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Seismic Behaviour of Reinforced Concrete Framed Structure with Flat and Conventional Floor Slab System

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Abstract:

A traditional common practice in construction is to support slab by beam and beam supported by column this may be called as beam slab load transfer construction technique. As due to this old traditional construction net height of room is reduced. Hence to improve aesthetical and structural aspect of multi storey, shopping mall ,offices, warehouses , public community hall, hospitals etc. are constructed in such a way were slab are directly on columns. This types of slab directly supported on column is termed as flat slab.

The present objective of this work is to study the behavior of flat slab with conventional RC framed building comprising of beam, column and slab. The parametric studies comprise of maximum lateral drift, base shear, time period, and axial forces generated in the frames for all seismic zones in India. For these cases, models has been created for conventional RC framed building, flat slab building without drop panels and flat slab with drop panels for plan size of 43.5m*35 m(43.5 along x-direction and 35 m along y-direction), analyzed with ETABS for seismic zones II, III, IV and V. This study also focused on the difference between seismic behavior of flat slab building without drop panels and flat slab building with drops.

INTRODUCTION:

1.1 Background:

Earthquake load acting on a structure depends on epicenter distance and depth of hypocenter below earth surface and the energy released during an earthquake. For easier understanding, it can be said that the line of action joining hypocenter to the center of mass of structure indicates direction of load vector. The most determinant effect on a structure is generally caused by lateral component of earth quake load. As compared to gravity load effect, earthquake load effects on buildings are quite variable and increase rapidly as the height of building increases. For gravity loads, structure is designed by considering area supported by a column and spans of beam; whereas for earthquake loads, design is a function of total mass, height. It is likely that low and mid rise structures, having good structural form can carry most of earthquake loads. The strength requirement is a dominant factor in the design of structure. As height increases the rigidity (i.e. the resistant to lateral deflection) and stability (i.e. resistant to overturning moments) of structure gets affected, and it becomes necessary to design the structure preferably for lateral forces, moments, story drift and total horizontal deflection at topmost story level.

Pure rigid frame system or frame action obtained by the interaction of slabs, beam and column is not adequate. The frame alone fails to provide the required lateral stiffness for buildings taller than 15 to 20 (50m to 60m) stories. It is because of the shear taking component of deflection produced by the bending of columns and slab causes the building to deflect excessively. There are two ways to satisfy these requirements. First is to increase the size of members beyond and above the strength requirements and second is to change the form of structure into more rigid and stable to confine deformation.

First approach has its own limits, whereas second one is more elegant which increases rigidity and stability of the structure and also confine the deformation requirement. In earthquake engineering, the structure is designed for critical force condition among the load combination. This paper investigates the comparison of conventional reinforced concrete building system i.e. slab, beam & column to the flat slab building. These results are compared for different seismic zones. In addition, flat slab building without drop panels and flat slab building with drop panels are also compared.

A. Loading:

Live loads can be anticipated approximately from a combination of experience and the previous field

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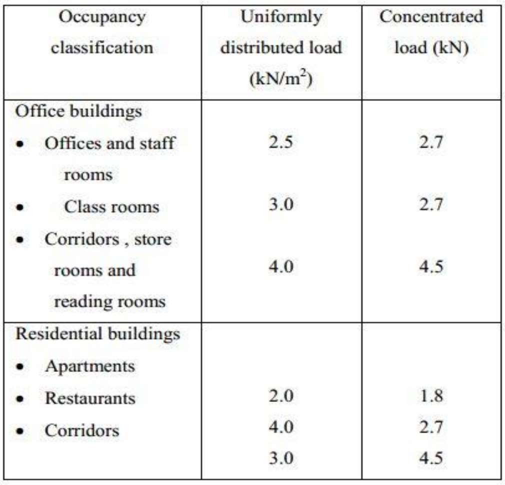
observations. Wind and earthquake loads are random in nature and it is difficult to predict them. They are estimated based on a probabilistic approach. The following discussion describes some of the most common kinds of loads on multi-storied structures.

