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SEISMIC PERFORMANCE OF FLAT SLAB WITH COLUMN

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Abstract:
As flat slab building structures are relatively more adaptable than customary concrete framed structure, so it turns out to be progressively powerless against seismic loading. In composite segment development, steel and concrete are incorporated as such that the upsides of the materials are enrolled in effective way. The fundamental goal of this examination is just to consider the seismic conduct of various sorts of flat slab building framework with composite segments. Like wise the similar investigation is finished with various kinds of flat slab working with customary column sections. Seismic parameters are followed by IS-1893-2016. And also there are many types of composite columns and from those fully encased steel columns (FESC) and concrete filled steel tube columns (CFST) are taken for the analysis. G+9 storied Model analyses preferred from previous studies by using Staad pro, a software package for the analysis and design of civil engineering structures. Flat slab design parameters are followed by IS-456- 2000.

Keywords
Flat slabs, composite column, structural analysis software Staad pro, seismic response, seismic zones.

I. INTRODUCTION

GENERAL

Flat-slab is one of the most widely used systems in reinforced concrete construction because of its high degree of structural efficiency. It uses simple formwork and reinforcing arrangements, and requires the least story height. Although efficient in resisting gravity load, the flat-slab system is inherently flexible and can have excessive lateral drift when subjected to seismic load- ing. Its susceptibility to severe damage during strong earthquakes is well documented (Rosenbluth 1986; Hawkins 1980).
In zones of high seismicity, the flat-slab systems are designed such that the slab-column space frame supports gravity loads and the shear walls pro- vide resistance to lateral load (Wey and Durrani 1992; Robertson and Dur- rani 1992; Moehle and Diebold 1985). However, it is required by the building codes [UBC: Uniform 1991; ACI: Building 1989] that the gravity load sub- system must be able to deform with the lateral load resisting system without any loss of its load carrying capacity. Thus, in reality the two subsystems act together. Furthermore, since the design seismic force recommended by the codes are generally much less than what the structure would experience during a major earthquake, a certain degree of nonlinear response is to be expected. How well a practical linear dynamic analysis procedure captures the frame-wall interaction and the nonlinear response feature remains to be studied. In the present paper, the evaluation of the results of a finite element-based three-dimensional (3D) dynamic analysis of a 9-story building.
In this study the focus is on the performance of flat slab RCC structure with all types likes flat slab without drop, flat slab with drop and flat slabs with perimeter beams which engage its actions to earthquake situation with composite column. As it is very much obvious from earlier literature so as to the flat slab arrangement is not stable in seismic force, so we are going to analytically investigate the outcome of flat slab normally with concrete encased columns and in different earthquake zones. The method considering for the analysis are Response spectrum analysis method, linear static analysis method as per the Indian Standard codal provisions and by using Staad pro software

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II. LITERATURE REVIEW

- Research Paper on Seismic Performances of Flat Slab through Composite Columns Mr. Ranjeet Singh1, Prof. G.V .Joshi, M-Tech student, G.H. Raisoni college of Engineering and Management Wagholi, Pune Assistant professor, Civil Engg. Dept., G.H. Raisoni college of Engineering and Management Wagholi,Pune Corresponding author: Mr. Ranjeet Singh
- This study basically focus on the flat slab Reinforced Concrete Cement building structure behavior under the seismic loading conditions. The building structures which are made up of flat slabs are more flexible than traditional frame building structure and to progress the behaviors of structures which are taking flat slabs underneath the earthquake conditions of loading, establishment of flat slab through drops and deprived of drops are measured in the literature. The Ground (G +9) tall building structures with storied height about 3.5 meter is made in E-tabs software's. It is concluded that the drift values follows a parabolic curve laterally storied heights with extreme value up to 4th floor. The important natural period values are high in flat slabs with drops structure as associated to neglecting panel drop.
- Seismic Performance Evaluation of Reinforced Concrete Moment Frames with Gravity Columns
- Bulent Akbas, Ph.D. Bilge Doran, Ph.D. Ali Bozer, Ph.D. Onur Seker, Ph.D.4 Mahmoud Faytarouni and Jay Shen, Ph.D.
- Moment frames with gravity columns in reinforced concrete (RC) buildings have been used extensively for the last decade in the United States. Unlike traditional beam–column–slab structures, they provide some advantages in terms of construction time and architectural and economical aspects in design process. The system consists of gravity-only columns resting directly on slabs and seismic force–resisting moment frames. Reinforced concrete special moment frames in two principal directions are typically placed at the perimeter as a lateral force– resisting system.

