Industrial Engineering Journal
ISSN: 0970-2555
Volume : 52, Issue 10, No. 2, October : 2023

A COMPARATIVE STUDY OF DIFFERENT SLAB SYSTEM UNDER SEISMIC LOAD

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Abstract.
Flab Slabs are used in many area like in the parking lots, office building and malls, where column to column distances are for away from one another and the largest free areas are required. Based on reinforcement provided, beam support, and the ratio of the spans, building slabs are classified into different types. Conventional building (CVB), Camouflage building (CFB), Flat-Slab Building (FSB), and Flat-Slab with periphery Beam building (FSPB) systems were incorporated in the present study. Analysis was done using the response spectrum method in ETABS software. The parameters under study are modes shapes, frequency, time period, base shear & storey drift under dynamic load. The building is situated in Kolkata, West Bengal, India. The base shear of building with CVB systems followed by CFB, FSB, and FSPB systems are studied. After the analysis of the Flat-Slab with Periphery Beam Slab system building their performance result is shown in this investigation.

Keywords: Flat-Slab, ETABS, Base Shear, Storey Drift.

1.0. Introduction A Flat-Slab is a two-way RC slab with the absence of beam and girder that result in the transfer of load directly to the compression member (column) that support them, Flat-Slab is nowadays popular in many places like office, commercial buildings, and parking structure, where large column-free spaces are required. Flat-Slab is majorly supported by beam and then to the column so they are widely known as beam-column construction, thus resulting in clear ceiling elevation. Talking about their aesthetic view they are poor but strength-wise they have good performance. Reinforced concrete Flat-Slab buildings represent decorous and easy to construct on the floor system. These kinds of structures are preferred equally by architects and clients for the reason that they provide a decent artistic view, flawless light visibility, and much new improvement as parallel to other buildings in terms of rapidity of construction, frugality, etc. A Flat-Slab building is a building in which slabs are directly supported to the columns. The column head occasionally enlarges to avoid punching shear, provision of column head should be practiced, which the enlarged portion is built normally to the column. The distribution of moment is near in column portion this is the reason to resist that moment we make the column head thicker. A conventional Building is a standard building that has a regular size of the RC member and materials. The camouflage building knows as the building who have different size of RC members like Beam, column, and slab. The flat slab building does not have any beam, load transfer through the slab to direct to the column. The flat slab with periphery beam building has a beam on an external wall, in the internal wall the beam is not present there.

1.1. Objectives Of The Present Study
1. Modeling of four buildings with different slab systems namely, Conventional Building, Camouflage building, flat-Slab Building, and Flat-Slab with periphery beam building In Etabs.
2. Assigning the model to various type of load that is dead load, live load, dynamic load.
3. Appling the response spectrum method to the four models to perform dynamic analysis base on IS 1893(Part-I)-2002.
4. Analysis of the result obtained from Etabs.
5. Making comparisons between seismic parameters like storey drift, base shear, time period, mode shapes of the four models having different slab systems.
6. Formulation figures and tables depicting the comparisons between.

2.0.Review Of Literature

Yusuf [1] in this research, compared with the conventional and a camouflage model of Flat-Slab based on frequency analysis, response spectrum analysis, and the cost are also compared with each other and this is also based on the base shear vs. displacement of the structure parameter using SAP 2000 software and designed the slab by using different codes such as IS 456, ACI 318, NZS 3101, etc and Time history analysis is also performed on the Flat-Slab building, done for dynamic response. According to this research, the researchers are finding Behavior of building is based on the comparison of the nonlinear static pushover analysis for MCE peak ground acceleration as per IS 1893:2002 part-I. Rectangle planned Flat-Slab and with perimeter-beam are performed in this research using the above code. From this research, the researchers have discovered Camouflage is a good alternative if it is required on the building for its good aesthetic and light visibility point of view and Flat-Slab building being the good in aesthetic and another advantage in terms of architecture point of view are found to be less economical as compared to another model. So Flat-Slab with a perimeter beam is better as compared to a Flat-Slab without a beam. However, it is also not performing better during lateral loading.