B. Gravity Loads:

Dead loads due the weight of every element within the structure as well as live loads that are acting on the structure when in service constitute gravity loads. The dead loads are calculated from the member sizes and estimated material densities. Live loads prescribed by codes are empirical and conservative based on experience and accepted practice. A floor should be designed for the most adverse effect of uniformly distributed load and concentrated load over 0.3 m by 0.3 m as specified in Table below, but they should not be considered to act simultaneously. All other structural elements such as beams and columns are designed for the corresponding uniformly distributed loads on floors. Reduction in imposed (live) load may be made in designing columns, load bearing walls etc., if there is no specific load like plant or machinery on the floor.

Table 1.1 : Live Load Magnitudes



Occupancy classification	Uniformly distributed load (kN/m^2)	Concentrated load (kN)
Office buildings		
• Offices and staff rooms	2.5	2.7
• Class rooms	3.0	2.7
• Corridors , store rooms and reading rooms	4.0	4.5
Residential buildings		
• Apartments	2.0	1.8
• Restaurants	4.0	2.7
• Corridors	3.0	4.5

This is allowed to account for reduced probability of full loading being applied over larger areas. The supporting members of the roof of the multi-storied building is designed for 100% of uniformly distributed load; further reductions of 10% for each successive floor down to a minimum of 50% of uniformly distributed load is done. The live load at a floor level can be reduced in the design of beams, girders or trusses by 5% for each $50m^2$ area supported, subject to a maximum reduction of 25%. In cases where the reduced load of a lower floor is less than the reduced load of an upper floor, then the reduced load of the upper floor should be adopted in the lower floor also.

C. Earthquake Load:

Seismic motion consists of horizontal and vertical ground motions, with the vertical motion usually having a much smaller magnitude. Further, factor of safety provided against gravity loads usually can accommodate additional forces due to vertical acceleration due to earthquakes. So the horizontal motion of the ground causes the most significant effect on the structure by shaking the foundation back and forth. The mass of building resists this motion by setting up inertia forces throughout the structure. The magnitude of the horizontal shear force “F” depends on the mass of the building “M”, the acceleration of the ground “a” and the nature of the structure. If a building and the foundation were rigid, it would have the same acceleration as the ground as given by Newton’s second law of motion, i.e. F = M x a.

However, in practice all buildings are flexible to some degree. For a structure that deforms slightly, thereby absorbing some energy, the force will be less than the product of mass and acceleration. But a very flexible structure will be subject to a much larger force under repetitive ground motion. This shows the magnitude of the lateral force on a building is not only dependent on acceleration of the ground but it will also depend on the type of the structure. As an inertia problem, the dynamic response of the building plays a large part in influencing and in estimating the effective loading on the structure. The earthquake load is estimated by Seismic co-efficient method or Response spectrum method. The later takes account of dynamic characteristics of structure along with ground motion. For detailed information on evaluating earthquake load, reader is referred to IS: 1893-2002.

1.2 BASIC ASPECTS OF SEISMIC DESIGN :

The mass of the building being designed controls seismic design in addition to the building stiffness, because earthquake induces inertia forces that are proportional to the building mass. Designing buildings to behave elastically during earthquakes without damage may render the project economically unviable. As a consequence, it may be necessary for the structure to undergo damage and thereby dissipate the energy input to it during the earthquake.

Therefore, the traditional earthquake-resistant design philosophy requires that normal buildings should be able to resist (Figure 1.1):

(a) Minor (and frequent) shaking with no damage to structural and non-structural elements;

(b) Moderate shaking with minor damage to structural elements, and some damage to non-structural elements; and

(c) Severe (and infrequent) shaking with damage to structural elements, but with NO collapse (to save life and property inside/adjoining the building).

Therefore, buildings are designed only for a fraction (~8-14%) of the force that they would experience, if they were designed to remain elastic during the expected strong ground shaking (Figure 1.2), and thereby permitting damage (Figure 1.3). But, sufficient initial stiffness is required to be ensured to avoid structural damage under minor shaking. Thus, seismic design balances reduced cost and acceptable damage, to make the project viable. This careful balance is arrived based on extensive research and detailed post-earthquake damage assessment studies. A wealth of this information is translated into precise seismic design provisions. In contrast, structural damage is not acceptable under design wind forces. For this reason, design against earthquake effects is called as earthquake-resistant design and not earthquake-proof design.

