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Seismic Analysis of Conventional, Flat and Grid Slab RC Structures

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ABSTRACT

The response of the structure under dynamic loading depends on the characteristics of the structure such as Natural frequencies, Mode Shapes, Base shears, Displacements, Storey drifts and Accelerations. In present study, seismic analysis is carried out for different cases of RC slab systems with a total of nine models having different type of slabs such as Conventional, Flat and Grid slab along with their combinations in the RC structure. The FE analysis involving modal, equivalent static and response spectrum analyses are performed adopting Indian Standard Code for earthquake resistant design of structures for all the seismic zones and results such as natural frequency, base shear, displacement, and storey drift are compared.

KEYWORDS - Base Shear, Displacement, Modal Analysis, Seismic Zones, Storey Drift

1. INTRODUCTION

The rapid growth of the urban population and scarcity of space have considerable influence on the development of vertical growth consisting of low rise, medium rise, and high-rise buildings. Reinforced concrete structures are always subjected to gravity loads such as self weight, superimposed dead load and live load along with lateral loads such as seismic load and wind load.

Earthquake is a natural phenomenon, which results in damaging of structures and causing loss of lives. This leads to need of structural design based on seismic responses by adopting suitable methods to increase strength and stability of structures.

The main purpose of this earthquake resistant design of reinforced concrete is to design structural members of building like column, beam, and slab to withstand against the dynamic forces and make sure the building should be safe and firm. In this study three different type of slabs like conventional slab, flat slab and grid slab are considered along with their combinations.

1.1 Conventional Slab

All slabs are supported with beams and columns, with the load transferred to those elements as shown in Fig 1. A conventional slab is classified as either.

- One-way: Supported by beams on two opposite sides, carrying the load along one direction.

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- Two-way: Supported by beams on all four sides, carrying the load along both directions.

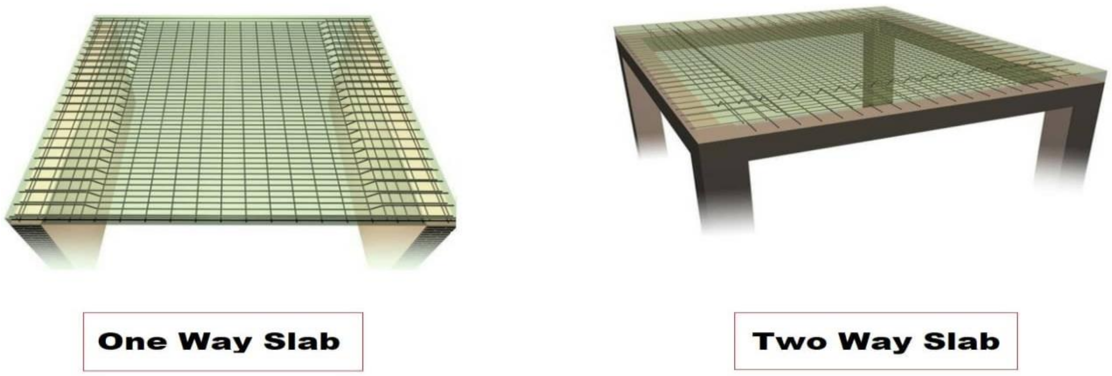


Figure 1: One Way and Two Way Slabs [8]

1.2 Flat Slab

Flat slab is an RCC slab built monolithically with supporting columns and reinforced in two or more directions. Beams are not provided to support the slab. The loads are directly transferred to the columns. In flat slabs, the columns are provided with enlarged heads called capitals or column heads. Typical Flat Slab and types of Flat Slab are shown in Fig 2.

