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A New Analysis And Design of Commercial Building with Flat Slab

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Abstract: With the increase in population and development of civilization, the demand for HOUSING is increasing at a peak rate. Especially in towns due to rapid industrialization, the demand is very high. Adapting the construction of Multi-storied Building not only matches with demand but also decreases the price of the single house. The aim of our project is to design a G+13 building with flat slabs instead of conventional slab. It is designed by using M25 grade concrete and Fe415 steel. The dead load, live load and seismic load are applied and the design for beams, columns, footing is obtained. Analysis & Design of the building with flat slab is done by using ETABS software. 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. Although flat slabs have been in construction for more than a century now, 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 Standard 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 regular geometry and regular layout are becoming quite common. Also behavior and response of flat slabs during earthquake is a big question. The inadequacies of these buildings are discussed by means of comparing the behavior with that of conventional beam column framing. Grid slab system is selected for this purpose. To study the effect of drop panels on the behavior of flat slab during lateral loads, flat plate system is also analyzed. 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 relation between the number of stories, zone and soil condition is developed.

Keywords: Flat Slab, Flat Plate, Grid Slab, Storey Drift, Punching Shear, ETABS.

I. INTRODUCTION

Flat slabs system of construction is one in which the beams used in the conventional methods of constructions are done away with. The slab directly rests on the column and load from the slab is directly transferred to the columns and then to the foundation. To support heavy loads the thickness of slab near the support with the column is increased and these are called drops, or columns are generally provided with enlarged heads called column heads or capitals. Absence of beam gives a plain ceiling, thus giving better architectural appearance and also less vulnerability in case of fire than in usual cases where beams are used. Basic definition of flat slab: In general normal frame construction utilizes columns, slabs & Beams. However it may be possible to undertake construction without providing beams, in such a case the frame system would consist of slab and column without beams. These types of Slabs are called flat slab, since their behavior resembles the bending of flat plates. A reinforced concrete slab supported directly by concrete columns without the use of beams.

Fig1. Slab With Columns.

II. COMPONENTS OF FLAT SLAB

Drops To resist the punching shear which is predominant at the contact of slab and column Support, the drop dimension should not be less than one -third of panel length in t hat direction. Column Heads Certain amount of negative moment is transferred from the slab to the column at the support. To resist this negative moment the area at the support needs to be increased .this is facilitated by providing column capital/heads. Flat slabs are appropriate for most floor situations and also for irregular column layouts, curved floor shapes, ramps etc. The benefits of choosing flat slabs include a minimum depth solution, speed of construction, flexibility in the plan layout (both in terms of the shape and column layout), a flat soffit (clean finishes and freedom of layout of services) and scope and space for the use of flying forms. The flexibility of flat slab construction can lead to high economy and yet allow the architect great freedom of form. Examples are; solid flat slab, solid flat slab with drop panel, solid flat slab with column head, coffered flat slab, coffered flat slab with solid panels, banded coffered flat slab.

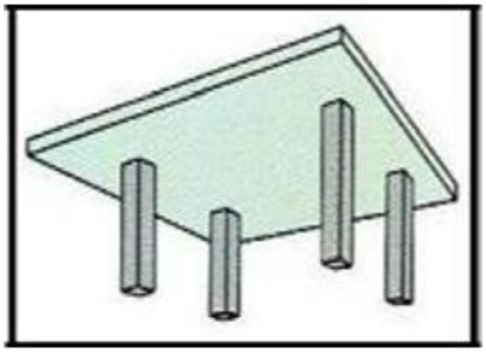

Fig2. Solid Flat Slab.

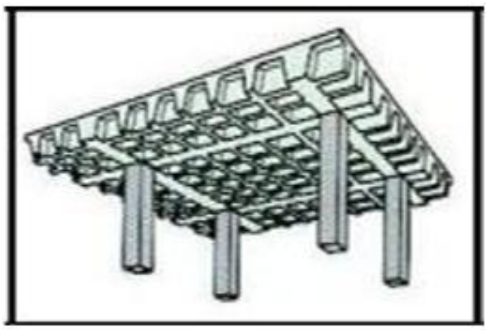

Fig3. Coffered Flat Slab.

