Study on Economical Aspects of Long Span Slabs

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Abstract—Economical aspects of long span slabs between flat slab and grid slab is presented here. The objective function is to come on the proper method of selecting the slab forms on variable span. The flat slab is modeled and analyzed using the direct design method and grid slab is modeled and analyzed using plate theory method. The costing is calculated in three stages, which contain quantity of steel, volume of concrete to be used in slabs & beams and the cost of form work. By adding all these parameters, cost of slabs per square meter is determined.

Keywords—Flat slab, grid slab, economical, comparison, long span

I. INTRODUCTION

A slab is a flat, two dimensional, planar structural element having thickness small compared to its other two dimensions. It provides a working flat surface or a covering shelter in buildings. It supports mainly transverse loads and transfers then to support primarily by bending element just like beam.

A reinforced concrete flat slab is one of the type which is used for long span, it is also called as beamless slab, is a slab supported directly by columns without intermediate beams or wall supports. Flat slab is a type of reinforced concrete construction that transmits the floor or roof load directly on columns without the aid of supporting beams. The flat slab is often thickened close to the supporting columns to provide adequate strength in shear and to reduce the amount of negative reinforcement in the support regions. Columns are flared at top to provide structure economical the portions of the slab near the columns are thickened. In some cases, the section of the column at the top as it meets the floor slab or a drop panel, is enlarged so as to increase, primarily the perimeter of critical section for shear and hence, increasing the capacity of the slab for resisting punching shear and to reduce negative bending moment at the support. Such enlarged or flared portion of Column at their tops are called the column head or the column capital. Flat slabs, now very common in the world, are originally an American development. The first patent for a recognizable reinforced concrete slab was given to C.A.P. Turner in year 1903, flat slab construction were described as “Mush rooms”.

Grids or coffered floor systems consisting of beams spaced at regular intervals in perpendicular directions, monolithic with a slab are generally employed for architectural reasons for large rooms such as auditoriums, vestibules, theatre halls, show rooms of shop where column free space is often the requirement.

The rectangular or square voids formed in the ceiling are advantageously utilized for concealed lighting. The size of the beams running in perpendicular directions is generally kept the same. Instead of rectangular beam grid, a diagonal grid can also be used with the beams inclined at 45° to the sides.

II. FLAT SLAB

A. Behaviour of Flat Slab

Two way slab, flat plates and flat slabs are very identical in their behavior. It is observed that maximum shear force and bending moment will be induced very near to the column face. To calculate the shear force and bending moment the slab is considered panel wise and to locate the points of negative and positive moments the slab is divided into column strips and middle strips.

The strips along the column lines are considered to act as a beam and are designed as a column strips. Deflection of these strips at column is zero and that at mid span is maximum as shown in fig 1.

The column strips behave as a continuous beam supported on column and deflects as shown in figure. The deflections at column supports A, B, C, and D are zero and maximum at mid – span E, F, G and H. The middle strip also behaves as a continuous beam supported on column strip and deflects as shown in figure. The deflection are minimum at the supports E, F, G and H of middle strips provided by column strips and maximum at mid span I. Thus point A, B, C, and D will have zero deflection and point I will have maximum deflection points E, F, G and H shall have intermediate value of deflection. The deflected flat slab at the centre of the panel shall have a saucer shape and shape around the column shall be convex upward. Hence there will be a point of inflection on such deflection profiles that pass through the column. The locus of point of inflection has been shown by dotted curves in the figure. The column strip AHD will have negative moment at point A and D and positive moment at H. The middle strip EIG will have negative moment at point E and G and positive moment at point I. As the middle strip are supported by the loads are transferred from the middle strip to the column strip which in turn transfer the loads on the columns. Thus the
column strips are more heavily loaded than the middle strips resulting in a higher value of moments in the column strips than that in the middle strip. The transfer of load from slab to column causes excessive shear stress in the slab adjacent to the column as shown in fig below. This causes initiation of shear cracks at a distance of effective depth of the slab from the face of the column. These cracks propagate towards the top. The failure occurs at the bottom compressed edge of the slab surrounding the column through punching.

In the worksheet yellow color blocks denotes the data to be supplied and green color blocks denotes the results through calculations.