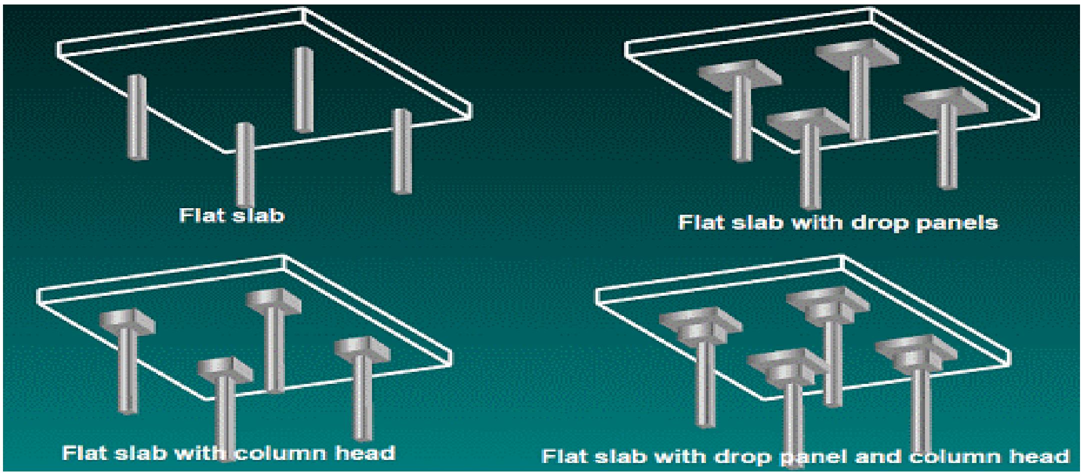


Figure 2: Types of Flat Slab [9]

1.3 Grid Slab

A grid is a planar structural system composed of continuous members that either intersect or cross each other as shown in Fig 3. Grid slabs are those structures in which beams are provided at square or rectangular intervals in perpendicular direction with slabs. Grid slab is used to cover large column free areas with aesthetic value and is subjected to loads applied normally to its plane.

Figure 3: Grid Slab [10]

2. BACKGROUND

A lot of research has been done in comparing Flat slab with drop & grid slab, Flat slab without drop & Grid slab, Flat slab with drop & Conventional RC slab, Flat slab without drop & Conventional RC slab and Grid slab & Conventional RC slab by different Static and Dynamic methods to compare time period, base shear, displacements, storey drifts, storey accelerations etc. considering different earthquake Zones as per the Indian Standard code of practice IS 1893. A brief review of the available information studies are presented below.

Sandesh D. Bothara and, Dr.Valsson Varghese (2012) [1], Himanshu Kandpal (2015) [2], Dakshayani S et .al (2016) [3], Mohammed Fatir et.al (2016) [4], Navjot Kaur Bhatia and Tushar Golait (2016) [5], Ch. Rajkumar and Dr. D.Venkateswarlu (2017) [6], Anju Mary Abraham and Dr S. Packialakshmi (2018) [7] and many more have dealt with Dynamic analysis of different slabs to investigate the behaviour of the structures as per the governing earthquake codes of respective countries but a very few work has been done on comparison of multi storied building having combinations of Flat slab without drop, Grid slab and Conventional RC slabs in single structure. Hence the present study aims at evaluating the performance and comparing the analysis results of RCC structures with combinations of Conventional RC slabs, Flat slab without drop and Grid slab for the same structure using ETABS.

3. OBJECTIVES

The main objectives of this study are.

1. To study the seismic performance of Conventional, Flat and Grid slab RC structures.
2. FE analysis involving Modal, Equivalent static and Response Spectrum Analyses to be carried out as per IS 1893 (Part 1): 2016.

4. METHODOLOGY

The Methodology includes

1. Studying the literature on analyses of conventional, flat and grid RC slabs.

2. FE analysis on typical 15 storey RC structure having Conventional, Flat and Grid slabs along with their combinations to obtain Natural frequencies, Mode Shapes, Base shears, Displacements and Storey drifts for zone V as per IS 1893 (Part 1): 2016.
3. All the results are tabulated, discussed and conclusions drawn.

5. MODELS DESCRIPTION

The models considered for analysis are shown in Fig 4 to 12 and their properties in Table 1.

Table 1 Properties of the Slab Systems

Sectional Properties		
No. Storeys	15	
Storey Height	3.6m	
Beam size	300mm x 600mm	
Column size	750mm x 750mm	
Slab thickness	Conventional Slab	200mm
	Flat Slab	220mm
	Grid Slab	250mm
Panel size	6m x 6m	
Material Properties		
Grade of concrete	M25	
Grade of steel	Fe-500	

5.1 CS SLAB SYSTEM: This has Conventional Slab in all 15 storeys of RC structure.

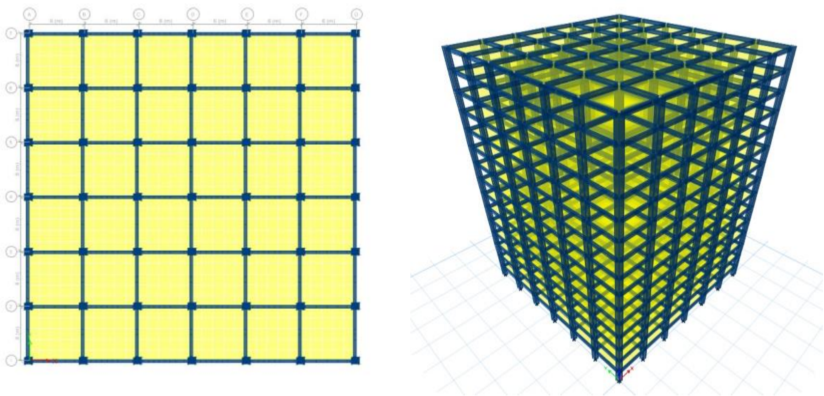


Figure 4: a. Plan view and b. Elevation view of CS model

5.2 FS+CS SLAB SYSTEM: This has Flat Slab from ground floor to 7th storey and Conventional Slab from 8th to 15th storey of RC structure.