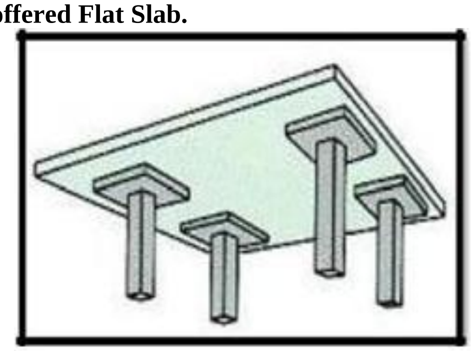

Fig4. Solid Flat slab with Drop Panels.

A flat slab is a flat section of concrete. These slabs are classically used in foundations, although they can also be used in the construction of roadways, paths, and other structures. Depending on the size and complexity of a flat slab, it may need to be designed by an engineer who is familiar with the limitations and needs of slabs, or it may be possible for a handy do it yourselfer to make one in an afternoon for a simple project. Typically, a flat slab is made with reinforced concrete, in which rebar is criss-crossed in the forms to provide support and reinforcement once the concrete is poured and hardened. The slab design is designed to be reinforced in several directions so that it can withstand stresses such as shifting ground, earthquakes, frost, and so forth. Failure to fully reinforce a flat slab can cause it to crack or give along weak lines in the concrete, which will in turn cause instability. For some sites, a flat slab is poured in situ. In this case, the site is prepared, forms for the concrete are set up, and the reinforcing rebar or other materials are laid down. Then, the concrete is mixed, poured, and allowed to cure before moving on to the next stage of construction. The time required can vary considerably, with size being a major factor; the bigger the slab, the more complex reinforcement needs can get, which in turn adds to the amount of time required for set up. Once poured, the slab also has to be examined and tested to confirm that the pour was good, without air pockets or other problems which could contribute to a decline in quality. In other cases, a flat slab may be prefabricated off site and transported to a site when it is needed. This may be done when conditions at the site do not facilitate an easy pour, or when the conditions for the slab's construction need to be carefully controlled. Transportation of the slab can be a challenge if it is especially large. Barges, cranes, and flatbed trucks may be required to successfully move it from the fabrication site to the site of the installation.

The flat slab foundation is not without problems. It can settle on uneven ground, allowing the structure to settle as well, for example, and during seismic activity, a slab foundation cannot hold up if the soils are subject to liquefaction. A flat slab can also become a major source of energy inefficiency, as structures tend to lose heat through the concrete. Advantages of flat-slab reinforced concrete structures are widely known but there are also known the disadvantages concerning their earthquake resistance. It is remarkable that both Greek codes, Reinforced Concrete Code and Seismic Code do not forbid the use of such structural systems however both Codes provide specific compliance criteria in order such structures to be acceptable. The advantages of these systems are:

- The ease of the construction of formwork.
- The ease of placement of flexural reinforcement.
- The ease of casting concrete
- The free space for water, air pipes, etc between slab and a possible furred ceiling.
- The free placing of walls in ground plan.
- The use of cost effective prestressing methods for long spans in order to reduce slab thickness and deflections as also the time needed to remove the formwork.
- The reduction of building height in multi-storey structures by saving one storey height in every six storey's thanks to the elimination of the beam height.

These structural systems seem to attract global interest due to their advantages mainly in countries in which the seismicity is low. The application of flat-slab structures is restrained due to the belief that such structures are susceptible to seismic actions. Moreover, it is known that in Central America, at the beginning of 1960's, flat-slab structures displayed serious problems during earthquake actions.

III. MODELLING AND ANALYSIS

The analysis and design of RCC building was carried out using the software ETABS. It is the most popular structural engineering software product for 3D model generation, analysis and multi-material design. It has an intuitive, user-friendly GUI, visualization tools, powerful analysis and design facilities and seamless integration to several other modeling and design software products. For static or dynamic analysis of bridges, containment structures, embedded structures (tunnels and culverts), pipe racks, steel, concrete, aluminum or timber buildings, transmission towers, stadiums or any other simple or complex structure, has been the choice of design professionals around the world for their specific analysis needs.

