stresses also reach a peak there. To tackle heavy moments, large shear stresses, certain stress reducing devices are provided in the form of drop panel or column head or both. These devices enhance the shear capacity besides increasing the slab stiffness. So, it is pertinent to study the effectiveness of these devices in reducing the shear stress and in controlling the deflection. One way of tackling the higher stresses in the vicinity of column is to increase the slab thickness, which reduces the shear stress as well as provides greater effective depth for negative bending moment occurring near the column. But this method of reducing the stresses is good enough only for smaller span and low imposed load, which in turn, increases the stresses due to its own weight, making the floor system quite inefficient. An ingenious approach to tackle the heavy shear stress around the column is to flare the column as it meets the slab, i.e. providing the column head which also increase the slab stiffness, without increasing the dead load of structure. Similarly, to have greater effective depth for negative bending moment, thickening of slab is done near the column, known as drop panel, which further reduces the shear stress and requires less reinforcement for negative bending moment without much aiding to dead load. Also, the drop panel enhances the slab stiffness, thereby, lessening the deflection of slab. In present study, attempts have been made to identify the range of span and imposed load which would be required for the design of flat slab. The IS code does not specify the limit of span for design of flat slab for floor system. Also to understand the provision laid by various codes to design flat slab for example IS456: 2000, CSA standard A23.3-94 and ACI 318-98 method. The two method namely direct design method and equivalent frame method have been adopted by these codes for finding moments and other forces. The direct design method and the equivalent frame method for gravity load analysis differ essentially in the manner of determining the distribution of bending moments along the span. The former uses moment coefficients, whereas the latter requires an elastic partial frame analysis. The procedure for apportioning the factored moments between the middle strip and the column strip is identical for both design methods. Both methods require the values of several relative stiffness parameters in order to obtain the longitudinal and transverse distribution of factored moments in the design strips. For this purpose, as well as for determining the dead loads on the slab, it is necessary to assume, initially, the gross section dimensions of the floor system. These dimensions may need to be modified subsequently and the analysis and design may therefore need to be suitably revised. 1. The direct design method, DDM, is an approximate procedure for the analysis and design of two-way slabs. It is limited to slab systems subjected to uniformly distributed loads and supports on equally or nearly equally spaced columns. The method uses a set of coefficients to determine the design moments at critical sections. Two-way slab systems that do not meet the limitations of the ACI Code must be analyzed by more accurate procedures. 2. The equivalent frame method, FEM, is one in which a three-dimensional building is divided into a series of two-dimensional equivalent frames by cutting the building along lines midway between columns. The resulting frames are considered separately in the longitudinal and transverse directions of the building and treated floor by floor.

1.2 Advantages of Flat Slab / Flat Plate Floor System

Flat Slabs are used by engineers in many buildings due to its advantages over other reinforced concrete floor system in different cases. The most important advantages of flat slabs are given below:

1. Flexibility in room layout: Partition walls can be placed anywhere. Also, it offers a variety of room layout to the owner and false ceilings can be omitted.
2. Reinforcement placement is easier: As reinforcement detailing of flat slab is simple, it is easier to place.
3.Ease of Framework installation: Big table framework can be used in flat slab.
4. Building height can be reduced: As no beam is used, floor height can be reduced and consequently the building height will be reduced. Approximately 10% of the vertical member could be saved and foundation load will also reduce.
5. Less construction time: Use of big table framework helps to reduce construction time.
6. Prefabricated welded mesh: Standard sizes can be taken, less installation time and better quality control. Moreover, auto sprinkler is easier.

1.3 Disadvantages of Flat Slab / Flat Plate Floor System Flat slabs have some disadvantages also. The major disadvantages are given below:

1. In flat plate system, it is not possible to have large span, but medium spans are acceptable.
2. This is not suitable for supporting brittle (masonry) partitions.
3. Use of drop panels may interfere with larger mechanical ducting.
4. In flat slabs, the middle strip deflection may be critical.
5. Compared to typical reinforced concrete two-way slab system, the thickness of flat plate slabs are higher.

