"Dynamic Analysis Of Special Moment Resisting Frame Building With Flat Slab And Grid Slab"

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ABSTRACT

A popular form of concrete building construction uses a flat concrete slab (without beams) as the floor system. This system is very simple to construct, and is efficient in that it requires the minimum building height for a given number of stories. Unfortunately, earthquake experience has proved that this form of construction is vulnerable to failure, when not designed and detailed properly, in which the thin concrete slab fractures around the supporting columns and drops downward, leading potentially to a complete progressive collapse of a building as one floor cascades down onto the floors below.

Grid floor system consisting of beam spaced at regular intervals in perpendicular directions, monolithic with slab .They are generally employed for architectural reasons for large room such as, auditoriums, theaters halls, show room of shops. Analysis and Design of flat slabs are still the active areas of research and there is still no general agreement on the best design procedure. The present day Indian Standards Codes of Practice outline design procedures only for slabs with regular geometry and layout. But in recent times, due to space crunch, height limitations and other factors, deviations from a geometry and regular layout are becoming quite common. Also behavior and response of flat slabs during earthquake is a big question.

KEYWORD :- Flat slab, grid slab, storey drift

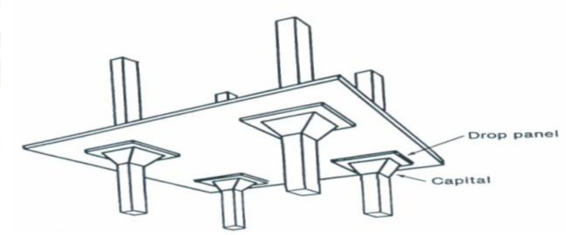
SCOPE OF STUDY

The lateral behavior of a typical flat slab building which is designed according to I.S. 456-2000 is evaluated by means of dynamic analysis. The inadequacies of these buildings are discussed by means of comparing the behavior with that of conventional flat slab & Grid slab system is selected for this purpose. To study the effect of drop panels on the behavior of flat slab during lateral loads, Zone factor and soil conditions – the other two important parameters which influence the behavior of the structure, are also covered. Software ETABS is used for this purpose. In this study between the number of stories, zone and soil condition is developed

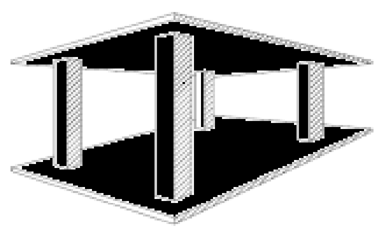
1. INTRODUCTION

1.1 FLAT SLAB

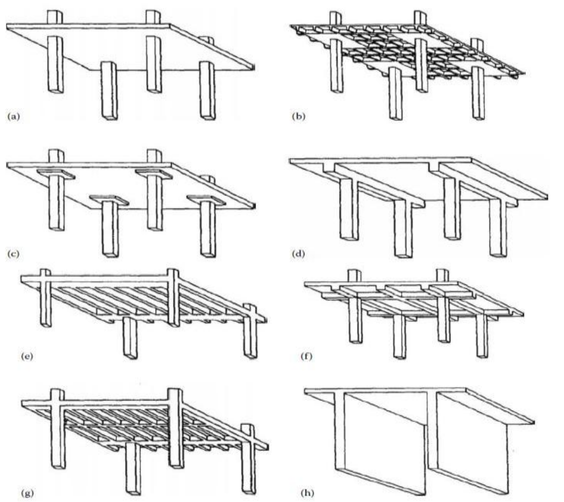
A reinforced concrete flat slab, also called as beamless slab, is a slab supported directly by column without beams. A part of the slab bounded on each of the four sides by centre line of the column is called panel. The flat slab is often thickened closed to supporting columns to provide adequate strength in shear and to reduce the amount of negative reinforcement in the support region. The thickened portion i.e. the projection below the slab is called drop or drop panel. In some cases, the section of column at top, as it meets the floor slab or a drop panel, is



Flat slab with drop & column head structure



Typical flat slab



Floor system

Enlarged so as to increase primarily the perimeter of the critical section for shear force hence increasing the capacity of the slab resisting two way shear and to reduce negative bending moment at such enlarged or flared portion of capital.