A. Building Materials

The required material properties like mass, weight density, modulus of elasticity, shear modulus and design values of the material used can be modified as per requirements or default values can be accepted. Beams and column members have been defined as 'frame elements' with the appropriate dimensions and reinforcement. Soil structure interaction has not been considered and the columns have been restrained at the base. The height of all the stories is 3m. The modulus of elasticity and shear modulus of concrete has been taken as E = 2.55 ×107 KN/m³ and G = 1.06 ×107 kN/m².

B. Dead loads & Live loads

After having modeled the structural components, all possible load cases are assigned. In this study we are primarily concerned with observing the deformations, forces and moments induced in the structure due to dead, live loads and earthquake loads. The load case 'Dead Load (DL) takes care of the self-weight of the frame members and the area sections. The wall loads have been defined under the case 'Live load (LL)'.

- Floor finish is assigned as 1 kN/m².
- Live load is assigned as 2 kN/m²

C. Load Combination

The structure has been analyzed for load combinations considering all the previous loads in proper ratio. In the first case a combination of self-weight, dead load, live load and wind load was taken in to consideration. In the second combination case instead of wind load seismic load was taken into consideration. All the load cases are tested by taking load factors and analyzing the building in different load combination as per IS456 and analyzed the building for all the load combinations and results are taken and maximum load combination is selected for the design load factors as per IS456-2000.Select Define from menu bar, select load combinations. Then specify the following load combinations:

- 1.5(DL+LL)
- 1.5(DL+LL+WX)
- 1.5(DL+LL-WX)
- 1.5(DL+LL+EQX)
- 1.5(DL+LL-EQX)
- 1.2(DL+LL+WX)
- 1.2(DL+LL-WX)
- 1.2(DL+LL+EQX)
- 1.2(DL+LL-EQX)
- DL+0.25LL
- 0.9DL+1.5LL

Method of analysis of statistically indeterminate portal frames:

- Method of flexibility coefficients.
- Slope displacements methods(iterative methods)
- Moment distribution method
- Kane's method
- cantilever method
- Portal method
- Matrix method
- STAAD Pro

Method of Flexibility Coefficients: The method of analysis is comprises reducing the hyper static structure to a determinate structure form by: Removing the redundant support (or) introducing adequate cuts (or) hinges.
Limitations: It is not applicable for degree of redundancy > 3

Slope displacement equations: It is advantageous when kinematics indeterminacy <static indeterminacy. This procedure was first formulated by axle bender in 1914 based on the applications of compatibility and equilibrium conditions. The method derives its name from the fact that support slopes and displacements are explicitly comported. Set up simultaneous equations is formed the solution of these parameters and the joint moment in each element or computed from these value.
Limitations: A solution of simultaneous equations makes methods tedious for manual computations. This method is not recommended for frames larger than too bays and two storey's.

Iterative methods: These methods involve distributing the known fixed and moments of the structural member to adjacent members at the joints in order satisfy the conditions of compatibility.
Limitations: It presents some difficulties when applied to rigid frame especially when the frame is susceptible to side sway. The method cannot be applied to structures with intermediate hinges.

Kani's method: This method over comes some of the disadvantages of hardy cross method. Kani's approach is similar to H.C.M to that extent it also involves repeated distribution of moments at successive joints in frames and continues beams. However there is a major difference in distribution process of two methods. H.C.M distributes only the total joint moment at any stage of iteration. The most significant feature of Kani's method is that process of iteration is self corrective. Any error at any stage of iterations corrected in subsequent steps consequently skipping a few steps error at any stage of iteration is corrected in subsequent consequently skipping a few steps of iterations either by over sight of by intention does not lead to error in final end moments. Acceleration of the ground, the type of structure and its foundation.

