Analysis Of Grid Floor And Its Parametric Study

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Abstract- *The main concern of this 21st century's architects & designers is the utility of free column space for big halls, auditorium & theaters for live shows in T.V. programs, shopping malls & vehicle parking area. Recent market demands large column free space with good aesthetics with beautiful lightening with better illumination & good acoustics for assembling in various occasions, as compared to conventional structural arrangement like beam-column or flat slab construction obstructing clear views of the object.*

The Grid floor system consists of beams spaced at regular interval in perpendicular / orthogonal directions with monolithic slab construction. The present work is a small contribution towards the economical arrangement by varying the effect of grid size with simply supported case, a central column & multiple column arrangement with consequent effect on the stress parameters such as bending moment, twisting moment, shear force & deflection at critical points in the grid floors. The analysis is done by using the plate theory as given in S.P. Timoshenko and Krieger textbook by considering an isotropic plate freely supported by four sides.The project incorporates the manual methods for the analysis however the exact method of analysis is stiffness matrix method with readymade computer programs but the point to point values of stress parameters and graphical representation of deflection is done more efficiently by manual method as compared to computer based analysis .

I. INTRODUCTION

Grid floor is the system in which beams are spaced at closed intervals ,monolithic with a slab. They are generally used where large column free space like auditorium , vestibules, theatre halls, showrooms, banquet halls is the main requirement.

GRID SLAB

The floor construction of a dwelling must fulfill several norms & the following design function must be taken into consideration-

1. The provision of a uniform level surface.
2. Sufficient strength and stability.
3. Thermal inclusion.
4. Resistance to fire.
5. Good aesthetics and environment.

Advantage of grid floor-

1. Grids are efficient in transferring concentrated loads as the whole structure participates in load transfer process.
2. Reduces the depth to span ratio of the rectangular grids.
3. Reduction in weight of structure and quantity of materials.
4. It fulfills the above said design functions.

Applications of grid slab-

1. Grid Floor slabs are built or constructed whenever large column free space is required.
2. Grid slabs are light in weight due to this it can carry heavy loads at longer span and may be designed with post tensioning and offer better seismic resistance to the supporting structure.
3. These slabs are often used for architectural purpose such as public assembly halls, auditorium halls, cinema theaters, airports etc.
4. Grid slab possesses strong crack and sagging resistance as well as can bear a large amount of load compared with other conventional slabs so this feature is important for employing this technology.

II. METHODOLOGY

In this study we have taken a live example of Gurudwara assembly hall of Pondicherry (floor plan) of size 17.7m×17.7mfor which grid floor analysis by **Rankine - Grashoff Method** and **Plate Theory** is done for Jabalpur city. The grid that we have used is two way grid . After doing analysis by approximate method and plate theory method based on other research papers**PlateCross Stiffened** case given by ***S.P.Timoshenko and S.Woinowsky-Krieger*** is considered for analysis giving bit changed values as compared to above mentioned two conventional methods.

III.METHODS OF ANALYSIS

(a) **Approximate methods (Rankine Grashoff theory)-** For small span grids with spacing of ribs not exceeding 1.5 meters, approximate methods can be used, but for grids of larger spans with spacing of ribs exceeding 1.5m, a rigorous analysis based on orthotropic plate theory is generally used.

Let q= Total load per unit area

q_1 and q_2= Total loads shared in x and y directions

a= Shorter dimension of grid b= Longer dimension of grid

Load Intensity –

In x-direction(q_1)= $q\times\left(\frac{b_y{}^4}{a_x{}^4+b_y{}^4}\right)$ In y-direction (q_2)= $q\times\left(\frac{a_x{}^4}{a_x{}^4+b_y{}^4}\right)$

Moments-

In x direction $M_X=\frac{q_1 b_1 a^2}{8}$ In y direction $M_Y=\frac{q_2 a_1 b^2}{8}$