METHODS

General

This report examines the seismic response of structures. The findings are of importance in the evaluation of the inherent seismic resistance of such structures, designed only for wind-induced lateral forces, and in the evaluation on the effect of implementation of specific design requirements. The conclusions, based on the examination of two flat slab structures, show that although specific design parameters (drift, base shear, overturning moment) exceed those induced by static wind pressure, the inherent capacity structure may be sufficient to resist moderate seismic excitation if the structure satisfy wind design criteria

Dynamic analysis shall be performed to obtain the design seismic forces and its distribution to different levels along the height of building and to the various lateral load resisting element.

Method of Dynamic Analysis:

Building with regular or nominally irregular plan configuration may be modeled as a system of masses lumped at floor levels with each mass having one degree of freedom, that of lateral displacement in the direction under consideration. Undamped free vibration analysis of entire building modeled as spring – mass model shall be performed using appropriate masses and elastic stiffness of the structural system to obtain natural periods (T) and mode shapes {f} of those of its modes of vibration that needs to be considered. The number of modes to be used should be such that the sum of total of modal masses of all modes considered is at least 90% of total seismic mass

DESIGN OF FLAT SLAB

Method of Design:

Two approximate methods are adopted by the codes for design of flat slab. These methods can be used provided the limitation.

The two design methods are:

a) The direct design method
b) The equivalent frame method

1.2 GRID SLAB

Grid floor systems consisting of beams spaced at regular interval in perpendicular directions, monolithic with slab. They are generally employed for architectural reasons for large rooms such as auditoriums, theatre halls, show rooms of shop where column free spaced void formed in the ceiling is advantageously utilized for concealed architectural lighting. The sizes of the beam running in perpendicular directions are generally kept the same. Instead of rectangular beam grid, a diagonal

ANALYSIS OF GRID SLAB

1. Approximate Methods
2. Analysis of grid floor by plate load theory

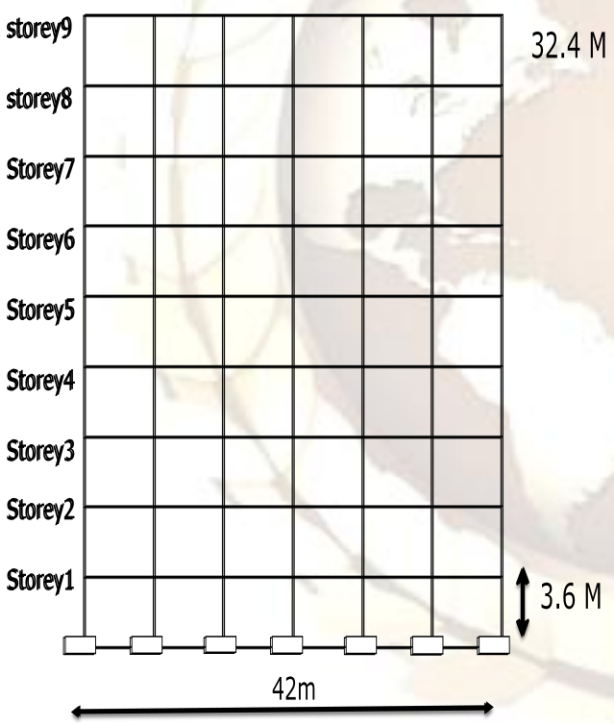
PLANNIG STAGE

1.	Plan dimensions	25.2 m x 42 m (Center to Center dist)
2.	Length in X- direction	42 m
3.	Length in Y- direction	25.2 m
4.	Floor to floor height	3.6 m
5.	No. of Stories	9
6.	Total height of Building	32.4 m
7.	Slab Thickness	250 mm
8.	Thickness of the drop	100 mm
9.	Width of drop	3000 mm
10.	Edge Beam	400 x 900 mm
11.	Size of the Column	1-3 story 850 x 850 mm
		4-6 story 750 x 750 mm
		7-9 story 600 x 600 mm
12.	Grade of concrete	M 25
13.	Grade of Steel	Fe 415