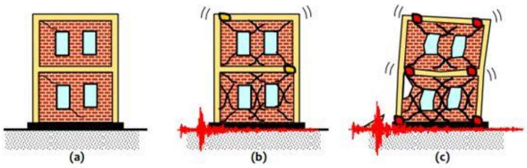


Figure 1.1 : Earthquake-Resistant Design Philosophy for buildings : (a) Minor (frequent) shaking – No/Hardly any damage, (b) Moderate shaking – minor structural damage and some non-structural damage, (c) Severe (Infrequent) shaking – Structural damage, but no damage

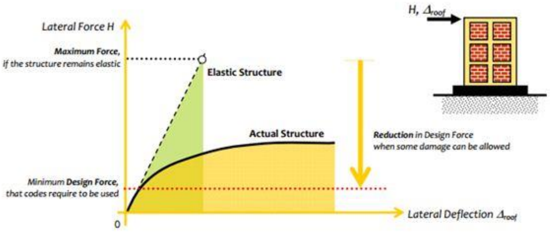


Figure 1.2 : Basic strategy of earthquake damage : Calculate maximum elastic forces and reduce by a factor to obtain design forces.

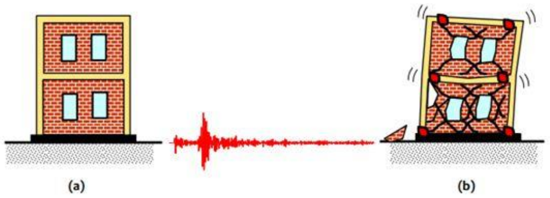


Figure 1.3 : Earthquake-resistant and NOT Earthquake-Proof :Damage is expected during an earthquake in normal constructions (a) undamaged building,and (b) damaged building.

The design for only a fraction of the elastic level of seismic forces is possible, only if the building can stably withstand large displacement demand through structural damage without collapse and undue loss of strength. This property is called ductility (Figure 1.4). It is relatively simple to design structures to possess certain lateral strength and initial stiffness by appropriately proportioning the size and material of the members. But, achieving sufficient ductility is more involved and requires extensive laboratory tests on full-scale specimen to identify preferable methods of detailing. In summary, the loading imposed by earthquake shaking under the building is of displacement-type.

Earthquake shaking requires buildings to be capable of resisting certain relative displacement within it due to the imposed displacement at its base. While it is possible to estimate with precision the maximum force that can be imposed on a building, the maximum displacement imposed under the building is not as precisely known. In earthquake design there are two options, namely design the building to remain elastic or to undergo inelastic behaviour.

LITERATURE REVIEW:

2.1 General:

Several researchers studied the effect of flat slab on seismic behavior of reinforced cement concrete structures. A brief review of previous studies on effect of flat slab on seismic behavior of reinforced cement concrete structures are presented in this section and past efforts most closely related to the needs of the present work.

2.2 Literature review on effect of flat slab on seismic behavior of reinforced cement concrete structures.

M.A.Eebrik[1] [2004] discussed about Flat-slab RC buildings exhibit several advantages over conventional moment resisting frames. However the structural effectiveness of flat-slab construction is hindered by its alleged inferior performance under earthquake loading. This is a possible reason for the observation that no fragility analysis has been undertaken for this widely-used structural system. This study focuses on the derivation of fragility curves using medium-rise flat-slab buildings with masonry infill walls. The developed curves were compared with those in the literature, derived for moment-resisting RC frames. This study also concluded that earthquake losses for flat-slab structures are in the same range as for moment-resisting frames for low limit states, and considerably different at high damage levels.

M.A.Eebrik[2] [2006] discussed about loss estimation analysis of flat-slab structures, a reinforced concrete structural form that exhibits behavior and response patterns distinct from conventional moment frames. The fragility information obtained for flat-slab structures presented in a companion paper is implemented into software HAZUS. The latter program includes many existing structural types, but does not deal with flat-slab structures. Fragilities already available in software HAZUS. After implementation, the earthquake losses in flat-slab buildings are predicted in comparison with the existing structural types in software HAZUS by using different scenario earthquakes for a selected study region. The prediction results are consistent with the seismic response characteristics of the compared structural types.

S.W.Han et al[3] [2009] told about the effective beam width model (EBWM) used for predicting lateral drifts and slab moments under lateral loads. They also studies on slab stiffness with respect to crack formation. This studies developed equations for calculating slab stiffness reduction factor by conducting nonlinear regression analysis using stiffness reduction factors.

