Automated Analysis and Parametric Study of Grid Floors

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ABSTRACT: Grids floors are type of floors which are supported by the series of equally spaced beams with are arranged in a regular grid pattern. There are different methods available for analysis of grid floors namely Rankine-Grashoff's method, Plate Theory, Stiffness Matrix Method.

These methods are elaborate and time consuming to obtain the solution .The task of solving the problem manually is often tedious, unrewarding and the brain often gets tired and distracted. The probability of making mistakes increases. There was a need for developing a general purpose program which reduces the time required for solving the problem and produce results with high degree of accuracy.

In this paper a parametric study is conducted on different methods of analysis of grid slabs. A general purpose program has been developed in Visual Basic environment by combining the methodologies. The program was validated with results of standard software available for the intended purpose. The results obtained from the program are plotted for comparison and the conclusions are drawn.

The interactive program developed under Visual Basic environment helped in saving time. The alterations or changes can be made easily. The results obtained from the program were in good co-relation with one another and the objective of the study is achieved.

KEYWORDS: Grid floors, Rankine-Grashoff's method, Plate Theory, Stiffness Matrix Method, Visual Basic, Graphical User Interface.

I. INTRODUCTION

Grid floors are types of floors with a flat surface, resting on series of interconnected beams called grids. It can be of solid concrete, wood, steel or composite. A grid floor essentially gives a more structural stability and stiffness without utilising a great deal of extra material. This makes a grid floor ideal for supporting vast areas like establishments or floors. The top surface of a grid section is a smooth surface, similar to a conventional building surface, yet the underside has a shape reminiscent of a grid. Grid floors have additional advantage of incorporating skylights or ornamental lightings in between grids. They are generally adopted for architectural purpose. They are commonly provided in the structures such as theaters, tradition corridors, shopping centers where section free space is frequently the principle necessity.

II. RELATED WORK

1. Mohammed S. Al-Ansari (2006) [1] In his view point, the accentuation has been moved to the utilisation of the Math-CAD program in building up a superior comprehension of the examination and outline of two-way grid sections. Author discovered that the estimated investigation strategy does not take into consideration variety in grids profundity (stifness) and closed the mechanizing the procedure of configuration aides in decreasing time and human exertion and furthermore disposes of the human mistake in calculation
2. Anithu Dev et.al (2006) [2] In his paper some of these methods for design of grid slabs are studied namely Rankine's Grashoff's method, Timoshenko's plate theory and stiffness method and contrasted and each other. The analysis is done on the premise of deflection, bending parameters, for example, twisting moments, shear force acquired from different strategies. Comes about demonstrated that Rankine - Grashoff strategy overestimates critical flexural moment and shear constrain. Scientific aftereffects of plate hypothesis are in great concurrence with that of ETAB.
3. Indrajit Chowdhury et.al (2014) [6] His paper proposes a semi expository strategy for the investigation of grid slab with any discretionary limit conditions settled, free and simple support. To validate the results, selected cases are compared with finite element analysis. Displacement and moment profile by the proposed method were plotted in MATHCAD software and then compared with the same profile obtained from FEM analysis. FEM results were lower bound by about 12% with respect to Timoshenko's value for simply supported.
4. Muhammed Yoosaf.K.T et.al (2013) [4] His study deals with the affect of various parameters on the economical spacing of transverse beams in grid floor. The parameters considered in this study are span to depth ratio, spacing of transverse beams, thickness of web and thickness of flange. The parametric study is carried out using the model proposed by ANSYS

12.0 software. The results of the study give an insight to the range for the magnitude of the various parameters to be considered for the optimum performance of grid floors.

III. OBJECTIVES AND METHODOLOGY

- Different methods for the design of grid floors are studied, namely Rankine's Grashoff's method, Timoshenko's plate theory and stiffness method.
- All the above methods are automated under Visual Basic environment.
- To analyse 12x18 grid floor using Rankine's Grashoff's method, Timoshenko's plate theory and stiffness method by the GUI program developed under Visual Basic environment
- To Checking the validity of the results obtained from program by comparing it with the STAAD.Pro software.
- The parametric study is conducted on the parameters such as bending moments, shear forces and deflection obtained from various methods.
- Discussions will be held on the results and conclusions will be drawn.

IV. OVERVIEW OF THE METHODS FOR DESIGN OF GRID FLOORS

Rankine-Grashoff Theory

The deflections of the central grid at the intersection considered as same by comparing the deflections, the flexural moments in alternate grid can likewise be resolved with the immediate extent to their separations from the inside. The ribs are analysed as flanged segments to oppose the moments and Shears.

