Analysis of Flat Slab

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Abstract: ***A popular form of concrete building construction uses a flat concrete slab (without beams) as the floor system. Flat slabs 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. This paper gives the guidelines for analysis of flat slab.***

Keywords: Flat slab, Lateral load, Punching Shear.

1. Introduction

The horizontal floor system resists the gravity load (dead load and live load) acting on it and transmits this to the vertical framing systems. In this process, the floor system is subjected primarily to flexure and transverse shear, where as the vertical frame elements are generally subjected to axial compression, often coupled with flexure and shear. The floor also serves as a horizontal diaphragm connecting together and stiffening the various vertical frame elements. Under the action of lateral loads, the floor diaphragms behave rigidly (owing to its high in plane flexural stiffness) and effectively distribute the lateral load to the various vertical frame elements and shear walls. In cast in situ reinforced concrete construction the floor system usually consists of one of the following

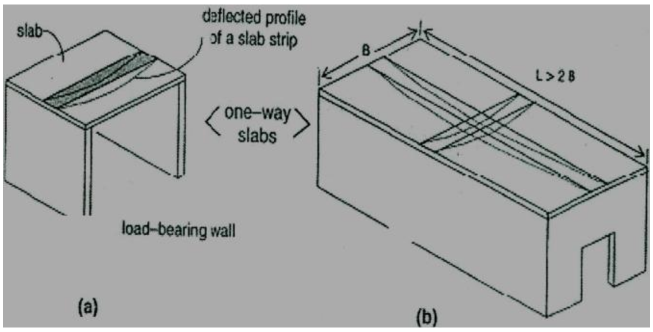

Figure 1.1: Wall Supported slab systems

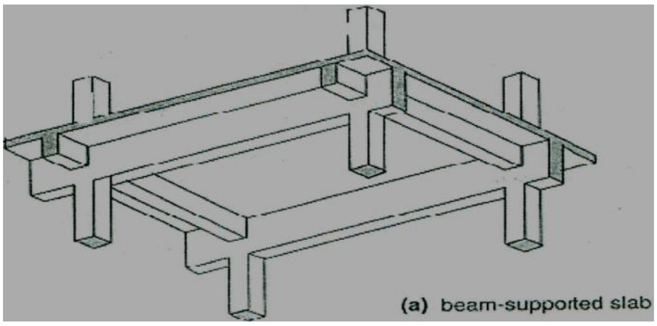

Figure 1.2: Beam Supported Slab System

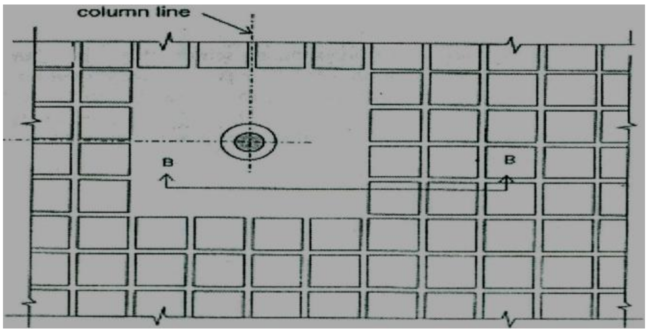

Figure 1.3: Two way ribbed (waffle) slab system

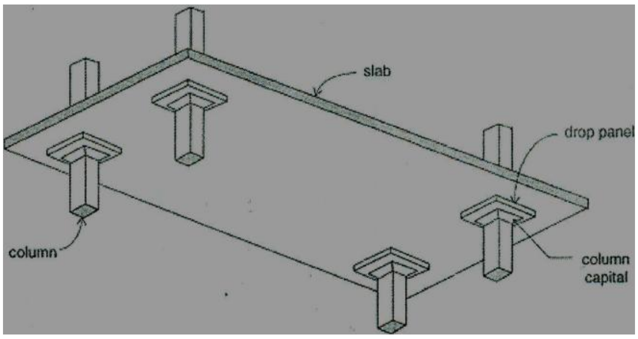

Figure 1.4: Flat Slab Systems

2. Flat slab

RC slabs with long spans extended over several bays and only supported by columns, without beams known as flat slab. Flat slab system is very simple to construct and is efficient in that it requires the minimum building height for a given number of stories.

Such structure contains large bending moment and vertical forces occur in a zone of supports. This gives a very efficient structure which minimizes material usages and decreases the economic span range when compared to reinforced concrete. Post-tensioning improves the structural behavior of flat slab structure considerably.