1.4 Research Gap:

Integrated Design Guidelines: Absence of unified guidelines that consider all critical design factors. Comparison between flay slab with using different code IS Code, ACI, EC2

1.5 Problem Statement:

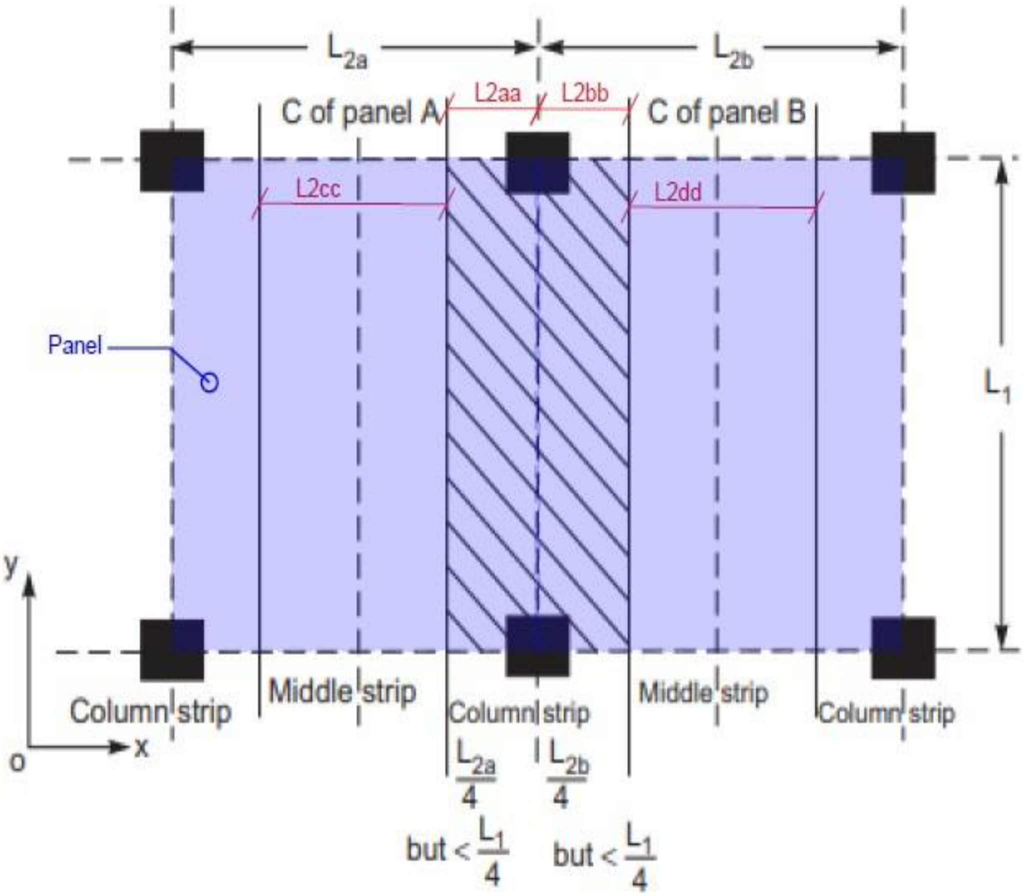
While flat slabs offer architectural flexibility and construction speed, there are significant gaps in understanding their long-term performance, cost-effectiveness, and environmental impact. Additionally, there is a need for effective retrofit techniques and comprehensive design guidelines to enhance their resilience and sustainability in seismic zones. This study seeks to address these gaps by evaluating flat slabs and proposing solutions to improve their structural integrity, cost efficiency, and environmental sustainability.