E. S.Finzel et al[4] [2011] The timing of initiation of flat-slab subduction beneath southern Alaska and the upper plate record of this process are not well understood. We explore the record of flat-slab subduction in southern Alaska by integrating stratigraphic, provenance, geochronologic, and thermochronologic data from the region directly above and around the perimeter of ongoing flat-slab subduction. S.D.Bothara et al[5] [2012] studies about comparative effect of earthquake on flat slab & Grid floor system consisting of beam spaced at regular intervals in perpendicular directions, monolithic with slab.U.Gupta et al[6] [2012] studies about flat slab building structures which are more significantly flexible than traditional concrete frame/wall or frame structures, thus becoming more vulnerable to seismic loading. Therefore, the characteristics of the seismic behavior of flat slab buildings suggest that additional measures for guiding the conception and design of these structures in seismic regions are needed.

To improve the performance of building having flat slabs under seismic loading, provision of part shear walls is proposed in the present work. The object of the this work is to compare the behavior of multi-storey buildings having flat slabs with drops to the two way slabs with beams and to study the effect of part shear walls on the performance of these two types of buildings under seismic forces. This work provides a good source of information on the parameters lateral displacement and storey drift.

A.B.Climent[7] [2012] investigates about the effective width of reinforced concrete flat slab structures subjected to seismic loading on the basis of dynamic shaking table tests. The study is focused on the behavior of corner slab column connections with structural steel I- or channel-shaped sections (shear heads) as shear punching reinforcement. To this end, a 1/2 scale test model consisting of a flat slab supported on four box-type steel columns was subjected to several seismic simulations of increasing intensity. It is found from the test results that the effective width tends to increase with the intensity of the seismic simulation, and this increase is limited by the degradation of adherence between reinforcing steel and concrete induced by the strain reversals caused by the earthquake.

Also, significant differences are found between the effective width obtained from the tests and the values predicted by formula proposed in the literature. These differences are attributed to the stiffening effect provided by the steel profiles that constitute the punching shear reinforcement. K.S.Sable et al[8] [2012] focuses on tall commercial buildings are primarily a response to the demand by business activities to be as close to each other, and to the city centre as possible, thereby putting intense pressure on the available land space. Structures with a large degree of indeterminacy is superior to one with less indeterminacy, because of more members are monolithically connected to each other and if yielding takes place in any one of them, then a redistribution of forces takes place. Therefore it is necessary to analyze seismic behavior of building for different heights to see what changes are going to occur if the height of conventional building and flat slab building changes.

K. S. Patil et al[9] [2013] study about optimum design of reinforced concrete flat slab with drop panel according to the Indian code (IS 456-2000) is presented. The objective function is the total cost of the structure including the cost of slab and columns. The cost of each structural element covers that of material and labour for reinforcement, concrete and formwork. The structure is model and analyzed using the direct design method. The optimization process is done for different grade of concrete and steel. The comparative results for different grade of concrete and steel is presented in tabulated form. Optimization for reinforced concrete flat slab buildings is illustrated and the results of the optimum and conventional design procedures are compared. The model is analyzed and design by using MATLAB software. Optimization is formulated is in nonlinear programming problem (NLPP) by using sequential unconstrained minimization technique (SUMT).

Y. Mirzaei et al[10] [2013] studies about the column failure due to an explosion can propagate in the structure through punching shear failure at the location of the neighboring columns, leading to progressive collapse. An analytical model is developed to be used in a finite element model of flat plate/slab structures to estimate the initiation of punching shear failure as well as post-punching shear response using ABAQUS.

V.K. Rahman1 et al[11] [2013] work on design of R.C.C. as well as pre-stressed concrete flat slabs for various spans and then compare the results. Programming in MS EXCEL is done to design both types of flat slabs. The idea is to reach a definite conclusion regarding the superiority of the two techniques over one another. Results reveal that a R.C.C. flat slab is cheaper than pre-stressed concrete flat slab for smaller spans but vice versa is true for larger spans.