In this method of two way slab central strip of the section EE and GH Fig 5.3 are acknowledged to share the load degree that the deflection or redirection of the two strips at the midpoint P is the same. In like manner, if q_1 is the load constrain on strip EF and q_2 on GH strip, then,

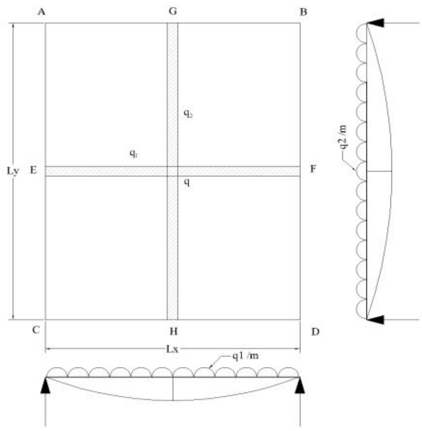


Fig 5.3: typical grid slab

$q_1 + q_2$

Considering deflection at point q we get,

$\frac{5}{384}\frac{q_1\, l_x^4}{EI} = \frac{5}{384}\frac{q_2\, l_y^4}{EI}$

$q_1 = q_2\,\frac{l_y^4}{l_x^4}$

$q_1 = q_2\, r^4$

$\frac{l_y}{l_x} = r$

$q_2\,(r^4 + 1) = q$

$q_2 = \frac{q}{1+r^4}$

$q_1 = \frac{q\, r^4}{1+r^4}$

The maximum bending moments are

$M_x = \frac{q_1\, l_x^2}{8}$

$M_y = \frac{q_1\, l_y^2}{8}$

Plate Theory

This is a rigorous strategy for examination. This depends on Timoshenko's investigation of orthotropic plate hypothesis considering plane stress examination. A reinforced solid grid floor with grids at close spacing in two commonly opposite bearings associated by grid slab in the middle of the ribs can be considered as an orthotropic plate unreservedly supported on four sides. The vertical deflection a at any point in atypical grid is expressed as

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

q=total uniformly distributed load per unit area.
E_c= elastic modulus of concrete
$E_c I_1$ and $E_c I_2$= flexural rigidity of the section.
C_1 and C_2= torsional rigidity of the section.
a_x and b_y= length of plates in x ate y direction respectively.
D_x and D_y= flexural rigidity per unit length of plates in x and y direction respectively.
C_x and C_y= torsional rigidity per unit length of plates in x and y direction respectively.
$2H= C_x+ C_y$
If a1 and b1 are the spacing of ribs in x and y directions respectively then we have the relations
$D_x= (E_c I_1/b_1)$, $C_x = (C_1/b_1)$
$D_y= (E_c I_2/a_1)$, $C_x = (C_1/b_1)$
The bending moments M_x and M_y, torsional moments T_{xy} and T_{yx} and shear force Q_x and Q_y are computed using the following equations.

$$Mx=- D_x\left(\frac{d^2a}{dx^2}\right)$$

$$My=- D_y\left(\frac{d^2a}{dy^2}\right)$$

$$T_{xy} =-\frac{C_1}{b_1}\left(\frac{d^2a}{dx\ dy}\right)$$

$$T_{yx}=-\frac{C_2}{a_1}\left(\frac{d^2a}{dx\ dy}\right)$$

$$Q_x= -\left(\frac{d}{dx}\right)\left[D_x\left(\frac{d^2a}{dx^2}\right)+C_y\left(\frac{d^2a}{dy^2}\right)\right]$$

$$Q_y= -\left(\frac{d}{dx}\right)\left[D_y\left(\frac{d^2a}{dy^2}\right)+C_x\left(\frac{d^2a}{dx^2}\right)\right]$$

Stiffness Matrix Method
Stiffness method or displacement method is an important approach to the analysis of structures .This is an important approach to the analysis of structures. This is used in its basic form for the analysis of structures that are linear and elastic although it can be adapted to non linear analysis. It is generally used for the analysis of statically determinate cases. This method in its basic form considers the nodal displacements of the structures as unknown.

V. PROBLEM DEFINITION

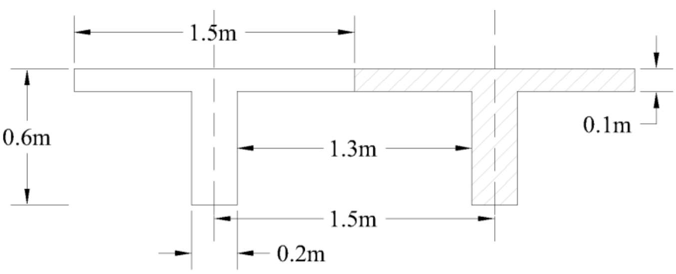
A reinforced concrete grid roof supported on wall has to be designed to cover an area 12m x18m the spacing of the ribs in mutually perpendicular directions being 1.5 m c/c. the slab has to support a imposed load 2 kN/m^2 of 0.6 kN/m^2 . Using M 20 concrete and Fe 415 HYSD bars.