Shear Force calculation-

In x direction $Q_X=\frac{q_1 b_1 a}{2}$ In y direction $Qy=\frac{q_2 a_1 b}{2}$

(b) Rigorous analysis (Timoshenko plate Theory)-The most popular one given by S.P. Timoshenko and Krieger . They have shown that the moments and shears in an anisotropic plate, freely supported on four sides, depends on the deflection surface. The effect of transverse contraction is neglected and twisting of slab is considered. This method is better than Rankine Grashoff method. The vertical deflection at any point of a symmetrical grid is given by

$$a=\frac{16q}{®^6}\left[\frac{\sin\left(\frac{®\,x}{a_x}\right)\sin\left(\frac{®\,y}{b_y}\right)}{\frac{D_x}{a_x^4}+\frac{2H}{a_x^2b_y^2}+\frac{D_y}{b_y^4}}\right]$$

$$D_X=\frac{EI}{b_1}\ D_y=\frac{EI}{a_1}$$

$$C_x=\frac{GC_1}{b_1}\ C_y=\frac{GC_2}{a_1}$$ Where, $$G=\frac{E}{2(1+«)}$$

$$C_1=C_2=\left(1-0.63\frac{x}{y}\right)\frac{x^3y}{3}$$

Design moments and Shear force using Plate Theory

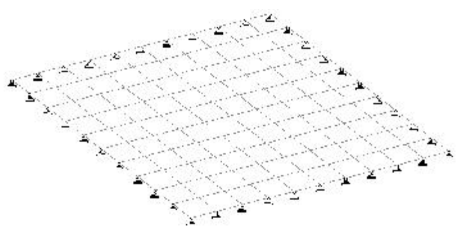
$$M_Y=-D_y\left(\frac{\partial^2 a}{\partial x^2}\right)\ M_x=-D_x\left(\frac{\partial^2 a}{\partial x^2}\right)$$

$$T_{xy}=-\frac{C_1}{b_1}\left(\frac{\partial^2 a}{\partial x\partial y}\right)\ T_{yx}=-\frac{C_2}{a_1}\left(\frac{\partial^2 a}{\partial x\partial y}\right)$$

$$Q_x=-\frac{\partial}{\partial x}\left[D_x\left(\frac{\partial^2 a}{\partial x^2}\right)+\frac{C_2}{a_1}\left(\frac{\partial^2 a}{\partial x\partial y}\right)\right]$$

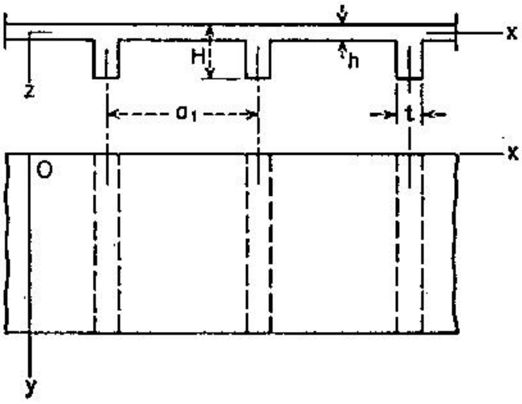
$$Q_y=-\frac{\partial}{\partial y}\left[D_y\left(\frac{\partial^2 a}{\partial y^2}\right)+\frac{C_1}{b_1}\left(\frac{\partial^2 a}{\partial x\partial y}\right)\right]$$

(c) Stiffness Method-This method is based on matrix formulation of the stiffness of the structure and gives closed form solution. By using this method the analysis can be done by considering rigid supports as well. Various application software are available to carry out analysis by this method.