R.K.Makode et al[12] [2014] discussed about the flat slab buildings in which slab is directly rested on columns, have been adopted in many buildings constructed recently due to the advantage of reduced floor to floor heights to meet the economical and architectural demands. K. S. Patil et al[13] [2014] Sequential unconstrained minimization technique (SUMT) is used for the solution of a comprehensive minimum cost design problem formulation. The formulation, based on Indian codes of practice (IS 456-2000), Solutions to the nonlinear programming problem are obtained with an appropriate computer program, This is used for solving a wide range of typical flat slab designs with varying span-to-depth ratios, live and dead loads, different grades of concrete and steel. A related sensitivity study enables the comparison of optimal and standard solutions. The different conditions of flat slabs are analyzed and design by using MATLAB software.

S.RAO et al[14] [2014] This paper presents the punching shear strength of high performance concrete (HPC) two way slabs under simply supported edge condition. Three number of HPC slabs and three numbers of normal concrete slabs as control specimens were cast and tested. All the slabs were tested under a central patch load, the results showed that the HPC slabs posses higher energy absorption, better performance, higher punching shear strengths than the control specimens.

THEORY:

3.1 Methods of Elastic Analysis:

Forces and displacements due to each horizontal component of ground motion are separately determined by analysis of an idealized building having one lateral degree of freedom per floor in the direction of the ground motion component being considered. Such analysis may be carried out by:

- The equivalent lateral force procedure (static method) or,
- Response spectrum analysis procedure (dynamic method)or,
- Another refined method of dynamic analysis is the elastic time-history method.

Both the equivalent lateral force and response spectrum analysis procedures lead directly to lateral forces in the direction of the ground motion component. The main differences between the two methods are in the magnitude and distribution of the lateral forces over the height of the building .The equivalent lateral force method is mainly suited for preliminary design of the building. The preliminary design of the building is then used for response spectrum analysis or any other refined method such as the elastic time history method

3.1.1 Equivalent Lateral Force Method (Seismic Coefficient Method):

Seismic analysis is carried out on the assumption that the lateral (horizontal) force is equivalent to the actual (dynamic) loading. This method requires less effort because, except for the fundamental period, the periods and shapes of higher natural modes of vibration are not required. The base shear which is the total horizontal force on the structure is calculated on the basis of the structure's mass, its fundamental period of vibration, and corresponding shape. The base end shear is distributed along the height of the structure, in terms of lateral forces, according to the code formula. Planar models appropriate for each of the two orthogonal lateral directions are analyzed separately; the results of the two analyses and the various effects, including those due to torsional motions of the structure, are combined. This method is usually conservative for low- to medium-height buildings with a regular conformation.

3.1.2 Response Spectrum Analysis:

This method is also known as modal method or mode superposition method. The method is applicable to those structures where modes other than the fundamental one significantly affect the response of the structure. Generally, the method is applicable to analysis of the dynamic response of structures, which are asymmetrical or have areas of discontinuity or irregularity, in their linear range of behavior. In particular, it is applicable to analysis of forces and deformations in multi-storey buildings due to medium intensity ground shaking, which causes a moderately large but essentially linear response in the structure. This method is based on the fact that, for certain forms of damping the response in each natural mode of vibration can be computed independently of the others, and the modal responses can be combined to determine the total response. Each mode responds with its own particular pattern of deformation (mode shape), with its own frequency (the modal frequency), and with its own modal damping. In general, the responses need to be determined only in the first few modes because response to earthquake is primarily due to lower modes of vibration.A complete modal analysis provides the history of response-forces, displacements, and deformations-of a structure to a specified ground acceleration history. However, the complete response history is rarely needed for design; the maximum values of response over the duration of the earthquake usually suffice. Because the response in each vibration mode can be modeled by the response of a SDOF oscillator, the maximum response in the mode can be directly computed from the earthquake response spectrum. Procedures for combining the modal maxima to obtain estimates (but not the exact value) of the maximum of total response are available. In its most general form, the modal method for linear response analysis is applicable to arbitrary three-dimensional structural systems. However, for the purpose of design of buildings, it can often be simplified from the general case by restricting its application to the lateral motion in a plane. Planar models appropriate for each of two orthogonal lateral directions are analyzed separately, and the· results of the two analyses and the effects of torsional motions of the structures are combined.

3.1.3 Elastic Time History Method:

A linear time history analysis overcomes all the disadvantages of a modal response spectrum analysis provided non-linear behavior is not involve .This method requires greater computational efforts for calculating the response at discrete times. One interesting advantage of such a procedure is that the relative signs of response quantities are preserved in the response histories. This is important when interaction effects are considered among stress resultants.