Input Data

L_x= 12m
L_y = 18m
S_x = 1.5m
S_y= 1.5m
Imposed load= 2.0 kN/m^2
Floor finish =0.6 kN/m^2
Cover = 0.05m.

Dimension of Slab and Beams

Adopt thickness of slab = 0.1m
Depth of ribs based on = $\frac{span}{depth}$ = 20
Depth= $\frac{12}{20}$ = 0.6 m
Width of the rib =0.2m
Over all Depth of the rib 0.6 m
D= 0.6 m
D_f = 0.6-0.1=0.5m
b_w= 0.2m. , bf = 1.5m.



VI. RESULTS AND DISCUSSIONS

The following are the results obtained from the various methods used for the analysis of grid slab, which are automated in Visual Basic software. The values are considered from the beams at the midspan along the width of grid slab having maximum values. Results obtained are tabulated and plotted in the form of graph.

Length	Rankine Grashoff's	Plate Theory	Stiffness Matrix	STAAD.Pro
X in m	Y Axis In Kn-m			
0	0	0	0	0
1.5	80.993	58.373	88.845	88.8
3	138.84	107.86	145.27	145.19
4.5	173.55	140.927	178.25	178.12
6	185.31	152.54	188.54	188.41
7.5	173.55	140.927	178.25	178.12
9	138.84	107.86	145.27	145.19
10.5	80.993	58.373	88.845	88.8
12	0	0	0	0

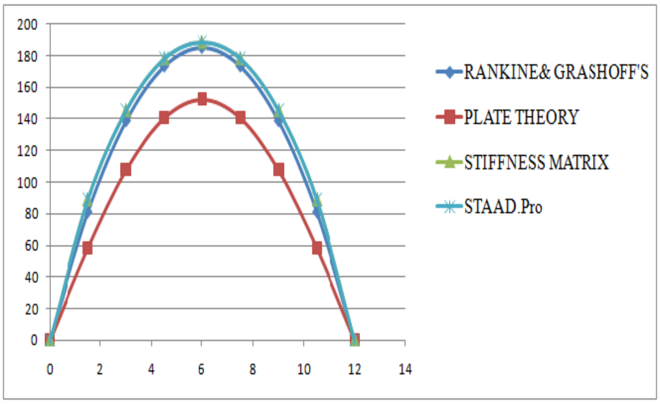


Fig 1: bending moment variation along the width of grid floor

- The bending moment values obtained varies in from of a parabola.
- The bending moment obtained by Rankine and Grashoff's methods shows a good harmony with the results obtained by Stiffness matrix method
- Values obtained from the Plate Theory deviates from the other results obtained from other results
- Results obtained from the Stiffness matrix method are consistent with the STAAD.Pro values. It also proves that developed program is valid.

Length	Rankine& Grashoff's	Plate Theory	Stiffness Matrix	STAAD.Pro
X in m	Y axis in mm			
0	0	0	0	0
1.5	12.118	8.5	12.05	12.22
3	20.774	15.7	22.06	22.178
4.5	25.968	20.5	28.61	28.761
6	27.7	22.2	30.89	31.407
7.5	25.968	20.5	28.61	28.761
9	20.77	15.7	22.06	22.178
10.5	12.120	8.5	12.05	12.22
12	0	0	0	0

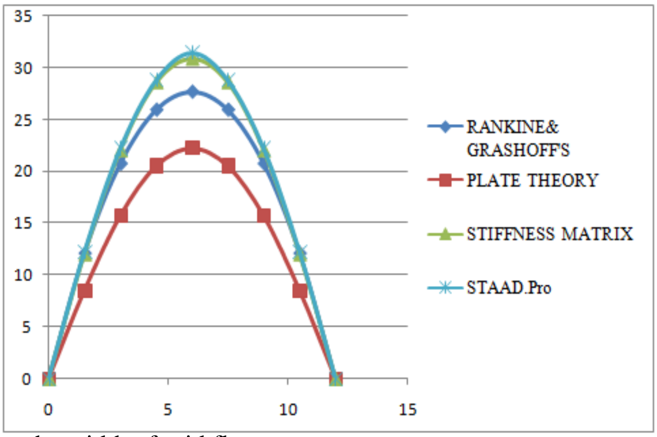


Fig 2: Deflection along the width of grid floor.

- The deflection values obtained varies in from of a parabola.
- The deflection obtained by Rankine and Grashoff's methods shows slightly lower value with the results obtained by Stiffness matrix method.
- Values obtained from the Plate Theory deviates from the other results obtained from other results
- Results obtained from the Stiffness matrix method are consistent with the STAAD.Pro values.