Giri and Jamle [2] in this research worked as a literature survey which has been carried to find out work done on FS and having drop also. With the help of the response spectrum method the lateral forces imposed on the structure. For further work in this direction, Flat-Slab with the various locations of the shear wall would create and when using the response spectrum method to analyze, decide various cases, find the most optimum case along with economical too. Many research works have already been done but the papers can’t show the manual approach, fixed the parameters first before doing the earthquake analysis. The response spectrum method could be used in these cases for determining the seismic response over the structural parts. In the literature review, the researchers have found some research gaps which can be done in the future on a stiffness parameter with its interaction to Flat-Slab.

Rahul and Mahesh [3] in this research, they have investigated the behavior of FS in four dissimilar cases such as 1. Flat-slab structures without the drop, 2. Flat-slab structures with column drop, 3. Flat-slab structures with shear-wall, 4. Flat-slab structures with column drop & shear-wall composed, this analysis done by ETABS software by using the method of response spectrum based on the terms of frequency, base shear, story displacements, and period. They also tried to discover in slab-column joint produces minimal punching shear. The type of combination produces. In this study, they have concluded some work on the Flat-Slab which refers to When the drop panels present the fundamental mode of frequencies increases by 20% of the flat-slab structures, providing shear-walls, it results in increasing of stiffness, so the 20% value increases up to 96%. For inner columns, punching shear stresses are cumulative linearly from top-bottom stories. Due to the gravity loads punching shear variation are not many changes from story to story. In FS the Punching shear failure occurs. The Punching reductions up to 25% when column drops are present.

Purushottam et al. [4] in this revision plastic voided slabs is associated with RC solid flat-slab over-evaluation in the design of the dimension 0f 4.54-meter x 4.54 meter (15 ft. x15 ft.), 6.05-meter x 6.05 meter (20 ft. x 20 ft.), 7.57-meter x 7.57 meter (25 ft. x 25 ft.) and 9.08-meter x 9.08 meter (30 ft. x 30 ft.) and the depth of slab is 0.25 meter. The solid flat-slab design followed by the ACI:318-11 provisions, the plastic voided slabs design using Euro code 2 and AS3600. They took parameters like total solid perimeter, weight, moment capacity flexural reinforcement of the voided slab, and also solid Flat-Slab is compared with both the systems and material cost analysis are done and propose the economical slab system. They have done this research based on live load and long team deformation using ACI:318-11 by ANSYS. After implementation based on this software, they concluded with the point as the deformation due to live-load and long-term deformation of the solid flat-slab and voided slab are in the permissible limit as per ACI:318-11. the voided slab shows decent agreement concerning the structural efficiency point.

Bariya [5] this study explores the punching shear behavior of two-way reinforced cement concrete flat-slabs with High Yielding Strength Deformed (HYSD bars) as tension reinforcement. F.E.A software

using for analyzing punching shear capacity for an Interior slab column connection of reinforced cement concrete flat-slabs. They have found the result that in the Interior column area increasing punching shear reinforcement (SB2 & SB3) initiation of crack is reduced. Without shear reinforcement in Interior slab-column connection is better resistance according 14.27 % & 39.56 % in SB3. In the same condition, the SB2 and SB3 have increased the displacement resistance.
Shaaban et al. [6] have taken the important aspect of Post-tension flat-slab & flat-slab under earthquake and finding the reaction also behavior. They compared those aspects with the conventional Flat-Slab. To avoid the sudden collapse, they used minimum bottom steel in the slab-column connection. For enhanced seismic performance the column cage provides in both directions. It is required to provide parting amid the shear-resisting elements and Post-Tension slab before the Post- Tension process so that stress is not gone to the shear-resisting elements.
Faria et al. [7] experimented with analysis 3 number of RC slabs 2.20-meter width and thickness is 0.15-meter using ATENA-3D software. Compared the result using Model-Code 2010 & Euro-code of 2. Top longitudinal reinforcement and top flexural reinforcement are the same providing, it results in stiffer response also reduction in extreme vertical displacement and raises the punching resistance. They concluded with some point which achieved in the column is where the greater ratio of reinforcement used, the result of punching capacity is less thereof flat-slab and also resulting from the extra rigid behavior. When the reinforcement was concerted near the column, the punching resistance is decent, using MC-2010 code the numerical and the experimental results are compared.
Liberati et al. [8] in this revision, 12 RC Flat-slab with (1800x1800x130) mm dimensions without shear-reinforcement were analyzed experimentally under symmetrical loading. The shear failure occurs due to bending collapse mechanisms and the development of reinforcements yielding. In exhibiting and punching, the 12 specimens are a failure at extremely brittle concrete without shear reinforcement. Two openings reduced up to 16% according to displacements smaller and maximum the ultimate strength in Flat-Slabs with reference slabs. In EC2 the shear reinforcement is not provided in slabs under punching loads, the result agreed well.