3.1.4 Equivalent Lateral Force Method:

This method of finding design lateral forces is also known as the static method or the equivalent static method or the seismic coefficient method. This procedure does not require dynamic analysis, however, it accounts for the dynamics of building in an approximate manner. The static method is the simplest one; it requires less computational effort and is based on formulae given in the code of practice. First, the design base shear is computed for the whole building, and it is then distributed along the height of the building. The lateral forces at each floor level thus obtained are distributed to individual lateral load resisting elements.

3.2 Seismic Base Shear:

The total design lateral force or design seismic base shear (Vn) along any principal direction
is determined by:

Vb = Ah W

Where Ah is the design horizontal acceleration spectrum value, using the fundamental natural period, T, in the considered direction of vibration and W is the seismic weight of the building. The design horizontal seismic coefficient Ah for a structure is determined by the expression:

$A_h = (Z\ I\ Sa/g)/2R$

For any structure with T ≤ 0.1 s, the value of Ah will not be taken less than Z/2 whatever be the value of 1/R.Z is the zone factor for the maximum considered earthquake (MCE). The factor 2 in the denominator is used so as to reduce the maximum considered earthquake (MCE) zone factor to the factor for design basis earthquake (DBE). I is the importance factor and depends upon the functional use of the structure, the hazardous consequences of its failure, post earthquake functional needs, historical value, or economic importance R is the response reduction factor which depends on the perceived seismic damage performance of the structure, characterized by ductile or brittle deformations. This factor is used to decide what building materials are used, the type of construction, and the type of lateral bracing system. Sa/g is the response acceleration coefficient for the respective damping, based on appropriate natural periods.

3.3 Seismic Weight:

The seismic weight of the whole building is the sum of the seismic weights of all the floors. The seismic weight of each floor is its full dead load plus the appropriate amount of imposed load, the latter being that part of the imposed loads that may reasonably be expected to be attached to the structure at the time of earthquake shaking. It includes the weight of permanent and movable partitions, permanent equipment, a part of the live load, etc. While computing the seismic weight of each floor, the weight of columns and walls in any storey should be equally distributed to the floors above and below the storey.
Any weight supported in between storeys should be distributed to the floors above and below in inverse proportion to its distance from the floors .As per IS 1893: (Part 1), the percentage of imposed load as given in Table 2 should be used .For calculating the design seismic forces of the structure, the imposed load on the roof need not be considered.

3.4 Distribution of Design Force:

The design lateral force is first computed for the building as a whole and then distributed to the various floor levels. The overall design seismic force thus obtained· at each floor level is then distributed to individual lateral load-resisting elements, depending on the floor diaphragm action.

METHODOLOGY

4.1 GENERAL :

The present objective of this work is to study the behavior of flat slab with conventional RC framed building comprising of beam, column and slab. The parametric studies comprise of maximum lateral drift, base shear, time period, and axial forces generated in the frames for all seismic zones in India. For these cases, models has been created for conventional RC framed building, flat slab building without drop panels and flat slab with drop panels for plan size of 43.5m*35 m(43.5 along x-direction and 35 m along y-direction), analyzed with ETABS for seismic zones II, III, IV and V. This study also focused on the difference between seismic behavior of flat slab building without drop panels and flat slab building with drops.

4.2 BUILDING MODELLING:

4.2.1 Building Configuration and Data:

For analysis, 8 storeys and plan area 43.5m*35 m(43.5 along x-direction and 35 m along y-direction) building is considered. The total height of building is 27.939 m with varying story to story height. There are 6 bays in building in X direction and 5 bays in Y direction. M30 grade concrete and Fe415 structural steel is used. Building is fixed at the base. Three models are considered for analysis, they are :

1. Conventional RC Framed Building
2. Flat Slab Building Without Drops
3. Flat Slab Building With Drops

Model	Slab Thickness (mm)	Beam(mm)
Conventional RC Framed Building	235	Plinth beam : 500*650 Floor/Roof beam : 450*600
Flat Slab Building Without Drops	310	NO
Flat Slab Building With Drops	470	NO

Table 4.1: The dimensions of the components

Label of beam & column and all models elevation, plan and 3D views are shown from Figure 4.2 to Figure 4.6.