Typical Grid floor considered in stiffness method

After analyzing the grid floor by these three methods one another case **Plate cross-stiffened bytwo sets of equidistant stiffeners**case is considered which provides some modified formulae for flexural rigidity and H.The calculated modified values are used to calculate various stress parameters which gives modified values of stress parameters which give more values than the values calculated by using plate theory formulae because of restricted torsional moment.



$$D_x = \frac{Eh^3}{12(1-\nu^2)} + \frac{E' I_1}{b_1}$$

$$D_y = \frac{Eh^3}{12(1-\nu^2)} + \frac{E' I_2}{a_1} \quad where, E' = \frac{E}{1-\nu^2}$$

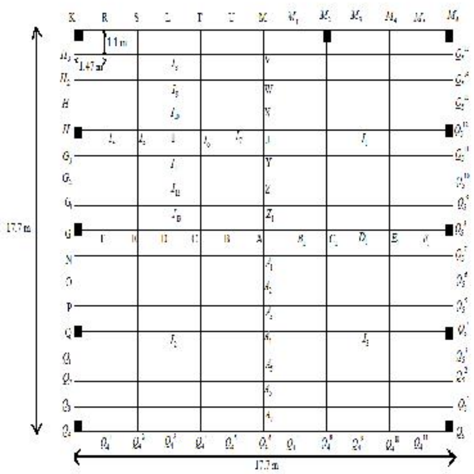
$$H = \frac{Eh^3}{12(1-\nu^2)}$$

In this study basically three grid sizes are taken for the comparative analysis they are-

(1)1.47m×1.47m (2)1.47m×1.1m (3)1.47m×0.885m

Along with these grid size variation column positions have also been changed to know the variation of stress parameters and its behavior. The three column conditions are-

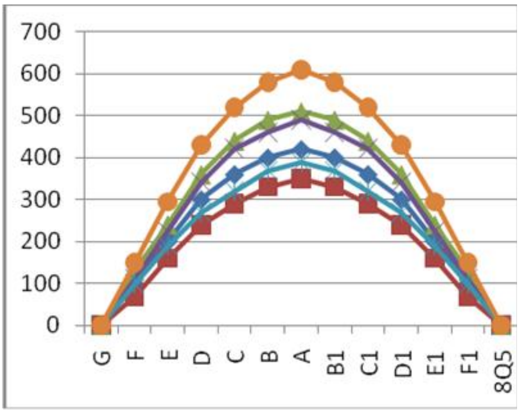
(1)Simply Supported Case (2)Central Column Case(3)Multiple Column Case



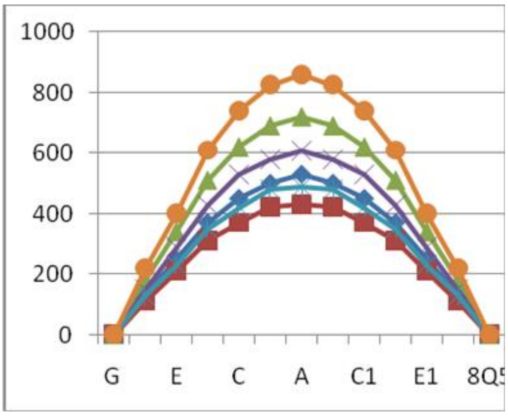
IV. RESULTS AND DISCUSSION

The results of the analysis carried by Rankin-Grashoff method, Plate theory & cross-stiffened case is presented below through representative graphs using excel worksheet.