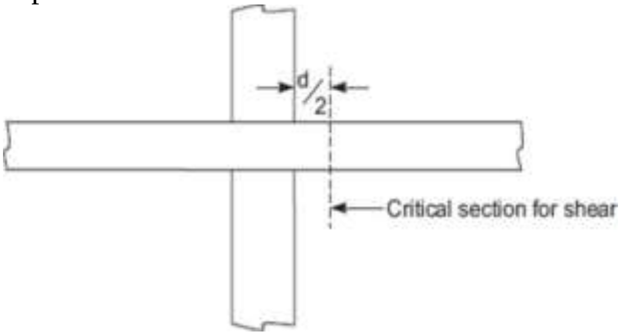
Baniya et al. [9] in this study, the 12 specimens of the slab were taken under punching behavior. Casting of 6 slabs as 2 layers and 1 layer of 4 slabs. In this sample, the dimension of “L, B, and t” is (1.1x1.1x.12) m. 0.06m of pre-flat-slabs layers, in the column the dimension was (0.150x0.150) and using 4 nos of 4 dia as main reinforcement and 10 dia at 50mm as shear reinforcement. This investigation as numerical and experimentally using different capacities of punching shear reinforcement of pre-Flat-Slabs are analyzed. The deformation capacity & the punching strength was exempted as the numerical model of pre- Flat-Slabs. The higher punching shear compared with closed stirrups of specimens in Vertical shear reinforcement.
Sarvari and Esfahani [10] in the investigational program, 17 slabs were taken under post-punching behavior using different covers and reinforcement. In slab-column connections, the post-punching behavior was done according to concrete cover, the diameter of tensile reinforcement, compressive, shear, bent-up, effects of integrity. a rise of the post-punching strength using reduction of the diameter of the tensile-reinforcement and escalation of the concrete cover of the tensile-reinforcement. Using truss reinforcement which develops the post-punching behavior and punching. This study according to by ACI 318-14 code, where the 0.56 is tensile reinforcement. Compressive- reinforcements not improving the punching as well as the post-punching. Increasing the concrete cover in the tensile area result better as post- punching and punching as respective 32% & 14% of slabs. the post- punching strength rises using reduction of the diameter of tensile-reinforcement and using truss-reinforcements was resulted in better ductile punching behavior.

3.0. Introduction to Flat-Slab

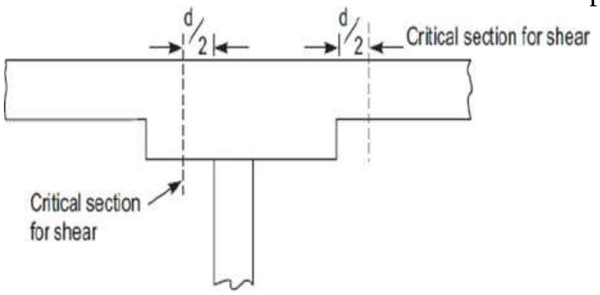
In the modern-day, the reinforced concrete Flat-Slab building is more used and easy to construct in floor system. The artistic view respect in now day the architects and the client preferred those structure equally. In the reinforced concrete Flat-Slab building flawless light visibility is more than the conventional reinforced concrete slab building. It also improves as parallel to other buildings under teams of the rapidity of construction. Reinforced concrete Flat-Slab building the beam is not present in the slab so the load transfer slab to column and it directly support on the column. The column may greater than normal dimension to resist the punching shear in the slab. The column head is enlarged portion due to moment. This enlarged portion is called the column head. In column-slab joints the drop is provided to reduce the punching shear, the drop system is called a drop panel. In below the Flat-Slabs are categories.

3.1. Type of Flat-Slab

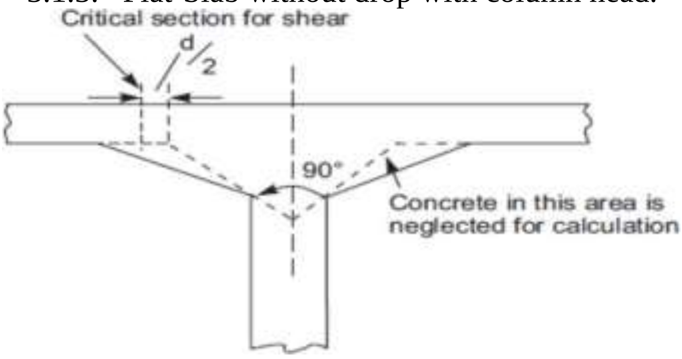
3.1.1. Flat-Slab without drop and column head.