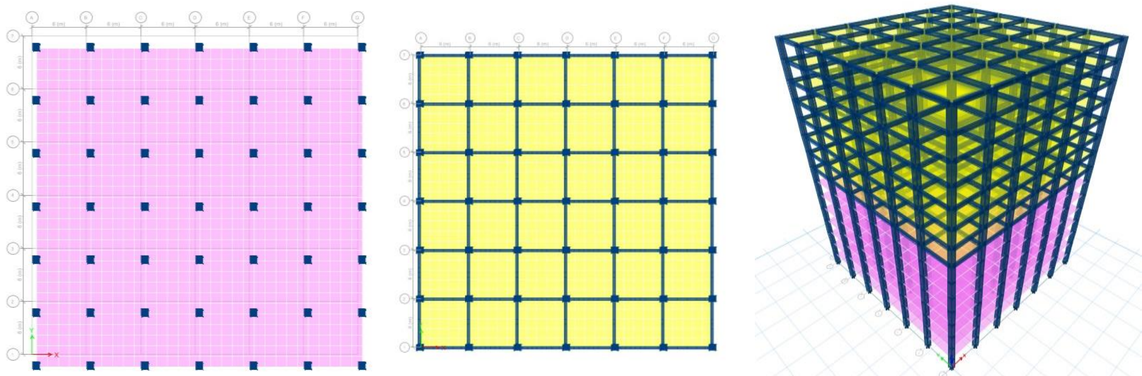


Figure 5: a. Plan view from Ground storey to 7th storey, b. Plan view from 8th storey to 15th storey and c. Elevation view of model FS+CS

5.3 GS+CS SLAB SYSTEM: This has Grid Slab from ground floor to 7th storey and Conventional Slab from 8th to 15th storey of RC structure.

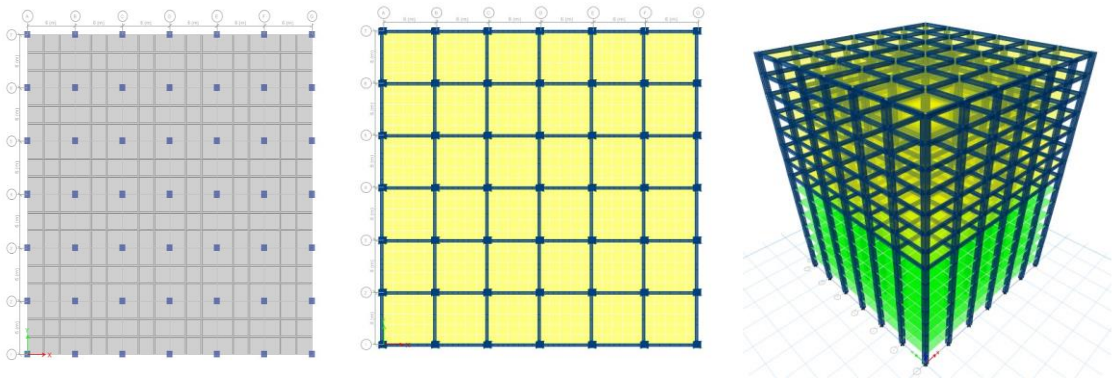


Figure 6: a. Plan view from Ground storey to 7th storey, b. Plan view from 8th storey to 15th storey and c. Elevation view of model GS+CS