All the properties of Building are mentioned below:
Size of Beam in all Direction: 300*600 mm
Size of column: 700*700 mm
Thickness of Slab: 235 mm
Thickness of Flat Slab: 310 mm
Thickness of Drop Panels : 470 mm
Size of Drops : 3 m
Live Load : 5 KN/m^2
Floor Finish: 2 KN/m^2
Importance Factor: 1.5
Response Reduction Factor: 5
Type of soil: medium

All seismic zones, ie. Zone II, Zone III, Zone IV, Zone V are considered for analysis.

Analysis of building is performed as per IS1893 (part1):2002. Both Equivalent Static analysis and response Spectrum Analysis are performed in ETABS. Parameters like Lateral Displacement, Story Drift, axial forces, base shear were studied and mode shapes of the building are shown.

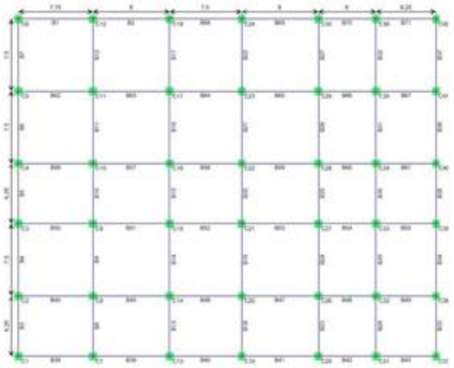


Figure 4.1 : Label of Beam for all models (units in m)

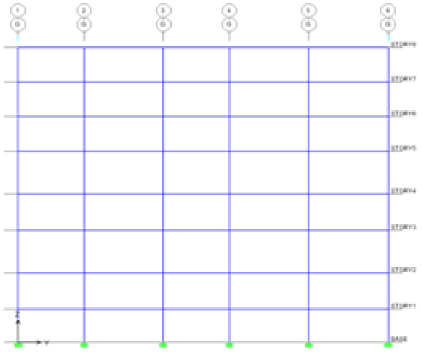


Figure 4.2 : Elevation

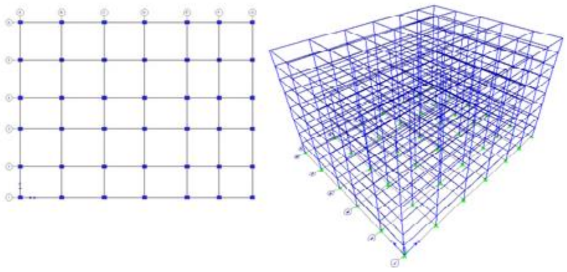


Figure 4.3 : Plan and 3D view of Conventional RC Framed Building

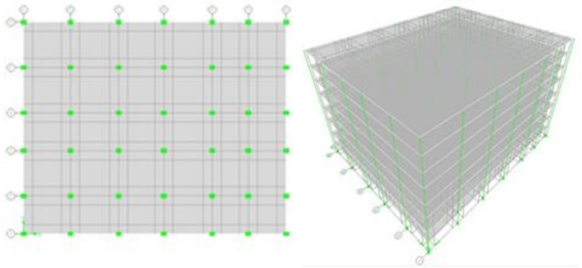
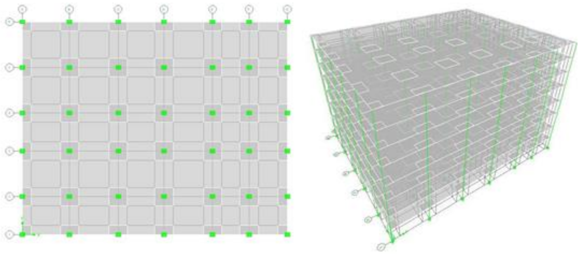


Figure 4.4 : Plan and 3D view of Flat Slab Building Without Drops



RESULTS AND DISCUSSIONS:

5.1 Data's Of Various Parameters In Four Seismic Zones :

The following data's are read for the combination of dead load and RSX in X-direction and for dead load and RSY in Y-direction.