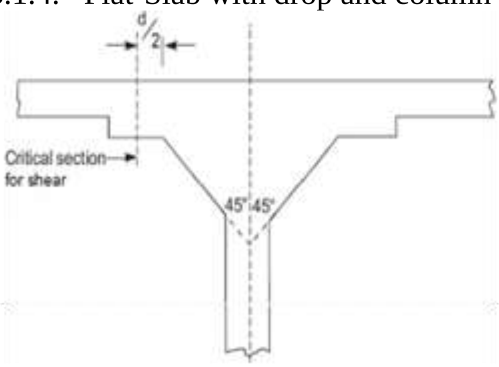
3.1.2. Flat-Slab without column head with drop.



3.1.3. Flat-Slab without drop with column head.



3.1.4. Flat-Slab with drop and column head.



3.2. Method of Design of Flat-Slab

Multitudes of processes and procedures are used in designing Flat-Slabs and assessing these slabs in flexures. These ways of procedure are as follows.

- The empirical method
- The sub-frame method
- The yield line method
- Finite–element analysis

To analyze smaller frames, an empirical method can be used whereas the sub-frame method is used in case of more irregular frames. The designs are understood by using acceptable computer code however terribly fact, the actual fact is exploitation sub-frame ways for terribly sophisticated style are often very pricey. The foremost cost-efficient and consistent installation of reinforcements are often achieved by applying the yield line technique. A careful and complete examination of cracking and deflection should be done separately because as this process requires a collapse mechanism. Any sort of irregularity in-floor support or any huge opening, huge loads for these finite element analyses is found to be very effective. For the purpose of finding deflections and cracked width, we can use Finite-Component analysis. Portions that need special care in Design of Flat-Slab

3.3. Advantages of Using Flat-Slab in Construction

3.3.1. Flexibility in room layout- It is advantageous to Architect to use Flat-Slab in a room because by the use of Flat-Slab architects can introduce inner walls where so ever. Another advantage can be that it prevents the use of false ceilings and finishes at the bottom of the slab.

3.3.2. Reduction of Building Height-Use of Flat-Slab results in lowering of elevation of a building which results in lowering of the partition wall that result in lowering the weight of the structure that ultimately leads to transfer of less load to the foundation (approx.-10%).

3.3.3. Less Construction duration-It consume less time for the construction of Flat-Slab by the use of big table formwork

3.3.4 Ease in Installation - All M.E.P services can be attached straight on the soffit of the slab in place of bending them to dodge the beams.

3.3.5 Buildable Score- By the use of this technique one can easily use standardized structural members and prefabricated sections into the design for ease in construction, which makes the structure more buildable, and also reduces manpower site increasing productivity.

3.3.6 Use of Prefabricated Welded Mesh- This technique helps to reduce the installation time of Flat-Slab. These meshes are available in standard size and provide better quality control in the construction of Flat-Slabs.

4.0 Methodology And Modeling 4.1.General

In this investigation, four models are comparing with each other under earthquake, live, and dead load respectively. The models are concessive of G+3 building of floor to floor height of 3.35m and the ground floor height is 4m. The site location or building is situated at Kolkata, West Bengal, India. This model and numerical analysis were done by nonlinear finite element software ETABS 2016. The models are compared between Conventional Building, Camouflage building, flat-Slab Building, and Flat-Slab with periphery Beam. In this analysis, the parameter was considered as nodal shape, base shear, and the displacement.

4.2. Study of modeling

4.2.1. Model Configuration :-All buildings consider as 4 story buildings and the plan configuration is symmetrical. The building dimensions are 40.7m in length, 11.5m in width, and 14.05m in height. The building plan and elevation are shown as below. All building plan has same floor area and floor to floor height of 3.35m and the ground floor height is 4m.