III. METHODOLOGY

To study the behavior of various models in case of seismic parameters, previous studies are preferred , the building plan, material and sectional properties and results are preferred to study of analysis results. The construction is modelled in three Dimension as viable construction via E tabs program. In the current effort, G+9 storied steel-clad concreted surround structures located in Zones III as per IS Codes is well- thought-out aimed at the learning. Total amount of straight outlines and perpendicular outlines are described then the flooring altitude is assumed. The structure elevation is stated forty five meter. The structures are considered as spaced surrounds. The intended planetary borders are considered for seismic load, live load, dead load and wind loads. The buildings are associated for Shear base, displacements of stores, story drift, storey shear and time period. The investigation were accepted with the subsequent model cases.

- Size of components of structure included in our design
  - Concrete and Steel
  - Column: 0.5 X 0.5 m
  - Slab thickness: 0.15 m
  - Plates Thickness: 0.23m
  - Floor to Floor Distance: 3.5 m
  - Slab Span: 5.5m x 5.5m
  - Floors: G+9
  - Grade of Concrete: M20 & M25
  - Self Load – 5.625 KN/m
  - Dead Load – 6.62 KN
  - Live Load- 4 KN

IV. ANALYSIS OF FLAT SLAB IN STAAD PRO

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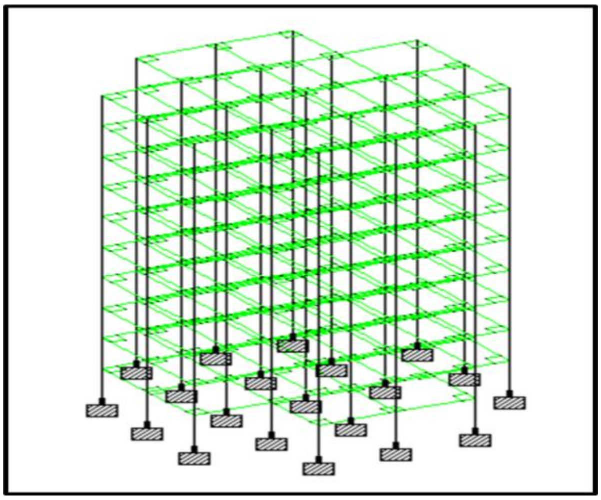

Fig.1. Showing Flat Slab Structure in Staad pro

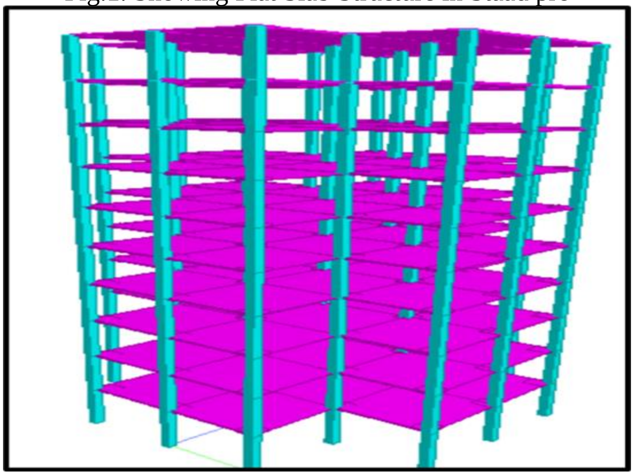

Fig. 2 Showing 3d view of Flat Slab Structure in Staad pro.