1.6 Objectives

1. Punching Shear Failure: Analyze the possible failure mode of Reinforced Concrete flat slabs, focusing on punching shear near columns.
2. Code Comparison: Study the methods of analysis and design of flat slabs with staggered columns using: - IS 456-2000 - ACI 318-98 - EC2: Part 1-2004 3. Excel Worksheet: Develop an Excel worksheet for the analysis and design of flat slabs by IS code IS Code, ACI, EC2 2.6

2. DESIGN OF FLAT SLAB AS PER IS 456:2000, ACI 318, EC2

A detailed design of a flat slab with panel dimensions 6.0m X 5.0m is presented on subsequent pages following the provisions of EC2 for various conditions viz. Flat slab with & without drop panel, flat slab with & without column head, etc. The design is carried out using an excel spreadsheet developed by me.



Material specifications & geometric properties of slab panel are as below:

Density of RCC	δconc	25	kN/m^3
Density of steel	δsteel	7850	kg/m^3
Grade of concrete	fck	20	Mpa
Grade of steel	fy	415	Mpa
Size of column	B_C / D_C	500.00	mm
Floor to floor height	H_{FL}	4.50	m
Slab span in 'Y' direction	L1	6.00	m
Slab span in 'X' direction	L2a	5.00	m
	L2b	5.00	m
Column strip dimesions	(Along length of slab)		
L2aa = 0.25L2a < 0.25L1	L2aa	1.25	m
L2bb = 0.25L2b < 0.25L1	L2bb	1.25	m
Middle strip dimesions	(Along length of slab)		
L2cc = L2a - (L2aa X 2)	L2cc	2.50	m
	L2dd	2.50	m
Column drop required		Yes	
Column drop dimesions			
Ldrx = L2a/6	Ldrx	0.83	m
Ldry = L1/6	Ldry	1.00	m
Considered drop dim.	Ldr	1500.00	mm
Thickness of drop	t_D	100.00	mm
Remark on drop thk.		OK	
Column head required		Yes	
Column head dimesions			
Lhx = L2a/4	Lhx	1.25	m
Lhy = L1/4	Lhy	1.50	m
Considered head dim.	Lh	1500.00	mm
Thickness of head	t_H	1500.00	mm

Basic ratios of span-to-effective-depth, *l/d*, for members without axial compression

Structural system		*K*	Highly stressed concrete $\rho = 1.5\%$	Lightly stressed concrete $\rho = 0.5\%$
Beams	Slabs			
Simply supported	One- or two-way spanning slabs simply supported	1.0	14	20
End span of continuous beams	End span of one-way spanning continuous slabs or two-way spanning slabs continuous over one long edge	1.3	18	26
Interior spans of continuous beams	Interior spans of continuous slabs	1.5	20	30
N/A	Flat slab (based on longer span)	1.2	17	24
Cantilever	Cantilever	0.4	6	8

Thickness of flat slab

Span to Eff depth ratio	l_n/deff	24.000	
Effective depth	deff_th	187.50	mm
Considered eff. depth	deff	190.00	mm
Effective cover to reinf.	Cc	30.00	mm
Overall depth of slab	Ds or h	220.00	mm
Remark on slab depth		OK	

Load Calculation

DEAD load calculation

Selfweight of slab	W_{DL1}	5.181	kN/m^2
Load of floor finishes	W_{DL1}	1.000	kN/m^2
Total dead load	W_{DL}	6.181	kN/m^2
LIVE load calculation	W_{LL}	5.000	kN/m^2
Check for LIVE load		0.809	
$W_{LL}/W_{DL} < 1.25$		OK	

Total design load	W_D	11.181	kN/m^2
$W_D = W_{DL} + W_{LL}$			
Factored design load	W_{DF}	15.844	kN/m^2
$W_{DF} = 1.35W_{DL} + 1.50W_{LL}$			
Total load on the floor	F	475.331	kN
$F = W_{DF}$ X L1 X L2a			

Circular supports shall be treated as square supports having the same area.
Equivalent side of the column head having the same area:

Equivalent side	a	1.329	m
$a = (\pi/4 \text{ X } Lh^2)^{0.5}$			
Clear span along length	l_n	4.500	m
Check for span		3.900	m
$l_n > 0.65L1$		OK	