M_x (in KN-m) distribution curve for top and bottom story from G to $^8Q_5$

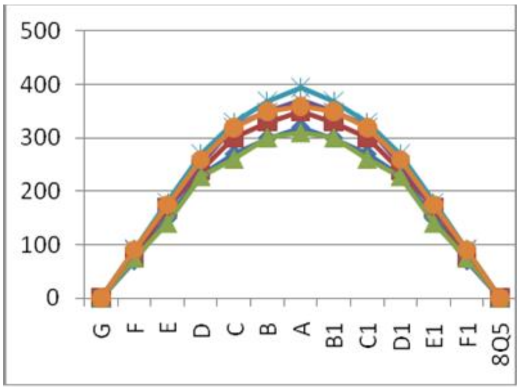


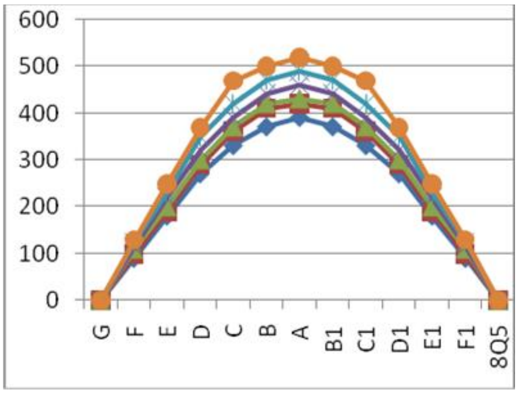
Top Story



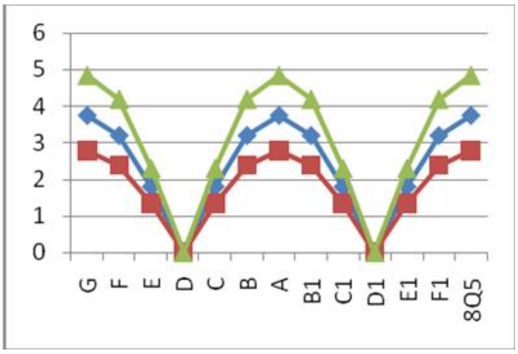
Bottom Story

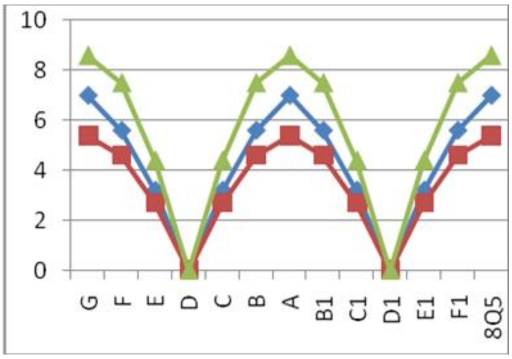
M_y (in KN-m) distribution curve from G to $^8Q_5$