14.	Panel Dimensions	8.4 x 8.4 m
15.	Width of middle strip	4200 mm
16.	Width of Column strip	4200 mm
	Zone III	For all soil condition

Loading to be considered for the analysis purpose

Sr. no.	Loading	Terrace	Remaining floor	
1	Dead load	4.0 kN/m^2	6.5 kN/M^2	Flat slab
		4.0 KN/m^2	4.0 KN/m^2	Grid slab
2	Live load	1.5 kN/M^2	4.0 kN/M^2	Flat slab
		1.5 kN/M^2	4.0 kN/M^2	Grid slab
3	Grid	4.0 kN/m^2 @ parapet weight 10.0 kN/m^2 @ regular floor weight (for Flat slab & Grid slab)		
No loading considered in internal beam for grid slab building				

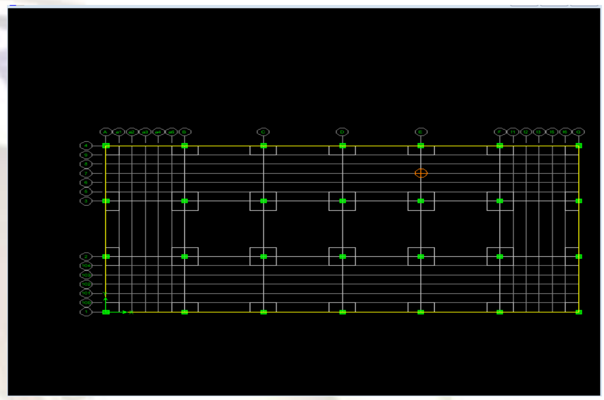


ELEVATION OF FLAT SLAB

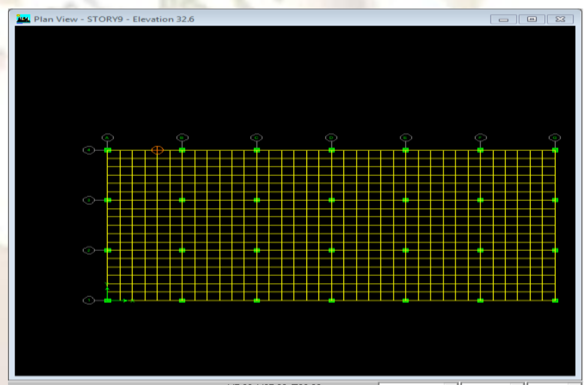
Load combination considered

- 1.5 DL + 1.5 LL
- 1.5 EQX + 1.5 DL
- - 1.5 EQX + 1.5 DL
- 1.5 EQY + 1.5 DL
- - 1.5 EQY + 1.5 DL
- 1.2 EQX + 1.2DL + 0.3 LL
- - 1.2EQX +1.2 DL + 0.3 LL
- 1.2 EQY + 1.2 DL + 0.3 LL
- -1.2EQY +1.2 DL + 0.3 LL
- 0.9 DL + 1.5 EQX
- 0.9 DL – 1.5 EQX
- 0.9 DL + 1.5 EQY
- 0.9 DL – 1.5 EQY

Plan and 3D model of flat slab & grid slab (ETABS SOFTWARE)



Plan of flat slab



Plan of grid slab

Method of analusis of building

Statis Analysis:-

Existing flat slab building is analyzed manually for static load cases.since the given flat slab system satisfies all the condition required by Direct Design Method(DDM),both the methods of analysis are used viz. DDM, EFM ,and compared factored moment for gravity load condition are given for 600mm square column

Details of Bending moment in slab panel

Sr. No		Design Method	Negative Moment (KNm)	Positive Moment (KNm)	moment
1 2	Exterior panel	DDM EFM	640 430	470 530	1110 960
3 4	Interior panel	DDM EFM	790 930	420 350	1210 1280