Bending moment coefficients for flat slabs

	End support/slab connection				First interior support	Interior spans	Interior supports
	Pinned		Continuous				
	End support	End span	End support	End span			
Moment	0	0.086*Fl*	−0.04*Fl*	0.075*Fl*	−0.086*Fl*	0.063*Fl*	− 0.063*Fl*

Notes

1. Applicable to slabs where the area of each bay exceeds 30 m², $Q_k \leq 1.25\ G_k$ and $q_k \leq 5$ kN/m²
2. *F* is the total design ultimate load, *l* is the effective span
3. Minimum span > 0.85 longest span, minimum 3 spans
4. Based on 20% redistribution at supports and no decrease in span moments

	End support/slab connection				At first interior support	Middle interior spans	Interior supports
	Simple		Continuous				
	At outer support	Near middle of end span	At outer support	Near middle of end span			
Moment	0	$0.086Fl$	$-0.04Fl$	$0.075Fl$	$-0.086Fl$	$0.063Fl$	$-0.063Fl$
Shear	$0.4F$	—	$0.46F$	—	$0.6F$	—	$0.5F$

NOTE F is the total design ultimate load ($1.4G_k + 1.6Q_k$);
l is the effective span.

Values for K'

% redistribution	δ (redistribution ratio)	K'
0	1.00	0.208[a]
10	0.90	0.182[a]
15	0.85	0.168
20	0.80	0.153
25	0.75	0.137
30	0.70	0.120

Key
a It is often recommended in the UK that K' should be llimited to 0.168 to ensure ductile failure

Absolute sum of –ve and +ve moments

Total design moment (Along length of slab)

$M_O = Wl_nL1^2/8$ | M_O | 320.848 kNm

Factored moment | M_{OF} | 320.848 kNm

Appropriation of moments

INTERIOR Panels

Total -ve moment	-0.063FL1	-179.675
Total +ve moment	0.063FL1	179.675

Moment in column strip & middle strip

Moment classification	**Col strip**	**Middle strip**
Negative moment (kNm)	-134.756	-44.919
Positive moment (kNm)	98.821	80.854

Calculation of K $K = \frac{M}{bd^2 f_{ck}}$

Moment classification	**Col strip**	**Middle strip**
Negative moment	0.187	0.062
Positive moment	0.137	0.112

Calculation of K' 0.170

$K' = 0.60\delta - 0.18\delta^2 - 0.21$

Calculation of Z $z = \frac{d}{2}\left[1 + \sqrt{1 - 3.53K}\right] \leq 0.95d$

Moment classification	**Col strip**	**Middle strip**
Negative moment	150.488	178.922
Positive moment	163.297	168.874

Required area of reinforcement

Moment classification	**Col strip**	**Middle strip**
Negative moment	2157.743	604.943
Positive moment	1458.221	1153.692

EXTERIOR Panels

Distrubution of bending moment across the panel width

Moment classification	Col strip	Middle strip
Interior negative (kNm)	183.953	61.318
Exterior negative (kNm)	114.079	0.000
Positive moment (kNm)	98.821	80.854

Calculation of K $K = \dfrac{M}{bd^2 f_{ck}}$

Moment classification	Col strip	Middle strip
Interior negative	0.255	0.085
Exterior negative	0.158	0.000
Positive moment	0.137	0.112

Calculation of Z $z = \dfrac{d}{2}\left[1 + \sqrt{1 - 3.53K}\,\right] \leq 0.95d$

Moment classification	Col strip	Middle strip
Interior negative	125.134	174.494
Exterior negative	158.176	190.000
Positive moment	163.297	168.874

z/d for singly reinforced rectangular sections

K	z/d	K	z/d
≤ 0.05	0.950[a]	0.13	0.868
0.06	0.944	0.14	0.856
0.07	0.934	0.15	0.843
0.08	0.924	0.16	0.830
0.09	0.913	0.17	0.816
0.10	0.902	0.18	0.802
0.11	0.891	0.19	0.787
0.12	0.880	0.20	0.771