D. Building Behavior

Tall buildings respond to seismic motions differently than low rise buildings. The magnitude of inertia force depends on the building mass, ground acceleration, the nature of foundation, and the dynamic characteristics of the structure. Tall buildings are invariably more flexible than low rise buildings, and in general experiences much lower accelerations than low rise buildings. The magnitude of earthquake force is not a function of the acceleration alone, but influenced to a great extent by the type of response of the structure and its foundation. This interrelationship of building behavior and seismic ground motion also depends on the time period. Some factors which affect the building behavior are discussed here.

Influence of soil: The seismic motion that reaches a structure on the surface of the earth is influenced by local soil conditions. Low to mid-rise buildings have time period between 0.1 to 1 sec range, while taller more flexible buildings have periods between 1to 5 sec or greater. Harder soils, and bed rock transmit short period vibrations (caused by near field earthquake) while filtering out longer period earthquakes (caused by distant earthquakes), whereas softer soils will transmit longer period vibrations.

Structural response: If the base of structure is moved suddenly, the upper part of the structure will not respond instantaneously, but will lag because of inertial resistance and flexibility of the structure. Because earthquake ground motions are three dimensional, building deforms in a same manner. But inertia forces generated by horizontal components of ground motions required greater considerations for seismic design since adequate seismic resistance to vertical seismic loads is provided by member capacities required for gravity load design.

Load Path: Buildings are generally composed of vertical and horizontal structural elements. A complete load path is a basic requirement for all buildings. Seismic forces originating throughout the building, mostly in the heavier mass elements such as diaphragms, are delivered throughout the connections to diaphragm; the diaphragm distributes these forces to vertical force resisting system such as shear walls and frames. Through frame these forces are transferred to foundation; and foundation transfers these forces to supporting soil. Interconnecting, members needed to complete the load path is necessary to achieve good seismic performance.

E. Flat slab building behavior under lateral loading

The behaviour of flat slab structures for gravity loads is well established. However, behavior under lateral displacement is not well understood and lateral design methods are not well established. Frame action provided by flat slab and column is generally insufficient for buildings taller than 10 stories. The lateral behavior of flat slab structures is in doubt because of the relative flexibility of the connections when compared with beam column joints. A flat slab column framing is generally inadequate as a primary lateral load resisting system for multi-storey structures in high seismic risk zones because of problems associated with excessive drift. A system consisting of shear walls and flat slab with proper bracing systems is usually recommended for high rise buildings. Even there is a concern as to whether the connection possesses sufficient lateral displacement capacity to survive lateral deformations which can be reasonably expected. The stiffness of the typical wall or frame system is insufficient to protect the slab column connection from yield. Hence attention must be given to its inelastic seismic response. I.S. 1893-2002 says that "Since the lateral load resistance of the slab column connection system is small, flat slabs are often designed only for gravity loads, while the seismic force is resisted by shear walls. Even though slabs and columns are not required to share the lateral forces, these deforms with rest of the structure under seismic excitation. The concern is that under such deformations, the slab column system should not lose its vertical load capacity."

The slab column connections are subjected to gravity shear and unbalanced moment during earthquake. Transfer of shear and unbalanced moments is critical in flat slab behaviour, especially for horizontal loading which requires substantial unbalanced moment to transfer between slab and column. Unbalanced moment is transferred by combination of flexure, torsion and shear in the flat slab around the periphery of column faces. The shear from the unbalanced moment transfer is added to the gravity shear at connections. When combined shear becomes too large, a brittle punching failure will occur. If the connections are not properly detailed, punching failure may lead to progressive collapse. The concrete will provide a certain level of shear resistance around the columns but this may need to be supplemented by punching shear reinforcement arranged on concentric perimeters. Thus during transfer of loads either due to gravity or due to earthquakes, behavior of flat slab building depends on strength and behavior of slab connection.

F. Structural Dynamic behavior of Multiple-degree-of-freedom (MDOF) systems

Degree of freedom: Any mass can undergo six possible displacements in space - three translation and three rotations about an orthogonal axis system. The number of independent displacement required to define the displaced position of all the masses relative to their original position is called number of degree of freedom (DOFS) for dynamic analysis.