5.1.1 Lateral Displacement :

5.1.1.1 For Seismic Zone-V:

Model	Story 1	Story 2	Story 3	Story 4	Story 5	Story 6	Story 7	Story 8
Conventional Building	3.40	11.00	21.30	29.20	37.40	42.40	46.00	48.50
Flat Slab Building Without Drops	3.60	11.80	23.30	32.30	41.70	47.60	52.00	55.20
Flat Slab Building With Drops	3.20	9.70	18.30	24.70	31.30	35.30	38.00	39.60

Table 5.1 : Lateral displacement (in mm) in X-direction for zone-V

Model	Story 1	Story 2	Story 3	Story 4	Story 5	Story 6	Story 7	Story 8
Conventional Building	3.40	10.90	21.10	28.90	37.10	42.10	45.70	48.10
Flat Slab Building Without Drops	3.50	11.70	23.00	31.90	41.10	46.90	51.30	54.40
Flat Slab Building With Drops	3.10	9.50	18.00	24.20	30.80	34.60	37.30	38.90

Table 5.2 : Lateral displacement (in mm) in Y-direction for zone-V

5.1.1.2 For Seismic Zone-IV:

Table 5.3 : Lateral displacement (in mm) in X-direction for zone-IV

Model	Story 1	Story 2	Story 3	Story 4	Story 5	Story 6	Story 7	Story 8
Conventional Building	2.30	7.30	14.20	19.40	24.90	28.30	30.70	32.30
Flat Slab Building Without Drops	2.40	7.90	15.60	21.60	27.80	31.70	34.70	36.80
Flat Slab Building With Drops	2.10	6.50	12.20	16.40	20.90	23.50	25.30	26.40

Table 5.4 : Lateral displacement (in mm) in Y-direction for zone-IV

Model	Story 1	Story 2	Story 3	Story 4	Story 5	Story 6	Story 7	Story 8
Conventional Building	2.20	7.20	14.10	19.30	24.70	28.00	30.50	32.10
Flat Slab Building Without Drops	2.30	7.80	15.30	21.20	27.40	31.30	34.20	36.30
Flat Slab Building With Drops	2.10	6.30	12.00	16.10	20.50	23.10	24.90	26.00

CONCLUSIONS:

Studied the seismic behavior of three R.C framed building (i.e. frames with conventional slab, flat slab without drop panels and flat slab with drop panels) for all seismic zones in India. The following are the major conclusions:

1. Lateral drift in conventional R.C frame is less as compared to flat slab R.C frame without drop panels at each story in both X and Y-directions. Lateral drift of R.C.C frames with flat slabs vary from 4 to 28 (%) as compared to that of conventional R.C.C frames depending upon the storey.
2. For all the considered cases drift values was maximum at Story 3.
3. At all four seismic zones (i.e. zone-II, zone-III, zone-IV, zone-V) lateral drift of a conventional R.C frame, flat slab R.C frame with and without drops was within permissible limit in both X and Y-directions.
4. Lateral Drift of flat slab R.C framed structure without drop panels increases by 11 to 50 (%) as compared to that of flat slab R.C framed structure with drop panels. From the drift values we can conclude that drop panel increase stiffness of the flat slab and hence reduce deflection.
5. Axial force in interior columns of flat slab building without drops was more as compared to conventional building with two way slab. Axial force in interior column of R.C.C frames with flat slabs varies from 7 to 9 (%) as compared to that of conventional R.C.C frames depending upon the storey.
6. Axial force in corner and edge columns of flat slab building without drops was less as compared to conventional building with two way slab.
7. Axial force in corner column of flat slab R.C.C framed structure without drop panels vary from 18 to 20 (%) as compared to that of conventional R.C.C frames depending upon the storey.
8. Axial force in edge column of flat slab R.C.C framed structure without drop panels vary from 4 to 6

(%) as compared to that of conventional R.C.C frames depending upon the storey.
9. Axial force in interior, edge and corner columns of flat slab building with drops was more as compared to flat slab building without drops and the values varied from 7 to 10 (%).
10. The storey shears is maximum at plinth level for all types of column. After plinth level the storey shear decreases as the height of the building increases. The base shear will increase drastically as the zone factor increases. Base shear of flat plate building without drops is less than the conventional R.C.C building and the difference between the two is 10.53 %.

SCOPE OF FUTURE STUDIES:

1. The structure can be analysed with effect of Shear Wall.
2. The structure can be compared with post tensioned slab designed methods.
3. Comparative study of Seismic performance of multistoried RCC buildings with flat slab and grid slab can be performed.
4. Fragility analysis of flat-slab structures can be done.
5. Non-Linear Pushover Analysis of Flat slab Building can be performed using ETABS.

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