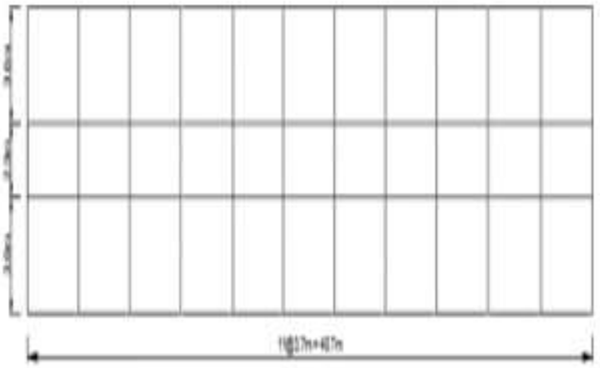


Figure. 3.1: Line Diagram of Floor Plan

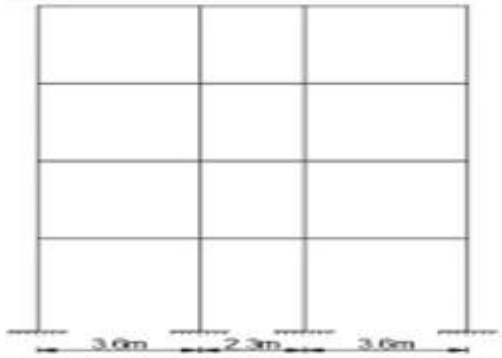


Figure .3.2: Line Diagram of Elevation

Material Properties – The material has been taken as per the given table in below.

Table.3.1. : Mechanical Material Properties

Member Name	Grade of Concrete	Grade of Steel
Beam	M25	Fe 415
Column	M30	Fe 415
Slab	M25	Fe 415

4.2.2. Stiffness Modifiers as per IS 1893 (Part-I): 2016 – Stiffness Modifiers are introduced in IS 1893 (Part-I): 2016 for the first time in clause no 6.4.3.1 of the code defines as the requirement for structural analysis. This clause valid for the 50m height of the building. For columns, it takes 70% of I gross, beams it takes 35% of I gross, and slab it take 25% of I gross. This percentage reduces the Moment of Inertia for the RCC structure. Before this clause, we are considering 100% of the moment of inertia for RCC structural in the structural analysis. In the RCC structure, the crack will be produced in the tension zone under a various types of load. So due to crack the MI will be smaller than the gross MI. that's why the concept was introduced for the reduced MI for the cracked section.

4.2.3. Site properties – The Building is situated in Kolkata, West Bengal, India. The soil condition is medium & as per IS: 1893 (Part-I)-2002 take the Zone (Z) is III.

4.2.4. Geometrical Properties of Models – The model configuration as per following the table in below.

Table 3.2.: Geometrical Properties

RCC Members	CVB	CFB	FSB	FSPB
Beam (mm)	300x400	300x120	-	300x450
External Column (mm)	300x530	300x530	300x530	300x450
Internal Column (mm)	300x300	300x300	300x300	300x300
Slab Thickness (mm)	120	120	250	250
External Wall Thickness (mm)	250	250	250	250
Internal Wall Thickness (mm)	150	150	150	150

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ISSN: 0970-2555
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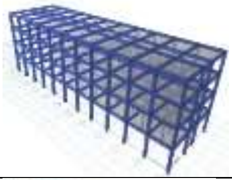
Table.3.3.: 3D View of Buildings.

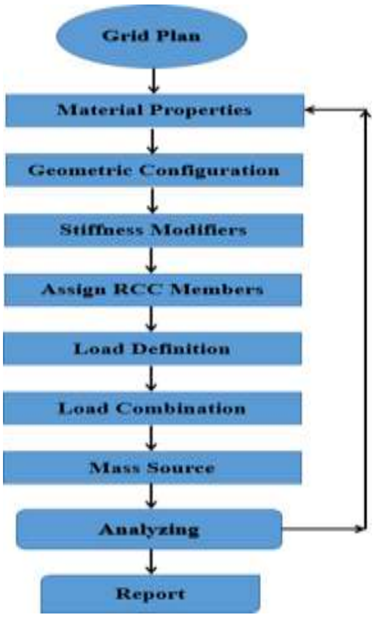
Model name	3D View
CVB	
CFB	
FSB	
FSPB	

4.2.5. Nodal Mass Participation

The effective mass participation issue signifies of shear of the system mass that contributes in an exceedingly specific mode. It offers a live of the energy contained among every resonant mode. A mode with an oversized EMPF is typically a big sponsor to the dynamic reaction of a structure.