Key
a Limiting z to $0.95d$ is not a requirement of Eurocode 2, but is considered to be good practice

Required area of reinforcement

Moment classification	Col strip	Middle strip
Interior negative	2728.593	909.531
Exterior negative	1692.151	0.000
Positive moment	1465.826	1199.312

Check for depth

$\varphi \rho f_y b d^2 (1 - 0.59 \rho \frac{f_y}{f'})$ Q 14921.961

For max +ve moment

Required depth of slab d_{REQD1} 81.379 mm

For max -ve moment

Required depth of slab d_{REQD2} 111.030 mm

Remark on depth provided OK

Check for shear in flat slab

Shear stress in flat slab

The critical section for shear for the slab will be at column perimeter

Length of critical section L_{CR} 0.500 m

Total factored shear V_u 471.369 kN

$V_u = W_F \times (L1L2a - L_{CR}^2)$

Total factored shear force τ_V 0.196 Mpa

$$\tau_V = \frac{1250w\,(A_{supp})}{(u_c + 9h)d}$$

4.7.6 Punching shear in flat slabs at columns

Check that:

(a) where shear reinforcement is to be avoided:

$$\frac{1250w\,(A_{supp})}{(u_c + 9h)d} \leq 0.5\text{N/mm}^2$$

(b) where shear reinforcement may be provided:

$$\frac{1250w\,(A_{supp})}{(u_c + 9h)d} \leq 0.9\text{N/mm}^2$$

(c) Check also that:

$$\frac{1250w\,(A_{supp})}{(u_c)d} \leq 0.9\sqrt{f_{ck}}$$

In the above verification

w is the total design ultimate load per unit area in kN/m^2
d is the effective depth of the slab at the column in mm
h is the thickness of the slab at the column in mm
A_{supp} is the area supported by the column in m^2
u_c is column perimeter in mm.

Perimeter $b_0 = 4*L_{CR}$	b_0	2000.000	mm
Concrete shear strength	τ_c	0.500	Mpa
Remark on shear cap		OK	

Check for shear in head

Eff depth at head portion d_{heff}		1690.000	mm
$b_0 = \pi(Lh + d_{heff})$	b_0	10.022	m
Total factored shear	V_u	348.698	kN
$V_u = W_F \times (L1L2a - \pi/4(Lh + d_{heff})^2)$			
Total factored shear force	τ_V	0.021	Mpa
$\tau_V = V_u / (b_0 \times d_{heff})$			
$k = 1 + \sqrt{200/d}$		2.00	
Mean reinf. ratio	ρ_1	0.02	
$C_{Rd.c} = 0.18/\gamma c$		0.12	
$v_{min} = 0.035k^{3/2} f_{ck}^{1/2}$		0.443	Mpa
$v_{Rd.c} = C_{Rd.c}\, k\, (100\, \rho_l\, f_{ck})^{1/3}$		0.821	Mpa
Concrete shear strength	τ_c	0.821	Mpa
Remark on shear in col head		OK	

$v_{Rd.c} = C_{Rd.c}\, k\, (100\, \rho_l\, f_{ck})^{1/3} \geq v_{min}$ (non-post or pre-tensioned design) 6.4.4 (6.47)

where

$k = 1 + \sqrt{200/d}$ less than or equal to 2 6.4.4 (6.47)

$\rho_l = \sqrt{\rho_{ly} \cdot \rho_{lz}}$ mean reinforcement ratio, ≤ 0.02 6.4.4 (6.47)

ρ_{ly} and ρ_{lz} the mean ratio of tension reinforcement in both directions (width of column + 3d each side).
$\rho_{ly} = A_{sly} / (bd_y)$ & $\rho_{lz} = A_{slz} / (bd_z)$ where b = 1000 mm