This is more acceptable concept to many designers. It is adopted in some office buildings. The flat slabs are plates that are stiffened near the column supports by means of 'drop panels' and/or 'column capitals' (which are generally concealed under 'drop ceilings'). Compared to the flat plate system, the flat slab system is suitable for higher loads and larger spans, because of enhanced capacity in resisting shear and hogging moments near the supports. The slab thickness varies from 125 mm to 300 mm for spans of 4 to 9m. Among the various floor systems, the flat slab system is the one with the highest dead load per unit area.

In general, in this type of system, 100 percent of the slab load has to be transmitted by the floor system in both directions (transverse and longitudinal) towards the columns. In such cases the entire floor system and the columns act integrally in a two- way frame action.

Some terminologies involved

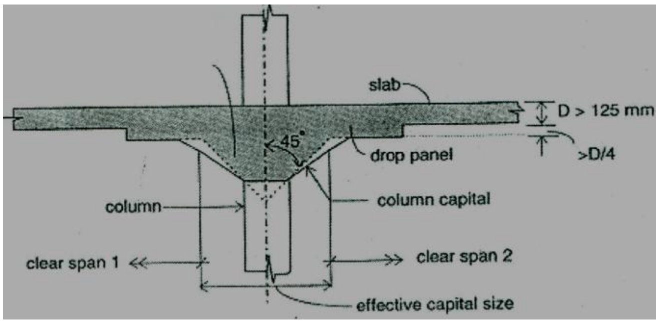

Figure 2.1: Drop panel and column capital

Drop Panels: The 'drop panel' is formed by the local thickening of the slab in the neighborhood of the supporting column. Drop panels or simply drops are provided mainly for the purpose of reducing shear stress around the column supports. They also help in reducing the steel requirements for the negative moments at the column supports. The code recommends that drops should be rectangular in plan, and have length in each direction not less than one third of the panel length in that direction. For exterior panels, the length measured perpendicular to the discontinuous edge from the column centerline should be taken as one half of the corresponding width of drop for the interior panel.

Column Capital: The column capital or column head provided at the top of a column is intended primarily to increase the capacity of the slab to resist punching shear. The flaring of the column at top is generally done such that the plan geometry at the column head is similar to that of the column. The code restricts the structurally useful portion of the column capital to that portion which lies within the largest (inverted) pyramid or right circular cone which has a vertex angle of 90°, and can be included entirely within the outlines of the column and the column head. This is based on the assumptions of a 45° failure plane, outside of which enlargement of the support is considered ineffective in transferring shear to the column.

Some evident of flat slab failure:

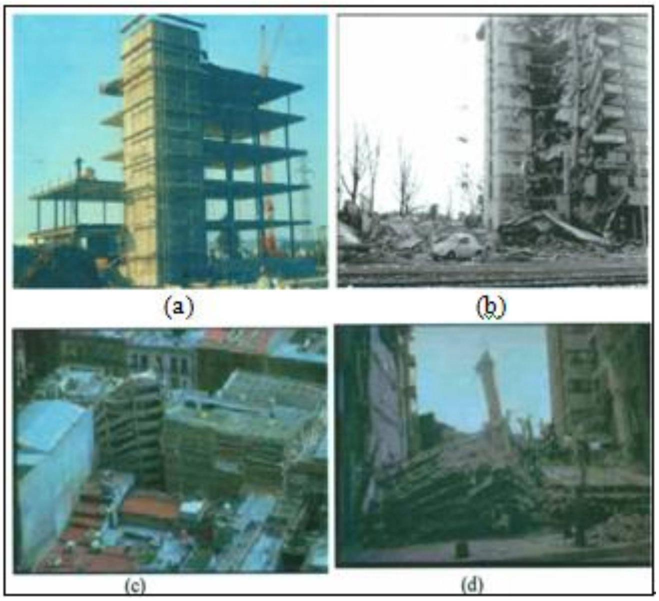

Figure 2.2: Some evident of flat slab failure

a) In this new skeleton building with flat slabs and small structural columns designed to carry gravity loads, the only bracing against horizontal forces and displacements is a reinforced concrete elevator and stairway shaft, placed very asymmetrically at the corner of the building. There is a large eccentricity between the centres of mass and resistance or stiffness. Twisting in the plan, lead to large relative displacements in the columns furthest away from the shaft and, this implies the danger of punching shear failure.
b) Punching Shear Failure in the Main Roof at corner Column.
c) This multi-floor parking garage collapsed like a stack of cards while some of the neighbouring buildings remained undamaged. Flat slab construction was the most vulnerable construction type with 85 total collapses during the 1985 quake at Germany.
d) In this building as in many others, the load-bearing column forced through the concrete floors as they collapsed around it. Severe resonance oscillations of the buildings caused strain at the juncture between columns and ceiling slabs; the concrete structure was destroyed and the steel reinforcements were strained until they failed. The vertical columns were compressed or (as in this picture) punched through the heavy floors that collapsed around them.