5.4 FS SLAB SYSTEM: This has Flat Slab in all 15 storeys of RC structure.

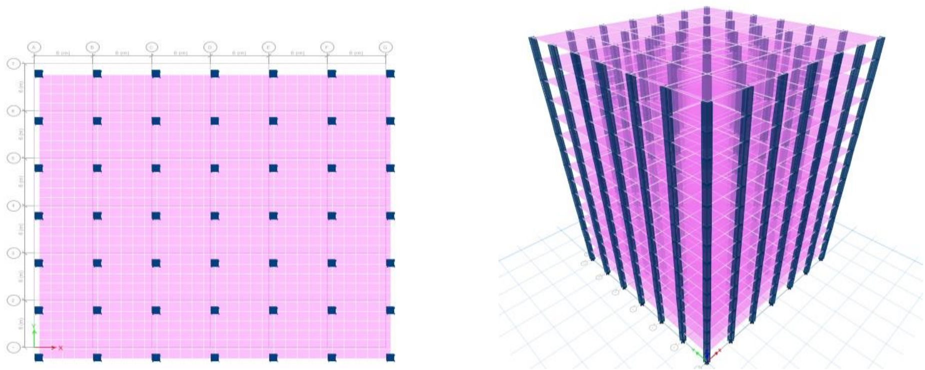


Figure 7: a. Plan view and b. Elevation view of model FS

5.5 CS+FS SLAB SYSTEM: This has Conventional Slab from ground floor to 7th storey and Flat Slab from 8th to 15th storey of RC structure.

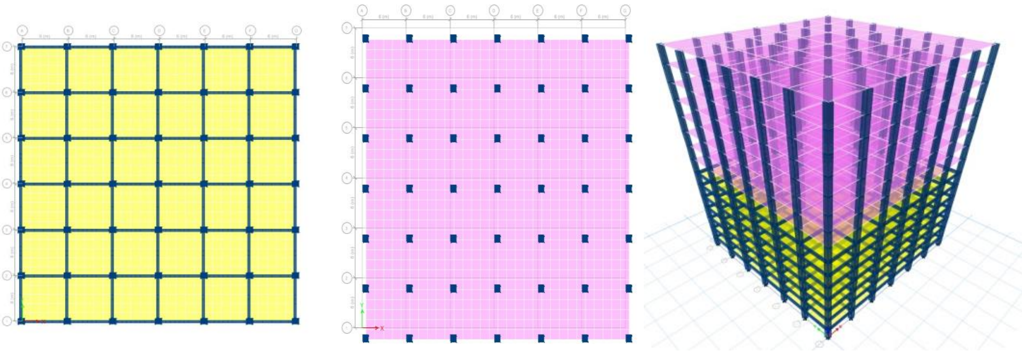


Figure 8: a. Plan view from Ground storey to 7th storey, b. Plan view from 8th storey to 15th storey and c. Elevation view of model CS+FS

5.6 GS+FS SLAB SYSTEM: This has Grid Slab from ground floor to 7th storey and Flat Slab from 8th to 15th storey of RC structure.

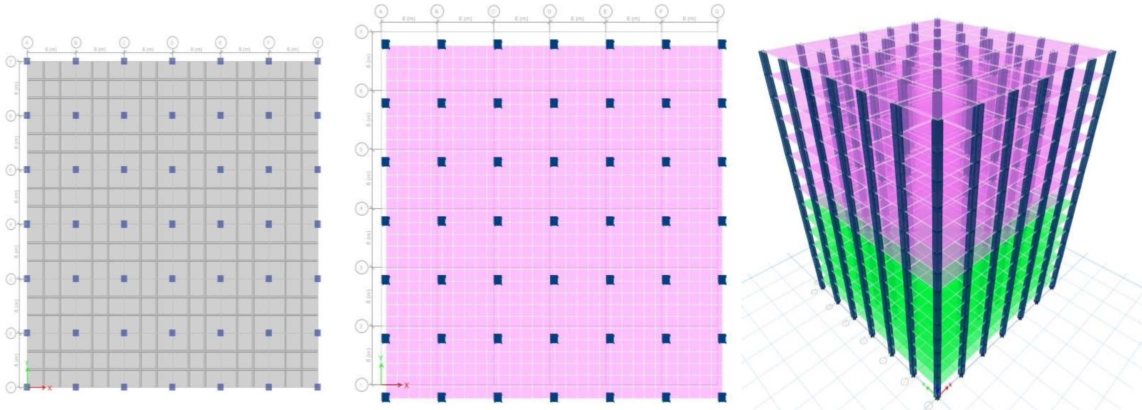


Figure 9: a. Plan view from Ground storey to 7th storey, b. Plan view from 8th storey to 15th storey and c. Elevation view of model GS+FS