- Single Degree of Freedom System
- Multi Degree of Freedom System
- Continuous System

Classification of vibration:

- Free and forced vibration
- Undamped and damped vibrations
- Linear and non-linear vibration

Free and forced vibrations: If a system, after an initial disturbance is left to vibrate on its own, the ensuing vibration is known as free vibrations. No external force acts on the Parapate Load should be the cross sectional is multiplied by unit weight. Slab Load should be combination of slab load plus floor finishes. SLAB LOAD can be calculated as the thickness of slab multiplied by unit weight of concrete (according to IS-CODE unit weight of concrete is taken as 25 kn/m^3).and FLOOR FINISHES taken as .1.5 kn/m2.

Live Load Calculation: Live Load is applied all over the super structure except the plinth. Generally LIVE LOAD varies according to the types of building. For Residential building LIVE LOAD is taken as 2kn/m2 on each floor and 2kn/m2 on roof.

G. Critical Load Combinations

While designing a structure, all load combinations, in general are required to be considered and the structure is designed for the most critical of all. For building upto 4 storeys, wind load is not considered, the elements are required to be designed for critical combination of dead load and live load only. For deciding critical load arrangements, we are required to use maximum and minimum loads. For this code prescribes different load factors as given below :

- Maximum load = w_{max} = 1.5(DL + LL)
- Minimum load = w_{min} = DL

The maximum positive moments producing tension at the bottom will occur when the deflection is maximum or curvature producing concavity upwards is maximum. This condition will occur when maximum load (i.e. both DL and LL) covers the whole span while minimum load (i.e. only DL) is on adjacent spans. Consideration may be limited to combination of: Design dead load on all spans will full design live loads on two adjacent spans (for obtaining maximum hogging moment.)

IV. PROPERTIES OF CONCRETE

Grade of concrete: Concrete is known by its grade which is designated as M15, M20, M25 etc, in which letter M refers to concrete mix and the number 15, 20, 25 etc. denotes the specified compressive strength ($f$ck) of 150mm size cube at 28 days, expressed in N/mm2. Thus, concrete is known by its compressive strength. In R.C. work M20, M25 grades of concrete are common, but higher grades of concrete should be used for severe and very severe and extreme environment.

Compressive strength: Like load the strength of concrete is also a quantity which varies considerably for the same concrete mix. Therefore a single representative value known as characteristic strength,is arrived at using statistical probabilistic principles.

Characteristic Strength: It is defined as that value of the strength below which not more than 5% of the test results are suspected to fall,(i.e., there is 95% probability of achieving this value, or only 5% probability of not achieving the same).

Characteristic strength of concrete in flexural member: It may be noted that the strength of concrete cube does not truly represent the strength of concrete in flexural member because factors namely, the shape effect, the prism effect, state of stress in a member and casting and curing conditions for concrete in the member. Taking this into consideration the characteristic strength of concrete in a flexural member is taken as 0.67times2.6 the strength of concrete cube.

Design strength(fd) and partial safety factor(γd) for material strength : The strength to be taken for the purpose of design is known as design strength and is given by
Design strength (fd) = characteristic strength($f$ck)
Partial safety factor for material Strength (γm)

The value of γm depends upon the type of material and upon the type of limit state. According to I.S. code, γm = 1.5 for concrete and γm = 1.15 for steel. Design strength of concrete in member = 0.67$f$ck /1.5=0.446 $f$ck ≈ 0.45 $f$ck. Generally concretes are strong in compression and very negligible respond (almost zero) to the tension. So reinforced (steel bars) are provided to resist the tension and to counteract the moment which can't resist by the concrete. The partial safety factor for concrete generally taken as 1.5 due to non-uniform compaction and inadequate curing and partial safety factor for steel is taken as 1.15.The compressive strength of concrete is always taken as because it is always lesser than the cube strength. So for the design work the maximum strength of the concrete is taken as -0.67fck/1.5=.45fck and for steel is fy/1.15=.87 fy.