2.1 Advantages of Flat Slab

- Increases speed of construction
- The construction is simple and economical because of the simplified form work, the ease of placement of reinforcement.
- The plain ceiling gives an attractive and pleasing appearance; in absence of beams, provision of acoustical treatment is easy.
- In general flat slab construction is economical for spans up to 10m and relatively light loads.
- Compare to the RCC less self weight, which results in reduced dead load, which also has a beneficial effect upon the columns and foundations

- Reduces the overall height of buildings or enables additional floors to be incorporated in buildings of a given height.

2.2 Major problems in flat slab

- Slab column connection does not possess the rigidity of the beam column joint.
- Shear concentration around column is very high due to the possibility of the column punching through the slab.
- Deflections tend to be very large due to lesser depth of slab.

3. Methods of Analysis of Flat Slab

Behavior of two-way slab system under gravity and lateral loads is complex. In the case of beam supported two way slabs, 100% of gravity loads on the slabs are transmitted to the supporting columns in both longitudinal at transverses directions. The mechanism of load transfer from slab to columns is achieved by flexure, shear & torsion in various elements. The slab beam columns system behaves integrally as a three dimensional system, with the involvement of all the floors of the building, to resist not only gravity loads, but also lateral loads. However a rigorous three dimensional analysis of the structure is complex, & not warranted except in very exceptional structures. Unlike the planer frames, in which beam moments are transferred directly to columns, slab moments are transferred indirectly, due to tensional flexibility of the slab. Also slab moments from gravity can leak from loaded to unloaded spans; this must be accounted for, in the analysis.

Presently, the Indian Standard Codes provide the guidelines for design of flat slabs. These are basically empirical and are supported by the vast experimentation. But since the standard experimentation has been done on standard layouts and configuration of the slabs; these design procedures are limited in their scope and applicability. Nowadays, irregular layouts are becoming common, and it is in this light that standard codal procedures seem Inadequate.

Code Definition of Flat Slabs

"The term flat slab means a reinforced concrete slab with or without drops, supported generally without beams, by columns with or without flared heads. A flat slab may be solid slab or may have recesses formed on the soffit so that a soffit comprises a series of ribs in two directions. The recess may be formed of permanent or removable filler blocks.

A flat slab is reinforced concrete flat slab reinforced in two or more directions to bring the load acting normal to its plane directly to supporting columns without the help of any beam or girder." The above definition is very broad and encompasses the various possible column supported two-way slabs mentioned earlier. As mentioned earlier the code procedure is based on the elastic analysis of equivalent frames under the gravity loads and follows closely the 1997 version of the ACI code. However unlike the unified code procedure, there is no elaboration in the I.S code for the particular case of two way slab with beams along column lines.

Design Philosophy

There are three methods of analysis of flat slabs viz.
1 Direct Design Method (DDM)
2 Equivalent Frame Method (EFM)
3 Finite Element Method (FEM)

Out of this, first 2 methods are recommended by the I.S. code for determining the bending moments in the slab panel (approximate methods); either method is acceptable (provided the relevant conditions are satisfied).These methods are applicable only to two way rectangular slabs (not one way slabs), and in the case of direct design method the recommendations apply to the gravity loading condition alone (and not to the lateral load condition).

Finite Element Method

The structures having irregular types of plans with which the EFM has limitations in analysis can be analyzed without any difficulties by the FEM. FEM is a powerful tool used in the analysis of flat slabs. Most finite element programs are based on elastic moment distribution and material that obey Hooke's Law. This works for steel plates but reinforced concrete is an elasto-plastic material and ones it cracks its behavior is non linear. As a consequence the support moments tend to be overestimated and the deflection of the slab is under estimated. Currently, one of the main criticisms of the FEM analysis is its reliance on the elastic solutions that result in high peaked support moments over the column. These support moments are unlikely to be realized under service loads due to cracking and thus the service span moments will be correspondingly increased. While using finite element method following considerations are important.
1)Choice of a proper finite element.
2)Degree of disceretisation
3)Overall computational economy.

Hence various finite element models are possible for the same problem. A model which can take into account all the important structural effects at the least computational cost is called as the best model.

Dynamic Analysis
1. Coefficient Method
2. Response Spectrum method
3. Time History Method

4. Conclusion

Flat slab 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. This paper gives information about major issues associated with the flat slab and different method for analysis of flat slab use to confirm the behavior of flat slab.

References

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