Dynamic analysis

1. Response spectrum method is used for analysis, Importance factor & response reduction factor are considered as 1 & 5 respectively. By considering 12 modes mass participation of flat slab building is achieved up to 96%(following table)
2. Therefore for all buildings 12 modes are considered.
3. Ritz Vector analyses are used for analysis. Rigid diaphragm action is considered for analysis

Center of mass & centre of rigidity coincides, due to regularity in the plan, mass and stiffness of the building.
Centre of mass & centre of rigidity lies at (21m, 12.6m)

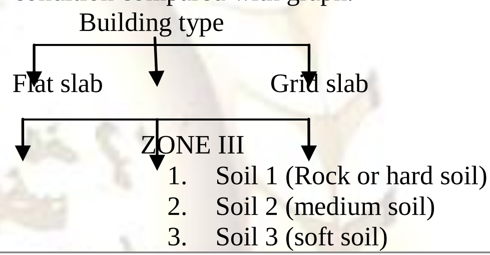
Details of time period and mass participation for flat slab

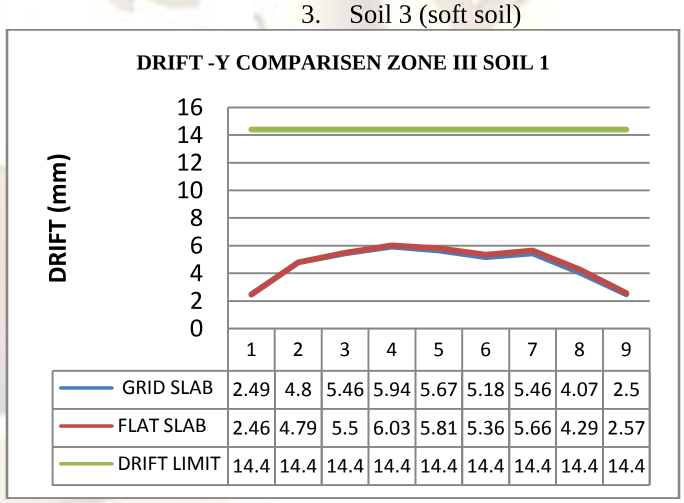
Mode No,	Time period	% mass participation	Cumulative Mass participation
1	1.472185	76.6451	76.6451
2	1.318386	10.8657	87.5108
3	0.573172	2.3588	89.8696
4	0.55808	1.333	91.206
5	0.320090	1.1464	92.349
6	0.313189	0.87236	93.22136
7	0.214571	0.73056	93.95192
8	0.2111013	0.6398	94.259172
9	0.149426	0.47539	95.06711
10	0.147395	0.35595	95.42306
11	0.087395	0.09812	95.52118
12	0.086613	0.0756	95.59678