$C_{Rd.c} = 0.18/ y_c$ NA to BS EN 1992-1-1-2004 6.4.4 (1)

$y_c = 1.5$ partial factor for material for ULS 2.4.2.4 table 2.1N

$v_{min} = 0.035 k^{3/2} f_{ck}^{1/2}$ NA to BS EN 1992-1-1-2004 6.4.4 (1) and stated in 6.2.2 (6.3N)

Transposed to :

$v_{Rd.c} = (0.18/ y_c)\, k\, (100\, \rho_l\, f_{ck})^{1/3} \geq v_{min}$ & $y_c = 1.5$ (Concise Eurocode 2, June 2006)

$v_{Rd.c} = 0.12\, k\, (100\, \rho_l\, f_{ck})^{1/3} \geq v_{min}$ (non post-tensioned design)

or

$v_{Rd.c} = 0.12\, k\, (100\, \rho_l\, f_{ck})^{1/3} + 0.1\, s_{cp} \geq (v_{min} + 0.1 s_{cp})$ (post-tensioned design)

b. Design value of the maximum shear stress at the control perimeter u_1

$v_{Ed\,1} = \beta\, V_{Ed} / (u_1 d)$ 6.4.3 (3) 6.38

c. Design value of the maximum punching shear resistance

$v_{Ed\,1} < v_{Rd.c}$ punching shear reinforcement is not required 6.4.3 (2b)

Check for shear in drop

Eff depth at drop portion	d_{deff}	290.000	mm
$b_0 = 4(Ldr + d_{deff})$	b_0	7.160	m
Total factored shear	V_u	424.564	kN
$V_u = W_F \times (L1L2a - (Ldr + d_{deff})^2)$			
Total factored shear force	τ_V	0.204	Mpa
$\tau_V = V_u / (b_0 \times d_{deff})$			
$k = 1 + \sqrt{200/d}$		2.00	
Mean reinf. ratio	ρ_1	0.02	
$C_{Rd.c} = 0.18/\gamma c$		0.12	
$v_{min} = 0.035k^{3/2} f_{ck}^{1/2}$		0.443	Mpa
$v_{Rd.c} = C_{Rd.c}\, k\, (100\, \rho_l\, f_{ck})^{1/3}$		0.821	Mpa
Concrete shear strength	τ_c	0.821	Mpa
Remark on shear in drop		OK	

2.1 Closure

This Part provides a complete insight on the provisions of EC2 for the design of flat slab. A detailed sample calculation is presented in order to throw light on codal provisions and their practical application.

3. RESULTS AND DISCUSSION

3.1General

The comparison of results of Flat Slab Design by various code for analytical calculations, software analysis and experimental investigation is discussed in below Parts.

3.2 Results of Design of Flat Slab as per IS Code, ACI, EC2

CODE	IS-456	ACI-318	Euro code
Shape of Flat Slab for concrete strength (m)	Rectangle 6.0m X 5.0m	Rectangle 6.0m X 5.0m	Rectangle 6.0m X 5.0m
Grade of concrete (N/mm)	20	20	20
Grade of steel (N/mm^2)	415	415	415
Negative moment (KN-m)	107.250	234.806	179.675
Positive moments (KN -m)	57.750	126.434	179.6
Thickness of slab for Serviceability criteria (mm)	240	150	220
Punching shear	Safe	Safe	Safe

3.3 Closure

In this Part, results of experimental investigation, analytical calculations and software analysis are tabulated. Graphical representations of values are useful forcomparison of results based on which conclusions of dissertation are drawn.

4. CONCLUSIONS AND FUTURE SCOPE

4.1 General

All the work done in this dissertation work is concluded in this Part. Also, future scope of this study has been given.