4.2.6. Procedural Flow Chart

Make the grid plan and assign material properties then go for geometric configuration and assign the value of stiffness modifiers after that assign RCC members. Now give the load definition and their combination. Assign the nodal mass source. Now perform analysis and checked for the report in nonlinear finite element software ETABS 201



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ISSN: 0970-2555
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5.0.Results and Discussion 5.1.General

The obtained after analysis of the different buildings in non-linear finite element software Etabs-2016 are.

Table 5.1: Nodal Analysis

Building	Model	CVB	CFB	FSB	FSPB
Case	**Mode**	**Period (Sec)**	**Period (Sec)**	**Period (Sec)**	**Period (Sec)**
Modal	1	1.148	2.503	1.493	1.344
Modal	2	0.948	1.994	0.942	1.299
Modal	3	0.82	1.705	0.748	1.017
Modal	4	0.378	0.551	0.236	0.381
Modal	5	0.302	0.376	0.149	0.352
Modal	6	0.264	0.337	0.137	0.317

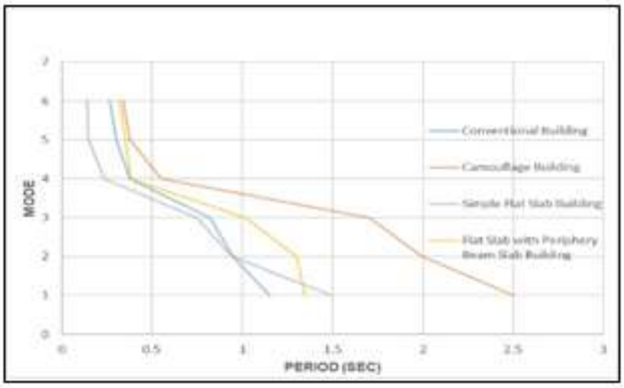

Figure 5.1: Graph of Nodal Analysis

Table 5.2: Base Shear for Both Direction

Story Name	Height (m)	CVB	CFB	FSB	FSPB
		Vb (kN)	**Vb(kN)**	**Vb(kN)**	**Vb(kN)**
Story4	14.05	374.0174	290.0695	212.184	169.7373
Story3	10.7	236.2476	187.6989	132.696	110.0319
Story2	7.35	111.4743	88.5664	62.613	51.9189
Story1	4	33.5396	26.7587	18.806	15.6912
Ground Floor	0	0	0	0	0

Industrial Engineering Journal
ISSN: 0970-2555
Volume : 52, Issue 10, No. 2, October : 2023

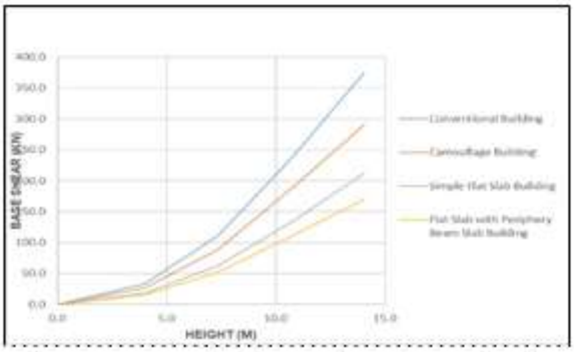

Figure 5.2: Graph of Base Shear for Both Direction

6.0.Conclusion

Dynamic analysis of flab slabs for different structures is done by following the provision recommended by IS: 456-2000. The result obtain check thoroughly and compared. The designing of Flat-Slab includes designing in the presence and absence of perimeter beam and the result obtained by both criteria are compared. The G+3 designing criteria is done considering the perimeter and provision given by the department of earthquake engineering as per IS 1893(Part-I): 2002. The major conclusion obtained are:

- Various structures are modelled and analysed and found that structures with Flat-Slab are more flexible and less resistant to lateral loading but among them, the conventional building shows better result. If an aesthetical concern is taken into consideration we can go for a camouflage structure
- Camouflage structure is found to have more modal time periods than any other structure.
- Flat slab buildings have a less bending moment, floor torsion, and shear forced at floor level than other compared structures.
- Concerning base shear, Simple flat slab buildings have a small amount of base shear than the convention building.
- Flat slab with periphery beam building given the good response base on lateral displacement, story drift, floor shear, and base shear compared to other buildings.
- The first-floor storey drift values spans from 0.0147 mm to 0.0263 mm for the different systems.

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