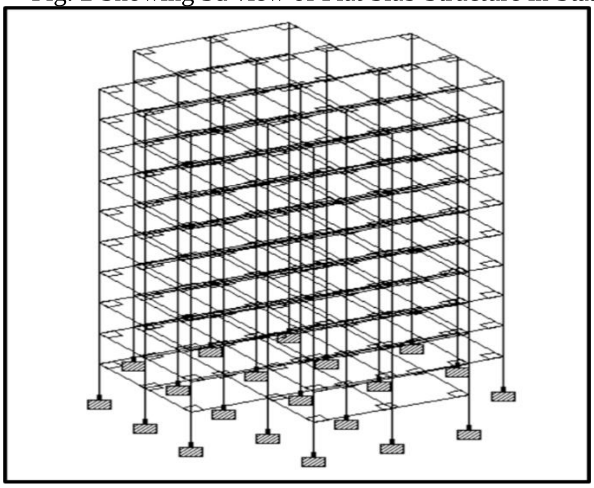

Fig. 3 Showing Concrete Structure in Staad pro

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V RESULT IN STAAD PRO

FAILURE DIAGNOSTICS

Project Name	:	PROJECT
Client Name	:	BABAR
Engineer Name	:	BABAR
Design File	:	E:\New folder\PROJECTBABAR-Column-1.rcdx
Analysis File	:	E:\New folder\PROJECTBABAR.STD
Analysis Last Modified	:	27-11-2022 05:16:04

No Failed Columns.

Software licensed to Administrator	Job No	Sheet No 1	Rev
	Part		
Job Title	Ref		
	By	Date 03-Jun-23	Chd
Client	File Structure1[1].std	Date/Time 04-Jun-2023 14:06	

Job Information

	Engineer	Checked	Approved
Name:			
Date:	03-Jun-23		

Project ID	
Project Name	

Structure Type	SPACE FRAME

Number of Nodes	1000	Highest Node	1111
Number of Elements	200	Highest Beam	323
Number of Plates	330	Highest Plate	653

Number of Basic Load Cases	-2
Number of Combination Load Cases	0

Included in this printout are data for:

All	The Whole Structure

Included in this printout are results for load cases:

Type	L/C	Name
Primary	1	DEAD LOAD
Primary	2	LIVE LOAD

Result

ISSN: 2456-9348
Impact Factor: 6.736

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***WARNING -  INSTABILITY AT JOINT   1110   DIRECTION = FY
 PROBABLE CAUSE SINGULAR-ADDING WEAK SPRING
 K-MATRIX DIAG=  1.1950020E+03 L-MATRIX DIAG=  0.0000000E+00 EQN NO     6356
 ***NOTE - VERY WEAK SPRING ADDED FOR STABILITY

***WARNING -  INSTABILITY AT JOINT   1110   DIRECTION = FZ
 PROBABLE CAUSE SINGULAR-ADDING WEAK SPRING
 K-MATRIX DIAG=  1.3262041E+04 L-MATRIX DIAG= -1.8189894E-12 EQN NO     6357
 ***NOTE - VERY WEAK SPRING ADDED FOR STABILITY

***WARNING -  INSTABILITY AT JOINT   1110   DIRECTION = MX
 PROBABLE CAUSE SINGULAR-ADDING WEAK SPRING
 K-MATRIX DIAG=  3.5549269E+05 L-MATRIX DIAG=  5.8207661E-10 EQN NO     6358
 ***NOTE - VERY WEAK SPRING ADDED FOR STABILITY

***WARNING -  INSTABILITY AT JOINT   1110   DIRECTION = MY
 PROBABLE CAUSE SINGULAR-ADDING WEAK SPRING
 K-MATRIX DIAG=  1.0811880E+06 L-MATRIX DIAG=  2.3283064E-10 EQN NO     6359
 ***NOTE - VERY WEAK SPRING ADDED FOR STABILITY