5.7 GS SLAB SYSTEM: This slab system has Grid Slab in all 15 storeys of RC structure.

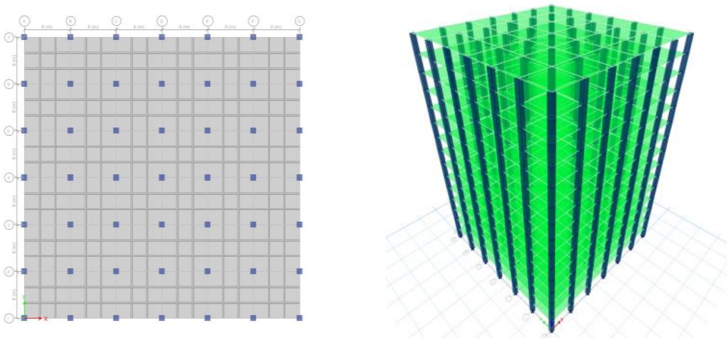


Figure 10: a. Plan view and b. Elevation view of model GS

5.8 CS+GS SLAB SYSTEM: This has Conventional Slab from ground floor to 7th storey and Grid Slab from 8th to 15th storey of RC structure.

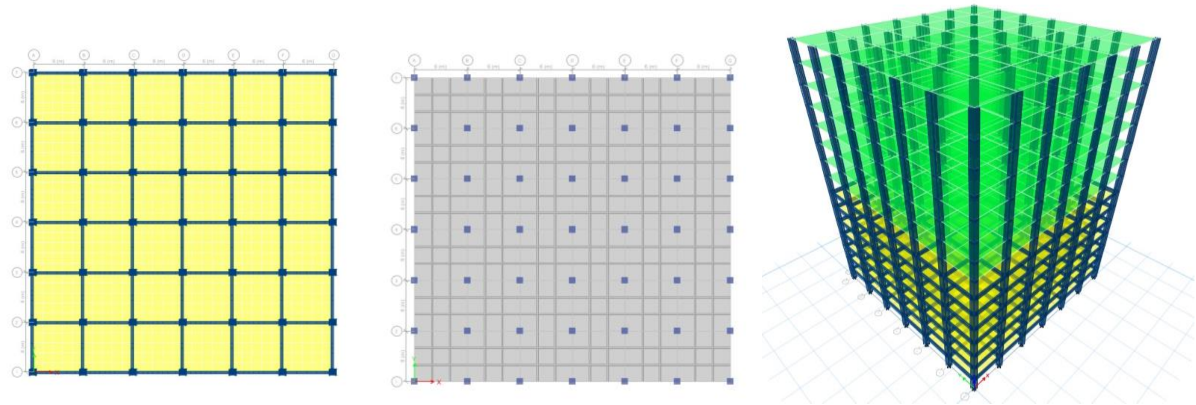


Figure 11: a. Plan view from Ground storey to 7th storey, b. Plan view from 8th storey to 15th storey and c. Elevation view of model CS+GS

5.9 FS+GS SLAB SYSTEM: This slab system has Flat Slab from ground floor to 7th storey and Grid Slab from 8th to 15th storey of RC structure.

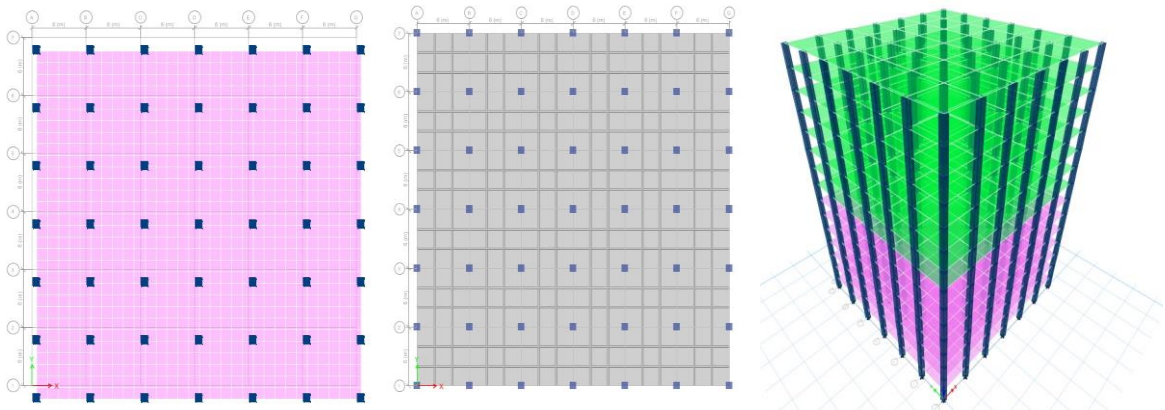


Figure 12: a. Plan view from Ground storey to 7th storey, b. Plan view from 8th storey to 15th storey and c. Elevation view of model FS+GS