Length	Rankine& Grashoff's	Plate Theory	Stiffness Matrix	STAAD.Pro
X in m	Y Axis In Kn			
0	61.71	39.93	63.25	63.2
1.5	46.28	36.89	44.28	44.3
3	30.84	28.23	28.04	28
4.5	20.57	15.28	11.99	12.12
6	0	0	3.94	3.94
7.5	-20.57	-15.28	-11.99	-12.12
9	-30.84	-28.23	-28.04	-28
10.5	-46.28	-36.89	-44.28	-44.3
12	-61.71	-39.93	-65.28	-63.2

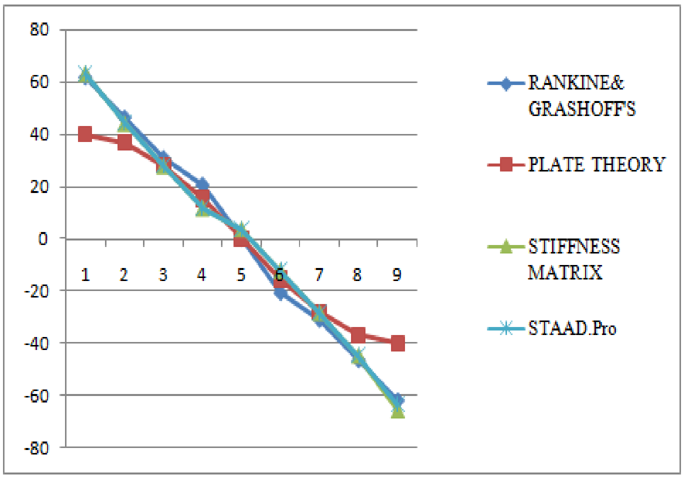


Fig 3: shear force along the width of grid floor.

- The Shear force values obtained varies in linearly thorough the supports.
- Shear force obtained in are in accordance with the values obtained.
- The Shear force obtained by Rankine and Grashoff's methods shows slightly lower value with the results obtained by Stiffness matrix method.
- Values obtained from the Plate Theory are significantly less when compared to other methods.
- Results obtained from the Stiffness matrix method are consistent with the STAAD.Pro values.

VII. CONCLUSION

- Rankine and Grashoff's method shows good co relation with the results obtained from stiffness matrix method and the STAAD.Pro.
- Plate theory underestimates the bending moment shear force values when compared to other methods.
- Stiffness matrix method shows a very good agreement with the values obtained from the STAAd.Pro.
- Rankine and Grashoff's method and plate theory can be only be used when the slab is simply supported on all sides
- Flexibility of the stiffness matrix method allows the user to change boundary condition, dimension of the beams.
- Composite grid floors and slab with sky lights or the voids can be easily modeled in stiffness matrix method
- Objective of the work has been achieved by the automation of the different numerical methods for the design of the grid floors.
- A productive general purpose program has been developed under visual basic environment.

APPENDIX –A

An interactive general purpose program is developed for the parametric study of grids. The task has been achieved by automating Rankine-Grashoff, Plate Theory and IS 456 method into a single window form and stiffness matrix method is automated under different form. Results are displayed in the form of tabs. Output of the form is made to store in a Notepad file. The figure below shows the from developed for the Parametric study of grid floors

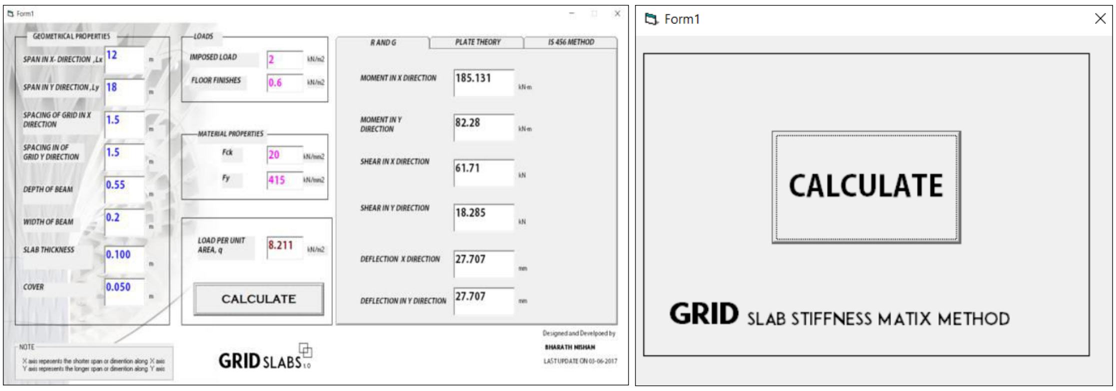


Fig A-1: Visual Basic form developed for parametric study on grid floor.

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