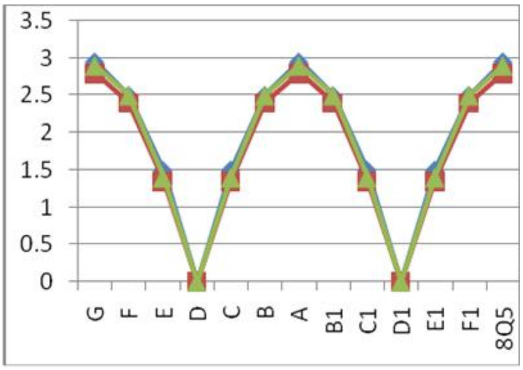


M_{xy} **(in KN-m) distribution curve from G to** $^{8}Q_{5}$

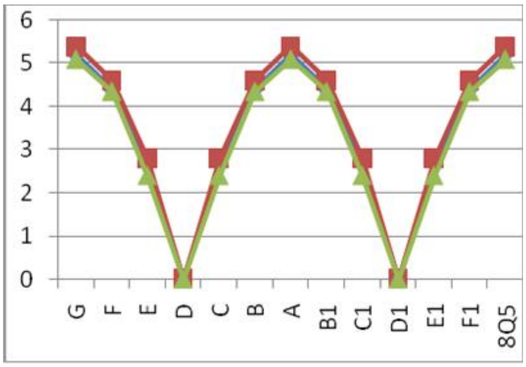




M_{yx} **(in KN-m) distribution curve from G to** $^{8}Q_{5}$

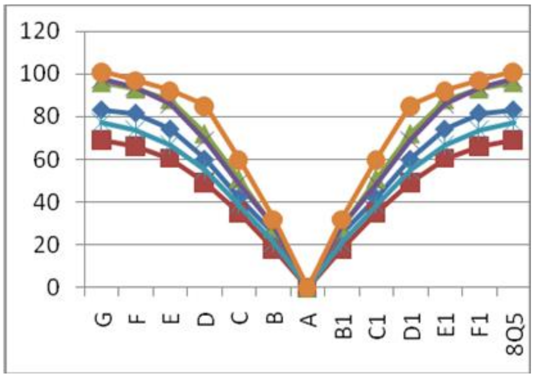


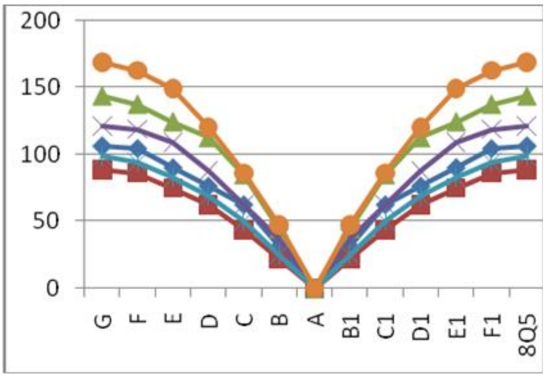
TOP Story



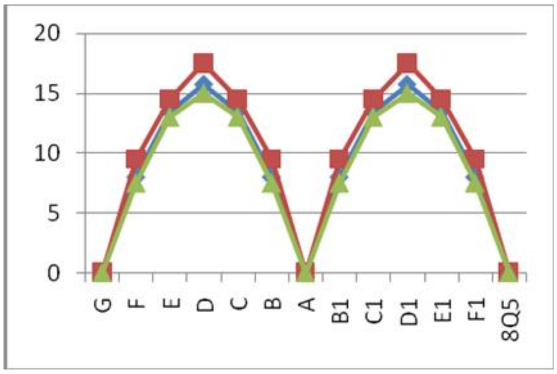
BOTTOM Story

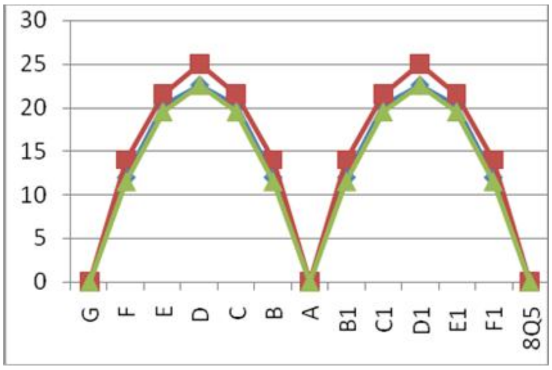
Q_x **(in KN) distribution curve from G to** $^{8}Q_{5}$



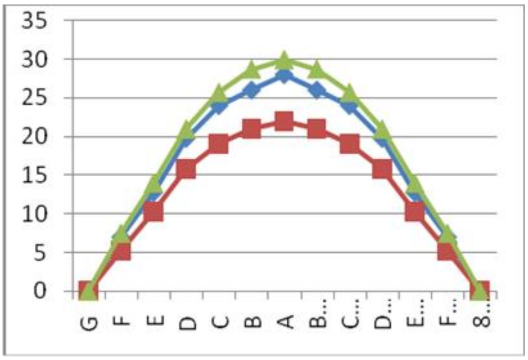


Q_y **(in KN) distribution curve from G to** $^{8}Q_{5}$

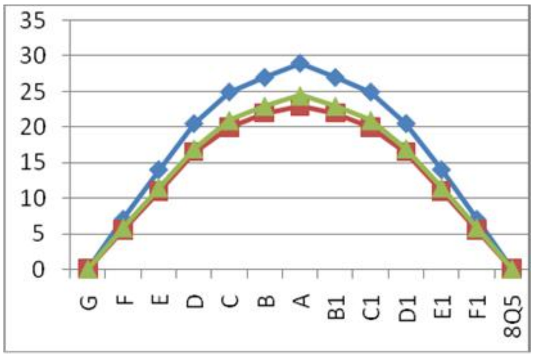




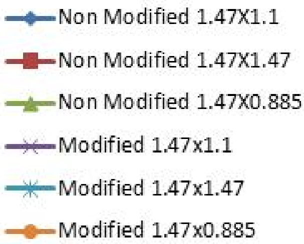
¢ (in mm) distribution curve from G to $^{8}Q_5$