6. RESULTS

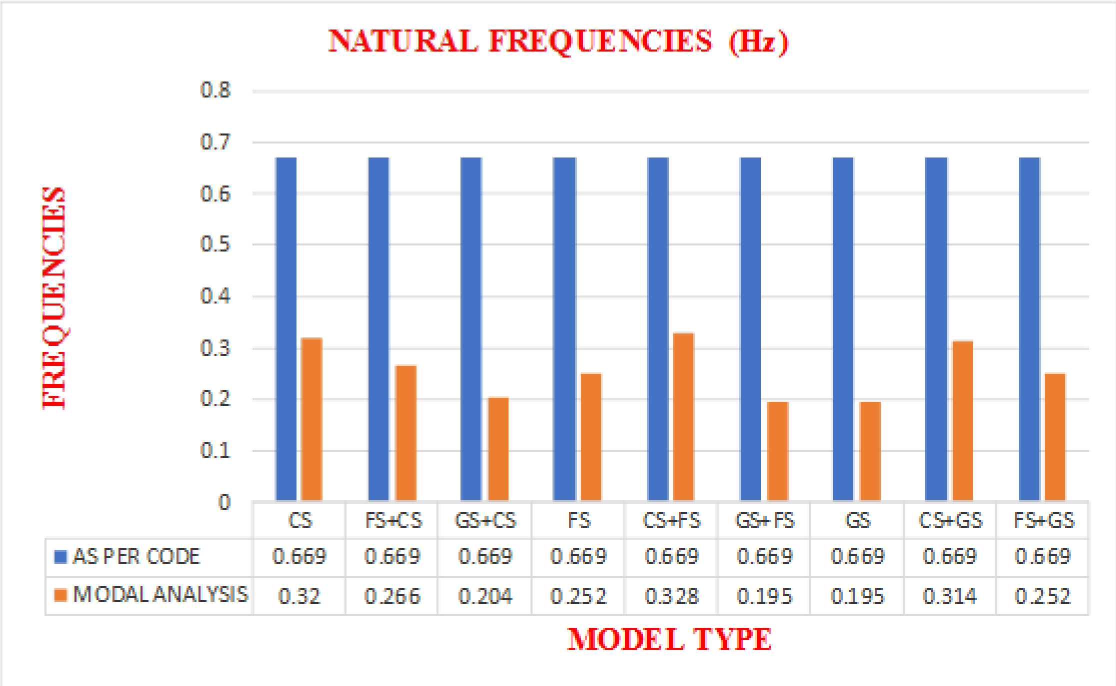
The FE analysis involving modal, equivalent static and response spectrum analyses are carried out and the results of natural frequency, Base Shear, Displacement and Storey Drift obtained for zone V as per IS 1893 (Part 1): 2016 are tabulated.

6.1 Modal Analysis

Modal analysis uses the overall mass and stiffness of a structure to find the various periods at which it will naturally resonate.

6.1.1 Natural Frequencies

All of RC slab structures with different slabs and their combinations are analysed and the Natural Frequencies obtained are compared with Natural Frequency obtained from IS 1893 (Part 1) 2016 are plotted as shown in Fig 13.



	CS	FS+CS	GS+CS	FS	CS+FS	GS+FS	GS	CS+GS	FS+GS
AS PER CODE	0.669	0.669	0.669	0.669	0.669	0.669	0.669	0.669	0.669
MODAL ANALYSIS	0.32	0.266	0.204	0.252	0.328	0.195	0.195	0.314	0.252

Figure 13: Comparison of Natural Frequencies of different RC Slab Systems with IS Code

6.2 Equivalent Static Analysis

Equivalent static method is the simplest method of analysis and requires less computational effort because, the forces depend on the code based fundamental period of structures with some empirical modifier, the design base shear V_B shall be distributed to the various flood levels at the corresponding centers of mass and finally this design seismic force at each floor level shall be distributed to individual lateral load resisting elements through structural analysis considering the floor diaphragm action.

6.2.1 Base Shear

Base shear is an estimate of the maximum expected lateral force on the base of the structure due to seismic activity. It is calculated using the seismic zone, soil material, and building code lateral force equations. The Base Shears of all the slab systems for seismic Zone V are shown in Fig 14.