4.2 Conclusions

1. The negative moment's section shall be designed to resist the larger of the two interior negative design moments for the span framing into common supports.
2. The positive mid-span moment is increasing and negative moment is decreasing when we analyze the slab.
3. In the Exterior support, the total design moments (Mo) are distributed as 100% in column strip and 0% in middle strip in both the case IS 456-2000 and ACI 318-08 & the total design moments (Mo) are distributed as 75% in column strip and 25% in middle strip in EC2- Part1-2004 .
4. By comparing with different codes we concluded that ACI 318, & euro codes are most effective in designing of flat slabs.

5. Drops are important criteria in increasing the shear strength of the slab.
6. Flat slab designs, as per IS Code, American Code, and Europe Code, offer distinct advantages and have specific

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areas where improvements are necessary. The comparative analysis indicates significant differences in performance

4.3 Scope of future study

1. Comparison of International Codes: Future studies can perform a detailed comparison of the design and performance of flat slabs using various international building codes (e.g., ACI, Eurocode, IS). This can help in identifying the strengths and limitations of each code and provide recommendations for best practices in different regions.
2. Preparation of excel worksheet analysis and design of flat slab with staggered column as per IS 456-2000, ACI 318 & EC2.
3. Formulate integrated design guidelines that combine the best practices and strengths of IS Code, American Code, and Europe Code.

5. REFERENCES

[1]. Lalit Balhar, Dr. J.N. Vyas, "Review On Comparative Analysis Of Flat Slab & Convetional RC Slabs With and Without Shear Wall", IRJET, Volume: 06 Issue: 02,Feb (2019).
[2]. Sumit Sharma, Ashish Yadav, and Mukesh Dubey, "Review On RCC StructureWith Flat Slab", International Journal of Advance Engineering and Research Development, Volume 5, Issue 02, February (2018).
[3]. R.S. More, "Analytical Study of Different Types of Flat Slab Subjected toDynamic Loading", IJSR, Volume 4 Issue 7, July (2015).
[4]. Avinash Patel and Seema Padamwar, "The Response Of Flat Slab and Grid Slab Systems in Conventional RCC Buildings", Indian J.Sci.Res. 14 (2): 516-521, (2017).
[5]. Sudhir Singh Bhaduria, Nitin Chhugani, "Comparative Analysis and Design of Flat and Grid Slab System with Conventional Slab System", IRJET, Volume: 04 Issue: 08, August (2017).
[6]. Mayuri S. Sethia, Prof. R.S. Deotale, P.S. Patankar, "Analysis and Design of FlatSlab, Grid Slab and Bubble Slab", IJSRD, Volume 5, Issue 02, (2017).
[7]. Ahuja V., Ahuja B.M., "Post tension flat slabs earthquake engineering & miscaspects in high seismic zones in the India environment," pp 2-4, (2009).
[8]. Bharath G.N., Gowda S. B. R., Chandrashekar A.V., "Review and Design Flat plate/Slabs Construction in India," Basaveshwara Nagar, Bangalore, pp 1-4, (2012).[9]. Durate I., Ramos A.M.P., Lucio V.J.G., "Strengthening of flat slabs with transverse Reinforcement," UNIC - Research Center in 7, (2008).
[10]. Luo Y.H., Durrani A.J., Conte J.P., "Equitant frame analysis of flat plate buildings for seismic loading," Journal of Structural Engineering, vol.120, pp 2137-2153, (1994).
[11]. Erberik M.A., Lnashai A.S., "Vulnerability analysis of flat slab structures," 13thWorld Conference on Earthquake Engineering, Vancouver, B.C., Canada, pp 2-14, (2004).
[12]. FIB. (2012). Bulletin 66: Punching shear of structural concrete slabs.International Federation for Structural Concrete (fib).
[13]. Indian Standards, New Delhi, "IS 456:2000, Plain and Reinforced Concrete -Code of Practice", Fourth Revision, July (2000).
[14]. American Concrete Institute, "ACI 318-08, Building Code Requirements forStructural Concrete and Commentary", January (2008).
[15]. European Standard, "Eurocode 2: Part 1-2004, Design of concrete structures -Part 1-1: General rules and rules for buildings", December (2004).

17