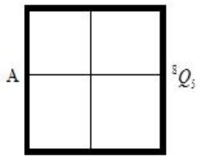


Top Story



Bottom Story





Grid plan of co-ordinates of mentioned graphs

Note:

- In central column case M_x , M_y &deflection is zero at all above mentioned points as these are end co-ordinates according to plate theory having plate size 8.85x8.85m considering simply supported.
- In simply supported case all the modified stress values calculated by taking cross stiffened case are greater than the values calculated by ordinary plate theory and in central column case there is very less difference between modified value & non-modified values (plate theory) .All above mentioned points are with respect to the grid plan of grid size 1.47x1.1m.

Point to point value-Let us take value of some of the co-ordinates with respect to grid size plan 1.47x0.885m of central column case (Top Story)

Points	Co-ordinates (m)	δ values (mm)
I_3	4.425, 8.85	0
D_{10}	4.425, 7.965	3.89
D_9	4.425, 7.08	7.3
D_8	4.425, 6.195	10.18
D_7	4.425, 5.31	11.94
D_6	4.425, 4.425	12.57

Now, calculating ¢ value for co-ordinate D_6 (4.425, 7.38) of grid **size 1.47x1.47m** by interpolation

$$3.89+\frac{(7.3-3.89)}{(7.08-7.965)}\times(7.38-7.965)=6.1$$ mm

By plate theory it's value is 6.02 mm

Similarly for D_5 (4.425, 5.91),=10.7 mm whereas by plate theory it's value is 10.15 mm

Now, calculating ¢ value for co-ordinate I_8 (4.425, 7.65) of grid **size 1.47x1.1m** by interpolation =4.71 mm whereas by plate theory it's value is 4.78 mm

Similarly for I_9(4.425, 6.65),

$$7.3+\frac{(10.18-7.3)}{(6.195-7.08)}\times(6.65-7.08)=8.69mm$$

By plate theory it's value is 8.66 mm.

From above calculation it is observed that point to point deflection at critical points with point to point value can be obtained by interpolation for other stories.

V. CONCLUSION

In this paper the analysis of grid floor is done and various parameters has been calculated. Along with analysis, grid size variation is done and its effect on all stress parameters is noticed. The conclusion is mentioned below:

1) Torsional moment cannot be obtained by Rankine-Grashoff method as it is an approximate method whereas can be found by using Plate theory. By using plate theory all stress parameters such as Q_x , Q_Y , M_x , M_y , M_{xy} , M_{yx} & ¢ can be obtained at each co-ordinates by using trigonometric ratios for simply supported, central column and multiple column case..

2) As the grid size is reduced, number of grids required to cover the plan is increased and all the stress parameter values are also increased. As in case of 1.47x0.885m grid case all parameters are having much higher values as compared to 1.47x1.1m, 1.47x1.47m.

3) A uniform distribution of moment, shear & lesser value of deflection in square size grid is observed which is similar to two-way slab.

4) The values calculated by considering plate crossed stiffened case gives higher values in simply supported case whereas in central and multiple column case it gives lesser values as compared to values calculated by Plate theory.

Scope for Future study

- To analyze the grid floor for multiple column case for grid sizes 1.47x1.1m and 1.47x0.885m.
- To compare the stress parameters by varying grid sizes in both x and y direction.
- Deflection distribution in both directions for different grid sizes.

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