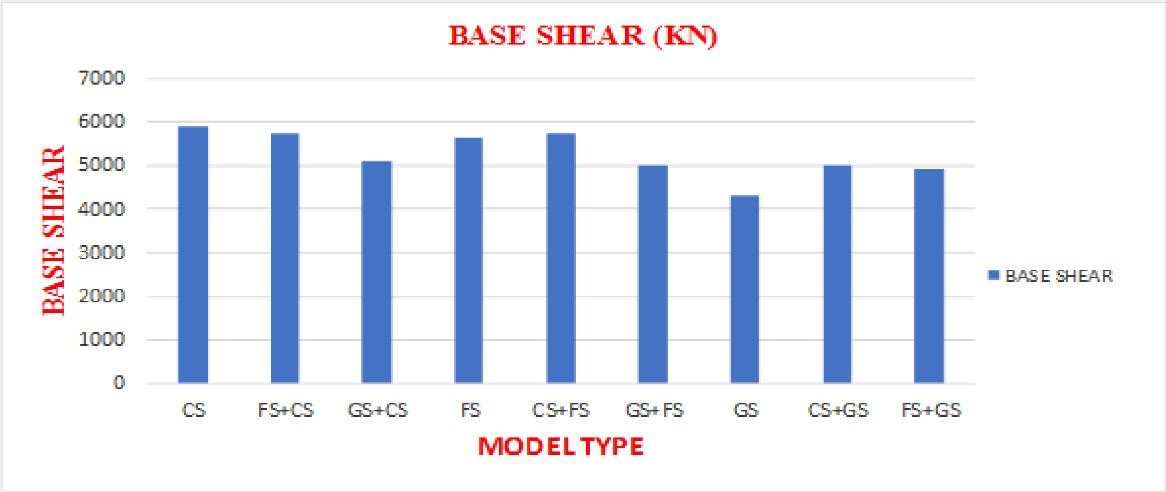


Figure 14: Base shears of RC Slab Systems for Zone V

6.3 Response Spectrum Analysis

A response spectrum is a plot of the peak or steady-state response (displacement, velocity or acceleration) of a series of oscillators of varying natural frequency that are forced into motion by the same base vibration or shock. The resulting plot can then be used to pick off the response of any linear system, given its natural frequency of oscillation. The displacements and Storey drifts obtained for seismic Zone V are plotted as shown in Fig 15 & 16.