Punching Shear Data: Flat slab exhibits higher stress at the column connection .They are most likely to fail due to punching shear which will occur due to the concentration of shear forces and the unbalanced bending and twisting moments . It has to be noted that the punching shear failure is rather more critical than the flexural failure. Such a concentration of shear force and moments leads to unsymmetrical stress distribution around the slab-column connections. The local and brittle nature of the punching shear failure is in the form of crushing of concrete in the column periphery before the steel reinforcement reaches the yield strain. The observed angle of failure surface is found to vary between 26° and 36°. Thus the punching shear capacity of a slab (in absence of shear reinforcement) depends on the strength of concrete, the area of tension reinforcement, the depth of the slab and the column size. The sudden disaster effect of the punching shear is a critical problem for any designer. Punching shear is a type of failure of reinforced concrete slabs subjected to high localized forces. In flat slab structures this occurs at column support points. The failure is due to shear: When the flat slab is exposed to a concentrated load larger than the capacity, the effect on the slab is referred to punching shear. In these slabs, the sheer force per unit length can become high close to the area of loading. If the capacity for punching in the slab is exceeded, a punching shear failure may occur within the discontinuity regions (D-region) of the flat slab. This type of failure is a brittle failure mechanism, and may cause a global failure of the structure. Punching shear failure is a typical failure for slab-column connection. The above figure shows an example of a global failure of a structure due to punching.

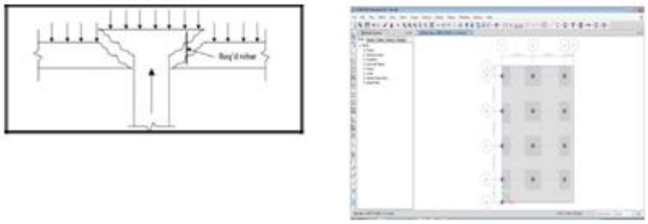

Fig5. Punching Shear failure.

Fig6. Column Drop.

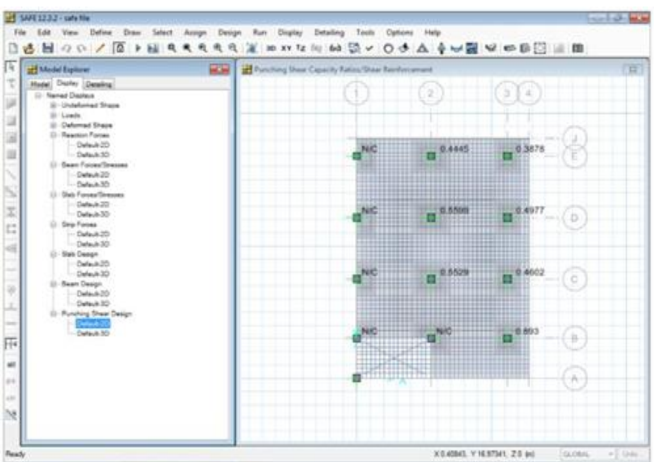

Fig7. Global collapse of the structure due to punching shear.

V. CONCLUSION

Flat-slab building structures possesses major advantages over traditional slab-beam-column structures because of the free design of space, shorter construction time, architectural – functional and economical aspects. Because of the absence of deep beams and shear walls, flat-slab structural system is significantly more flexible for lateral loads then traditional RC frame system and that make the system more vulnerable under seismic events.The purely flat-slab RC structural system is considerably more flexible for horizontal loads than the traditional RC frame structures which contributes to the increase of its vulnerability to seismic effects. The critical moment in design of these systems is the slab-column connection, i.e., the penetration force in the slab at the connection, which should retain its bearing capacity even at maximal displacements. The ductility of these structural systems is generally limited by the deformability capacity of the column-slab connection. To increase the bearing capacity of the flat-slab structure under horizontal loads, particularly when speaking about seismically prone areas and limitation of deformations, modifications of the system by adding structural elements are necessary.

VI. REFERENCES

[1]Design of Reinforced Concrete Structures by A. K. Jain,
[2] Surya Prakash S. Krishna Murthy,
[3]Design of R.C.C structural elements by S.S. Bhavikatti,
[4] Design of R.C.C slabs by K.C.Jain,
[5] Design of R.C.C structures by prof.N.Krishna Raju,
[6] Design of R.C.C structures by prof.S.Ramamrutham,

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