***WARNING -  INSTABILITY AT JOINT   1110   DIRECTION = MZ
 PROBABLE CAUSE SINGULAR-ADDING WEAK SPRING
 K-MATRIX DIAG=  3.5549272E+05 L-MATRIX DIAG=  2.9103830E-10 EQN NO     6360
 ***NOTE - VERY WEAK SPRING ADDED FOR STABILITY


  FOR LOADING -      1
  ***NOTE: TOTAL NO. OF JOINTS IS GREATER THAN 999
          NO OUTPUT FOR APPLIED JOINT EQUIVALENT LOADS

        STATIC LOAD/REACTION/EQUILIBRIUM SUMMARY FOR CASE NO.     1
        LOADTYPE DEAD  TITLE DEAD LOAD


         CENTER OF FORCE BASED ON Y FORCES ONLY (METE).
        (FORCES IN NON-GLOBAL DIRECTIONS WILL INVALIDATE RESULTS)

                      X =  0.109316226E+02
                      Y =  0.188416968E+02
                      Z = -0.626790812E-01
TOTAL APPLIED LOAD     1

   ***TOTAL APPLIED LOAD ( KN   METE ) SUMMARY (LOADING     1 )
       SUMMATION FORCE-X =          0.00
       SUMMATION FORCE-Y =     -18090.60
       SUMMATION FORCE-Z =          0.00

      SUMMATION OF MOMENTS AROUND THE ORIGIN-
      MX=       -1133.90  MY=          0.00  MZ=     -197759.57
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************** CONCRETE TAKE OFF **************
      (FOR BEAMS, COLUMNS AND PLATES DESIGNED ABOVE)
NOTE: CONCRETE QUANTITY REPRESENTS VOLUME OF CONCRETE IN BEAMS, COLUMNS, AND PLATES DESIGNED ABOVE.
      REINFORCING STEEL QUANTITY REPRESENTS REINFORCING STEEL IN BEAMS AND COLUMNS DESIGNED ABOVE.
      REINFORCING STEEL IN PLATES IS NOT INCLUDED IN THE REPORTED QUANTITY.

TOTAL VOLUME OF CONCRETE =       175.0 CU.METER

              BAR DIA         WEIGHT
              (in mm)         (in New)
              --------        --------
                 8              23434
                12              63752
                16              11273
                            ------------
             *** TOTAL=         98460
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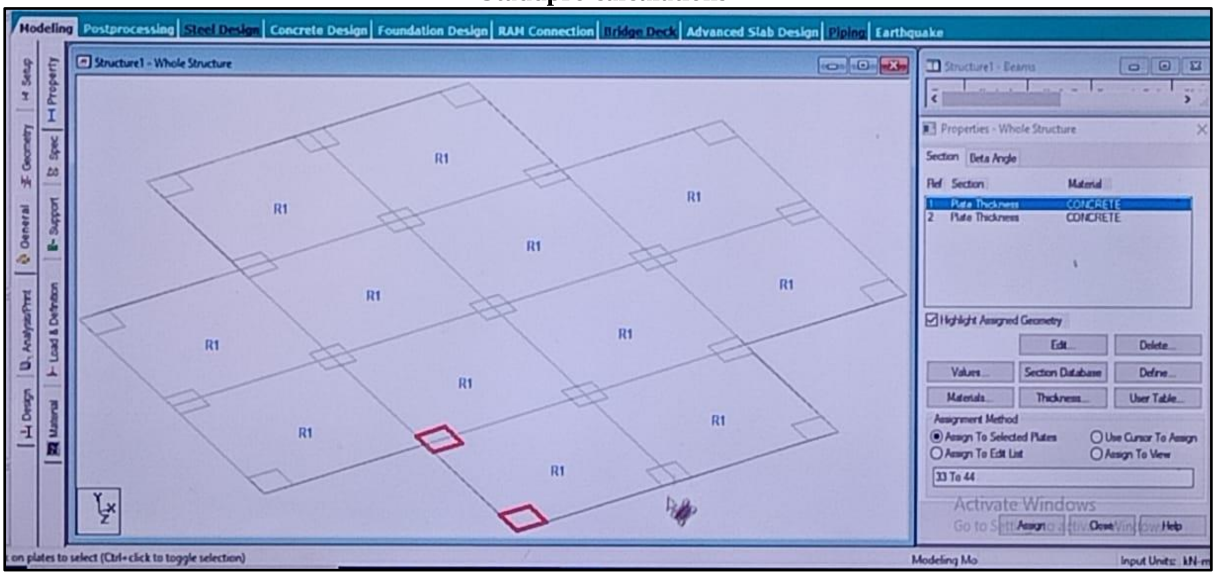
Staddpro calculations