Results:-

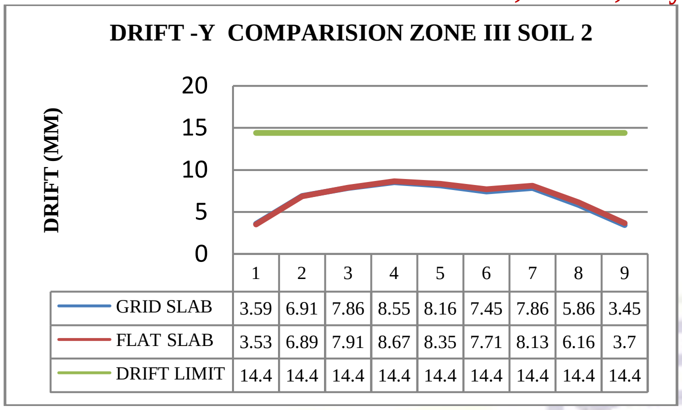
BUILDING DRIFT

1. Storey drift is defined as difference between lateral displacement of one floor relative to the other floor. As per IS. 1893-2002 CL.7.11.1; the storey drift in any storey due to the minimum specified design lateral force with partial load factor 1.00 shall not exceed 0.004 times the storey height. As per I.S. requirement it is limited to 0.4% of the storey height. Drift control is necessary to limit damage to interior partition, elevator and stair enclosures, glass. & cladding systems
2. In this case storey height is 3600 mm. therefore limited storey drift is calculated as storey drift /3600 =0.004
   Therefore, storey drift = 14.4 mm
3. In ETABS version 9.6.0 the ratio of (storey drift / storey height) is designated as storey drift this value should not exceed 0.004
4. After the dynamic analysis, combination which has maximum drift is selected. It is (Dl + EQY) since there is less stiffness for the building in Y-direction, building deflect more in y- direction
5. Storey drift of grid slab. Flat slab in Y-direction, when placed in Zone III and in three soil condition compared with graph.



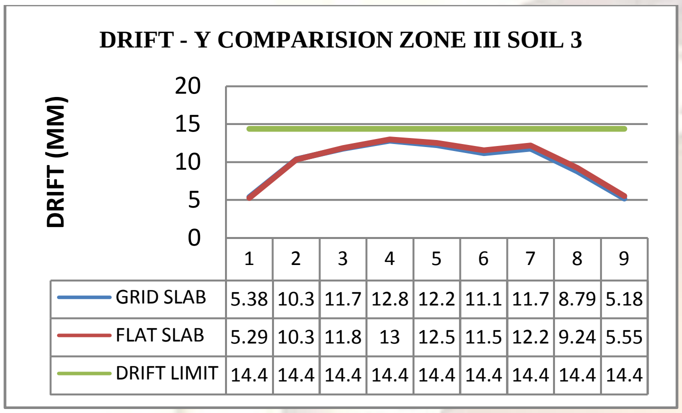


Graph 1



	1	2	3	4	5	6	7	8	9
GRID SLAB	3.59	6.91	7.86	8.55	8.16	7.45	7.86	5.86	3.45
FLAT SLAB	3.53	6.89	7.91	8.67	8.35	7.71	8.13	6.16	3.7
DRIFT LIMIT	14.4	14.4	14.4	14.4	14.4	14.4	14.4	14.4	14.4

Graph 2



	1	2	3	4	5	6	7	8	9
GRID SLAB	5.38	10.3	11.7	12.8	12.2	11.1	11.7	8.79	5.18
FLAT SLAB	5.29	10.3	11.8	13	12.5	11.5	12.2	9.24	5.55
DRIFT LIMIT	14.4	14.4	14.4	14.4	14.4	14.4	14.4	14.4	14.4

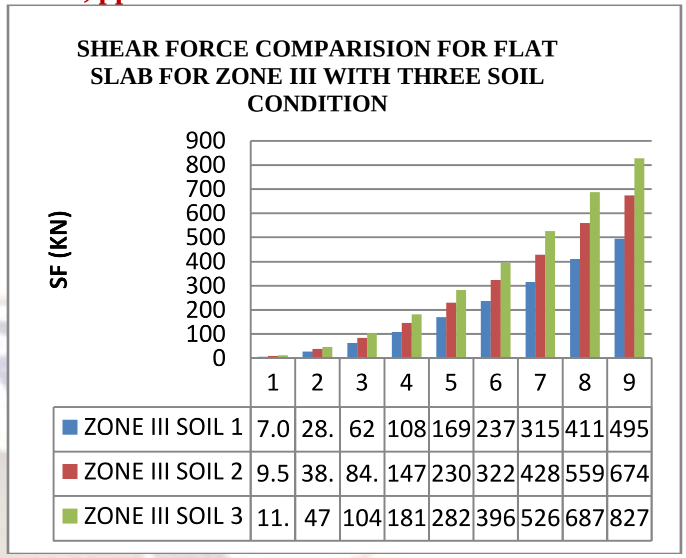
Graph 3

Conclusion from graph (graph 1 to graph 3):-

1. All graphs clearly show that grid slab has less drift compared to flat slab. Drift or relative displacement of a storey is the ratio of base shear experienced by that storey to total stiffness of column at that storey is same for all three type of slab. Maximum drift indicate maximum base shear.
2. Drifts of flat slab and grid slab are approximately equal up to storey 4.
3. Comparing strata condition, building on soft soil (soil 3) deflect more than other to soil condition.
4. All slab deflect within the limit when strata of type one i.e. rock, or hard soil.
5. Storey four and storey seven experience maximum drift but not exceeding the drift limit. This shows that column stiffness requirement of storey four and seven is greater than that or remaining storey.