6.3.1 Displacements

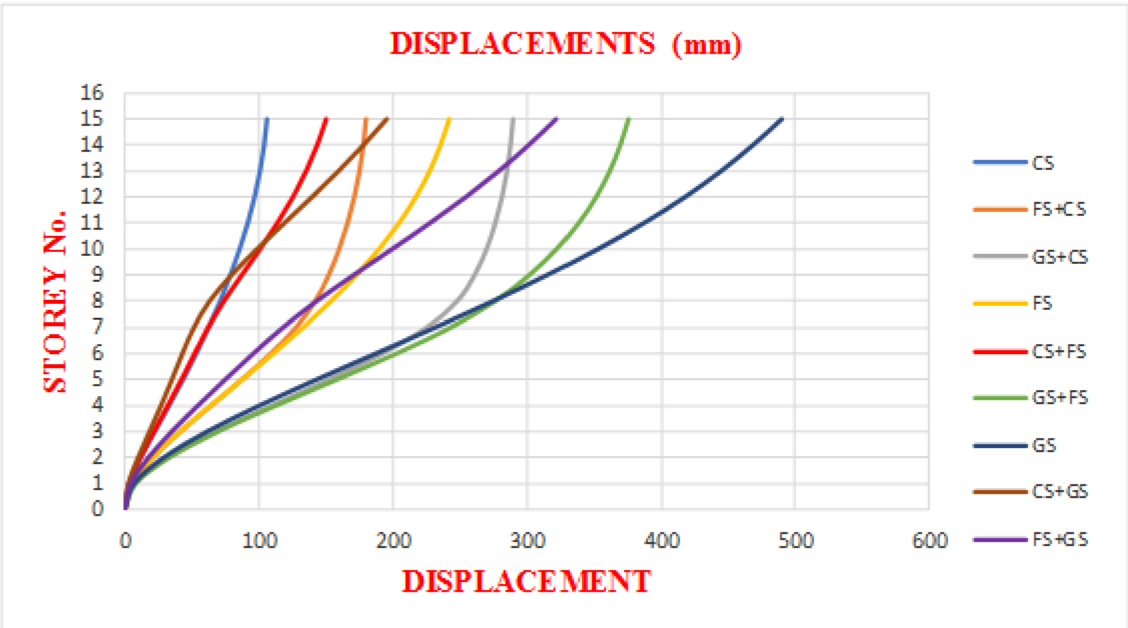


Figure 15: Displacements of RC Slab Systems for Zone V

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6.3.2 Storey Drifts

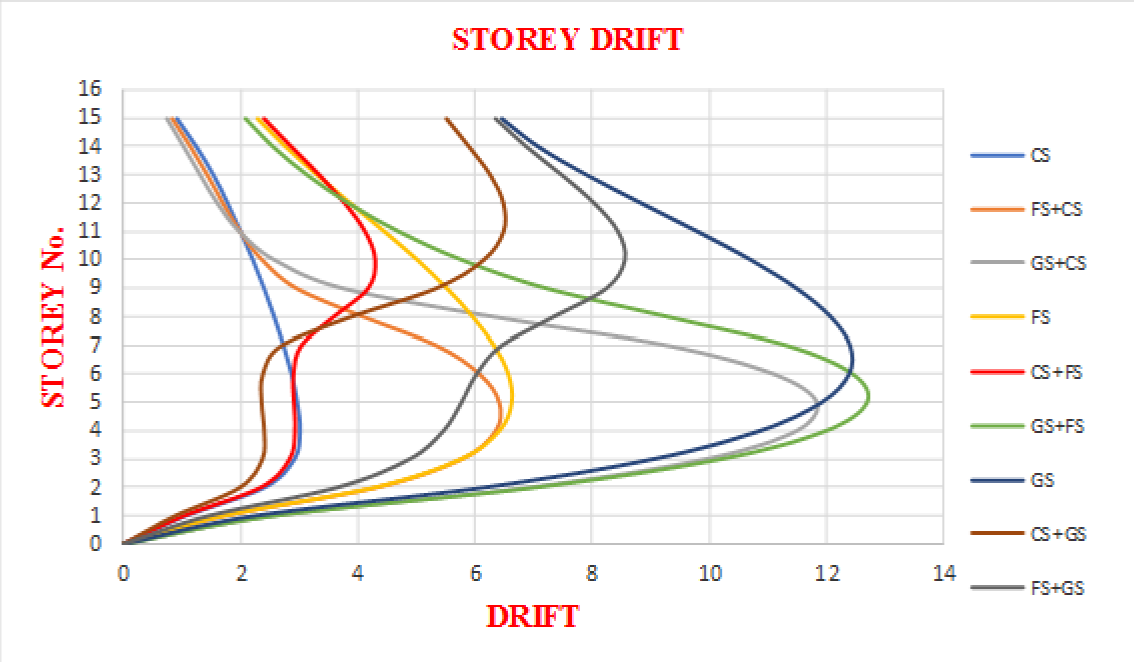

Figure 16: Storey Drifts of RC Slab Systems for Zone V

7. CONCLUSIONS

Following are the major conclusions drawn:

- It is observed that the Natural frequencies obtained from IS 1893 (Part 1) 2016 are much greater than Natural frequencies obtained from modal analysis for all the slab systems highlighting the defines of IS code in determination of Natural Frequencies.
- The natural frequencies of FS system and FS+GS systems are same, as they don't have any CS system which offer more stiffness to structure with beams, similarly GS system and GS+FS system frequencies are also same as no CS system is present.
- Conventional RC slab system with its combinations have higher natural frequencies than remaining slab systems due to high stiffness.
- The base shear of Conventional RC slab system is maximum among all the slab systems considered for analysis while the base shear of Grid slab system is least because mass of CS slab is high.
- Among the regular slabs the base shear of the CS slab system is 37.44% greater than GS system and the base shear of FS is 31.5% greater than GS slab.
- Among the combined slabs the base shear of FS+CS is 16% greater than FS+GS because of its mass.
- The maximum displacements are observed in Grid slab followed by FS and least in Conventional RC slab systems as they are more rigid to resists the later forces due to beams.

- The displacements of GS slab system are 3.61 times greater than CS slab system and 1.02 times greater than FS slab system.
- It is observed that a sudden rise in the displacements of CS+GS and FS+GS immediately after 7th floor due to change of slab.
- The storey drift is maximum at H/2 (H = Height of the building) for all the regular slabs, and it varies for the combined slab system.
- Storey drift for all cases of slab systems is within the permissible limit of 0.004h (h = storey height) as per IS 1983 (Part 1) 2016.
- In regular slabs the storey drift of GS is high, and CS has the least.
- In combined slab structures the storey drift of GS+FS is higher than GS and CS+FS have least storey drift.
- It is observed that a sudden rise in the storey drift of CS+GS and FS+GS immediately after 7th floor due to change of slab.
- The Lateral displacement of all slab systems are having minimum at plinth level and maximum at terrace level, as the number of stories increases lateral displacement also increases.

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