VI. ANALYSIS MANUALLY

Given,

$$L_1 = L_2 = 5.5\text{ m } C_1 = 500\text{ mm}$$
$$L_1 = 3.5\text{ m}$$

<u>Step-1 select the thickness of slab.</u>

As per clause 31.2 .1 & 24.1 f is 456
$\frac{L}{d}$ ratio with fee 415 steel

$$= 0.9(0.8 \times 40) = 28.8$$

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$$\text{Min effective depth} = \frac{\text{span}}{4 \text{ ratio}} = \frac{5500}{28.8}$$
$$= 190 \text{ mm} > 125 \text{ mm}$$

$$\therefore \text{OK}$$

NOW,
Assuming 12 mm∅ bars, Nominal cover = 30 mm.

$$\text{Total depth} = 190 + 30 + \frac{12}{2}$$
$$\therefore \text{ Adopt } \begin{Bmatrix} D = 225 \text{ mm} \\ d = 189 \text{ mm} \end{Bmatrix}$$

width of column strip = Width of middle

$$= \frac{\text{Span}}{2} = \frac{5500}{2}$$

= 2750 mm

Step-2 Calculate the loads.

Self weight of slab

$$= 1 \times 0.225 \times 25.$$
$$= 5.625 \text{ kN/m}^2$$

$$\{B \times D \times \text{Rcc (unitwt)}$$

Imposed Load $= 4\text{kN/m}^2$
Finished load $= 1\text{kN/m}^2$

$$\text{Total } (\omega) = 10.62\text{kN/m}^2$$

Design factored load

$$(\omega v) = 1.5 \times 10.625$$
$$= 15.94\text{kN/m}$$

Clear spacing between column

$$L_n = L_1 - \frac{c}{2} - \frac{c}{2}$$
$$= 5.5 - \frac{0.5}{2} - \frac{0.5}{2} = 5 \text{ m.}$$

Total design load

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$$\text{on the } = \mu = \text{ er } \times \text{Ln} \times L_2$$
$$\text{panel. } = 15.94 \times 5 \times 5.5$$

$$[k = 458.35\text{kN}]$$

Step-3 Calculate Bending Moments

$$M_0 = \frac{4L_n}{\delta} = \frac{438.35 \times 5}{8}$$
$$[M_0 = 273.97\text{kN.m}]$$

Interior panel (31.4.3.2)

$$\text{Negative Design moment} \quad = 0.65\text{Mo}$$
$$= 0.65 \times 273.97$$
$$= 178.08\text{kNm}$$
$$\text{Positive Design moment} \quad = 0.35\text{Mb}$$
$$= 95.89\text{kN.m}$$

building is not restrained against lateral sway
1.2 times the clear height

$$\text{length } = H - D = 3.5 - 0.225 = 3.275 \text{ m}$$
$$\text{Lee } = 1.2 \times 3.275.$$
$$[\text{ Lee } = 3.93 \text{ m}]$$