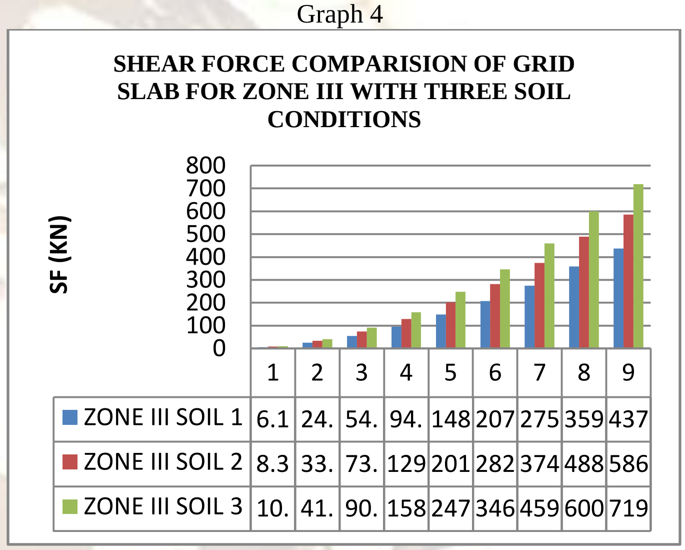
SHEAR FORCE:-

Shear force experienced by each storey of flat slab and grid slab is compared based on different soil condition. Existing building is located in zone III.



	1	2	3	4	5	6	7	8	9
ZONE III SOIL 1	7.0	28.	62	108	169	237	315	411	495
ZONE III SOIL 2	9.5	38.	84.	147	230	322	428	559	674
ZONE III SOIL 3	11.	47	104	181	282	396	526	687	827

Graph 4



	1	2	3	4	5	6	7	8	9
ZONE III SOIL 1	6.1	24.	54.	94.	148	207	275	359	437
ZONE III SOIL 2	8.3	33.	73.	129	201	282	374	488	586
ZONE III SOIL 3	10.	41.	90.	158	247	346	459	600	719

Graph 5

Conclusion from graph (graph 4 & 5):-

1. Flat slab experience maximum shear force, where as grid slab experiences less shear force. Shear force experienced by flat slab is 14 % higher than that of the grid slab for all combination of zone and soil conditions.
2. There is definite correlation between increase in shear force and storey drift with change in soil conditions for particular type of slab e.g. flat slab building in medium soil condition (soil 2) experiences 36% more drift and 36% more shear force than building located on hard strata, where flat slab building on soft soil condition both of them are 67% more. Similarly in case of grid slab also.

DESIGN MOMENT:-

Comparison of maximum moment obtained manually and by software for flat slab

Sr. No		Design Method	Negative Moment (KNm)	Positive Moment (KNm)	Moment (KNm)	Software (KNm)
1 2	Exterior panel	DDM EFM	640 430	470 530	1110 960	1085
3 4	Interior panel	DDM EFM	790 930	420 350	1210 1280	1132

Comparison of maximum moment obtained manually and by software for grid slab

	Manually	**Software**
Maximum moment (KNm)	**1813**	**1956**

CONCLUSION:-

1. Existing flat slab building performs well in zone III and with all soil conditions.
2. For improving drift conditions of flat slab in higher seismic zones lateral load resisting system should be coupled with slab column frame, and or stiffness of column should be increased.
3. Since soil condition drastically affects the behavior of building during earthquake, careful investigation of strata before selecting type of construction must be done.
4. 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.
5. Drops are important criteria in increasing the shear strength of the slab.
6. Negative moment is highly concentrated within the critical perimeter of the column, positive moment is much more uniform with maximum at column centerline.

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