Input data at the starting of the excel worksheet are as under

1. Live load \( (kN/m^2) \)
2. Dead load \( (kN/m^2) \)
3. Floor finish \( (kN/m^2) \)
4. Panel size in X and Y direction \( (m) \)
5. Grade of concrete \( (N/mm^2) \)
6. Grade of steel \( (N/mm^2) \)
7. Length of column \( (m) \)
8. Cover \( (mm) \)

B. Direct design method

It is simple and easy method of obtaining the moments in two way continuous slabs. The development of this method is based on the test results available for two way slabs and flat slabs. To ensure the two way slab behavior it is necessary to impose limitations. If the limitations are prescribed below are not satisfied then alternative solution is use

C. Limitations of Direct Design Method

- There shall be minimum of three continuous spans in each direction.
- The panels shall be rectangular, and the ratio of the longer span to the shorter span within a panel shall not be greater than 2.0
- It shall be permissible to offset columns to a maximum of 10% of the span in the direction of the offset notwithstanding the provision in above.
- The successive span lengths in each direction shall not differ by more than one – third of the longer span. The end spans may be shorter but not longer than the internal spans.
- The design live load shall not exceed three times the design dead load.

D. Atomization of Design

For the analysis and design procedure excel worksheet are prepared. In this work sheet only certain essential data are to be supplied and all the calculations are done on its own.

<table>
<thead>
<tr>
<th>Flat slab</th>
<th>Panels</th>
<th>Total cost of 9 panels</th>
<th>Unit cost/m²</th>
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<tr>
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</table>

TABLE I. COST OF FLAT SLAB PER M²

III. GRID SLAB

A. Analysis of Grid Floors

Analysis of grid floors can be carried out by three different methods which are

- Approximate methods
- Plate theory method
- Stiffness matrix method using computer

In present work the analysis and design of grid slab is carried by plate theory method. Different span slab form are selected and designed for span ranging from 5 to 13 meters. Total 5 slab forms are designed with span 5X5, 7x7, 9x9, 11x11, and 13x13 m

B. Atomization of Design.

For the analysis and design procedure excel worksheet are prepared. In this work sheet only certain essential data are to be supplied and all the calculations are done on its own.

In the worksheet red colour text denotes the data to be supplied and blue colour text denotes the results through calculations.

Input data at the starting of the excel worksheet are as under

1. Length of beam Lx, Ly (m)
2. Number of beams Nx, Ny (No’s)
3. Spacing of ribs (m)
4. Depth of beam (mm)
5. Width of beam (mm)
6. Width of flange (mm)
7. Grade of concrete and steel (N/mm$^2$)
8. Dead load (kN/m$^2$)
9. Live load (kN/m$^2$)
10. Floor finish (kN/m$^2$)

From the above supplied data we will get the total dead load of slab, beams in X and Y direction from this load per square meter is calculated. The following are the output parameters which are obtained using developed excel sheet.

1. Moment of inertia (mm$^4$)
2. Flexural rigidity of ribs
3. Modulus of shear (kN/m$^2$)
4. Torsional constants (cu-m)
5. Torsional rigidity
6. Central deflection check (mm)
7. Long term deflection (mm)
8. Span/deflection (mm)
9. Maximum bending moments (kN.m)
10. Maximum torsional moments (kN.m)
11. Shear forces (kN)

The design of slab is carried out to satisfy strength and serviceability criteria. The quantity assessment is carried out for designed slab and rate analysis is performed. Cost in terms of per meter$^2$ are derived of various slab forms for span ranging from 5 to 13 m as per table 2

<table>
<thead>
<tr>
<th>Panels</th>
<th>Total cost of 9 panels</th>
<th>Unit cost/m$^2$</th>
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IV. CONCLUSIONS

From the graph of costing, it can be concluded that

1. In flat slab as the span range increases, there is steady increase in the unit cost.
2. In grid slab as the span range increases, the increase in the unit cost is not significant.
3. Flat slab with smaller spans are proved to be economical but as the span range increases the grid slab becomes economical.
4. Thus Grid slab is proved to be more economical for long span slab in comparison to Flat slab

REFERENCES


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