$\frac{\text{Relative stiffness of}}{\text{Column}}$

$$= K_c = \frac{I_c}{\text{Lee}} = \frac{a^4}{12 \times \text{ Lee}}$$

$$\frac{0.5}{12 \text{ x } 3.93} = 1.325 \text{ X } 10$$

Relative Stiffness Of Slab Panel

$$\text{KS} = \frac{\text{IS}}{\text{LSE}} = \frac{\text{B X T3}}{\text{12 X LSE}}$$

$$= \frac{5.5 \text{ X } (0.225) \text{X } 3}{12 \text{ X } 5.5}$$

$$= 9.429$$

$$\propto C = \frac{\Sigma Kc}{Ks} = \frac{2 \text{ X } 1.325 \text{ X } 10^3}{9.492 \text{ X } 10^{-4}}$$

$$\propto C = 2.79$$

Hence from the table 17 IS 456 : 2000

$\propto$C min =0.12

2.79 > 0.12

Hence stiffness is sufficient

OK

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Step 4) distribution table

	Column strip KN/m	Ast mm2	Middle strip KN/m	Ast mm2
Interior panel negative moment	0.75 x 178.08 =133.56	212.8	178.08-133.5 =44.52	710
Positive moment	0.60 x 95.89 =57.53	914	95.89-57.53 =38.35	611
Outer panel negative at Exterior support	1 x 131.23 =131.23	2091	0	-
Negative at inner support	0.75 x 185.20 =138.90	2190	46.30	740
Positive at pannel	0.60 x 116.16 =69.70	1111	46.46	740

Step 05 :- Check the slab depth for bending (M = 138.9 KN m)
MU =0.85fy Ast d (1-Ast.fy/bd. fck)

D=121mm<189mm
Hence OK

Step 06 :- design of reinforcement :-
R/F at the interior support of outer panel column strip
Ast =2190 mm^2
AQ = 113.04mm^2 (12mmQ)

Spacing = AQ.b/Ast = 113.04 x 5.5 /2190
= 280mm C/C.

At the provide 12mmQ @140 C/C

R/F at outer support at top (Ast = 2091 mm^2)
{.: 12mm Q @145mm C/C}
R/F at middle span at bottom (Ast = 1111mm^2)
{ :. 12mm Q @ 275mm C/C}
R/F at inner support at top (Ast =2128mm^3)
{;. 12mm Q @ 146 mm C/C }

Minimum Reinforcement

Ast min = 0.12%
[Ast Min =742.5mm^2]

{:. Provide 10mm Q bars @ 275 mm c/c at middle strip to take up positive & negative moments }
Integrity reinforcement

Ast = 0.5 x Wv x L x 12 / 0.87 x fy
= 0.5 x 15.94 x (5.5)^2 x 10^3 / 0.87 x 415
[Ast = 667 mm^2]

;. Provide 2 bars of 20mm Q each way with length of 2Ld (2 x 806 = 1612 mm)

Step 07 :- Check the punching shear.
The critical shear plane is at a distance at a distance of D/2 from face of column.

Perimeter of (bo) = 4 (a+b)
Critical section = 4 (0.5+0.189)
(bo= 2.756mm)

Shear face on (Vv) = Wv [LxL-(a+d)(a+d)]

This plane = 15.94 (5.5 x5.5 –(0.68)(0.68)
= [Vv = 474.6 KN]

Nominal shear stress Cv = Vu/bo x d

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= 474.6 x10^3 / 2756 x 189
[Cv =0.91 N/mm^2]

Shear strength = Ks Tc [clause 31.6.3.1)

K3 = 0.5+ Bc < 1
Bc = 0.5/0.5 =1
[:. Ks = 1]
Tc = 0.25 fck = 0.25 25 =1.25 N/mm^2
Ks Tc= 1.25 N/mm^2 > 0.91 N/mm^2

{ Hence, no need to provide Shear reinforcement}

VII. CONCLUSION

- Though flat slab is a great structural system with respect to its aesthetic and functional use, it needs to be carefully chosen only in non-seismic zones.
- In India, it shall be used only in seismic Zone II as much as possible and not in higher zones. If ever we choose to use flat slabs, it needs a careful attention in the scheme to take care of the lateral load transfer.
- The structural design points needs to be strictly implemented.
- We have validated design of Flat Slab with both Staad pro software and manually by IS code (1893 part 1) and in Staad pro there are zero errors and manually we can conclude that there is no need of shear reinforcement.

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