Evaluation of Quantity and Cost of Grid Slab

Prof. Supriya[1], D. Konda[2]
[1,2]*Department of civil Engineering, W.I.T. Solapur, India*

Abstract— **The floor resting on the beams which are running in two directions is known as Grid Floor. These types of floors are used to cover a large obstruction free area and therefore, are a good choice for public assembly halls. The Grid structure is monolithic in nature and is stiffer. It provides pleasing appearance and also has less maintenance cost. However,construction of the grid floor is cost prohibitive. By investigating various parameters involved, a cost effective solution can be found for the grid floor. The present work includes the parametric investigation in terms of flexural actions such as bending moments, shear force and deflection. Spacing of Grid beam and number of ribs are the parameters considered for investigation. For a selected hall dimension say (Lx x Ly) m there is a wide variation of number of ribs at regular intervals. To find out at what spacing of ribs and number of ribs provided in a grid floor gives minimum total cost including steel and concrete, this study is carried out. For this the grid is analyzed and designed by limit state method.**

Index Terms— **Grid floors, spacing of grid beams, number of ribs and size of beams.**

INTRODUCTION

An assembly of intersecting beams placed at regular interval and interconnected to a slab of nominal thickness is known as Grid floor or Waffle floor. In this type of floor, a mesh or grid of beams running in both the directions is the main structure, and the slab is of nominal thickness. These floors are used to cover a large column free area and they are generally employed for architectural reasons for large rooms such as auditoriums, vestibules, theatre halls, show rooms of shops where column free space is often the main requirement (N.Krishnaraju 2005).

One of the limitations of grid floors is the construction cost which is prohibitive. Some of the researchers have carried out the cost comparison between flat slab and grid slabs using the plate theory. On the basis of analysis and design carried out, they concluded that concrete required in grid slab is more as compared to flat slab with drop and flat slab without drop (Amit A. Sathawane et al 2012).

Study on economical aspects of long span slabs between flat slab and grid slabs. Thus, grid slab is found to be more economical for long span slab in comparison to flat slab. Analytical study on square waffle slab for medium size floor system is considered to achieve the optimum dimensions of rib spacing, i.e. depth and width (J. Prasad, et al, 2005).

The magnitude of span to depth ratio considered is 16 to 60. The spacing of transverse beams is varied from 0.5m to 2.0 m. Thickness of slab and the rib are made constant and are equal to 0.1m and 0.15m respectively. The parametric study is carried out using the model proposed by ANSYS 12.0 software.

Various technical research papers shows that, the cost of construction of grid floors depends on various parameters like span, spacing of grid beams, and size of the peripheral & grid beams, span to depth ratio etc.

The present work includes the effect of spacing of grid beams and number of ribs in a grid floor. For this stiffness method is used for analyzing various spacing of grid beams.

The aim of this study is to find analytically, for a hall size (L/B) with constant ratio, the effect of these design parameters on the grid floor, and on the overall economy of the structure. Grid floor of size 25m x 25m is designed for various parameters and the cost of grid is found.

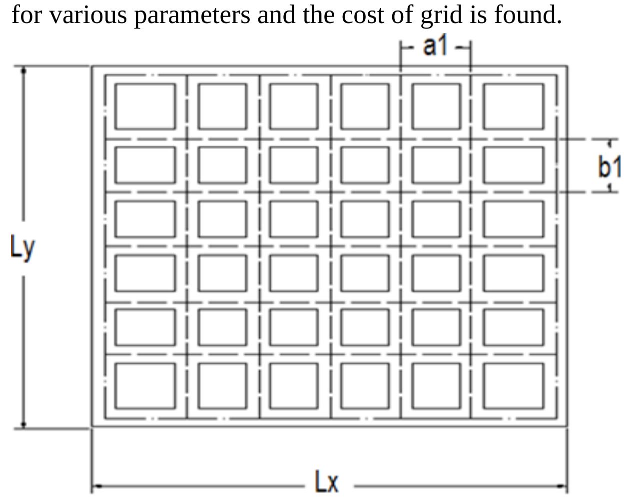


Figure shows a Grid Plan for the present study.

METHODS OF ANALYSIS

Grid is highly redundant structural system and therefore statically indeterminate. Various approaches available for the analysis of grid floor frame, are as listed below-
1) Analysis of grid by Rankine – Grashoff method
2) Analysis by plate theory
3) Stiffness method

1 Rankine – Grashoff Method

This is an approximate method. It is based on equating deflections in either direction at the junctions of ribs. This method is suitable for small span grids with the spacing of ribs not exceeding 1.50 m. In this method the slab is considered as simply supported on edges. This method computes moments and shear force per unit width of slab strip.

2 Plate Analogy Method

This is a rigorous method of analysis. This is based on Timoshenko's analysis of orthotropic plate theory considering plane stress analysis. As in Rankine-Grashoff method, in this method also the analysis is done by considering the grid simply supported on edges. Bending & torsion moments and shears are obtained per unit width of slab strip.

3 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's are available to carry out analysis by this method. In the present work while analyzing grid floor frame by stiffness method, the simple supports are considered at closer distance so as to simulate the support conditions similar to Rankine-Grashoff method and Plate theory.

Grid is highly redundant structural system and therefore, it is statically indeterminate. It is found that, the Stiffness method is most effective & accurate for analysis of Grid structures.

There are various applications and software's available, which can be used to carry out analysis by this method. The analysis of the grids for different parameters has been carried out and the results are presented in the excel sheet.

Aim of study:-

Grid slab is economical when the span is more than 8m. For a selected hall dimension say (25x25)m, there is a wide variation of number of ribs and spacing of ribs possible from (2.083 x 2.083) m to (5 x 5) m at regular intervals. To find out what spacing of ribs and number of ribs gives minimum total cost including steel and concrete, this study is carried out. For this the grid is analyzed using plate analogy method and designed by limit state method.

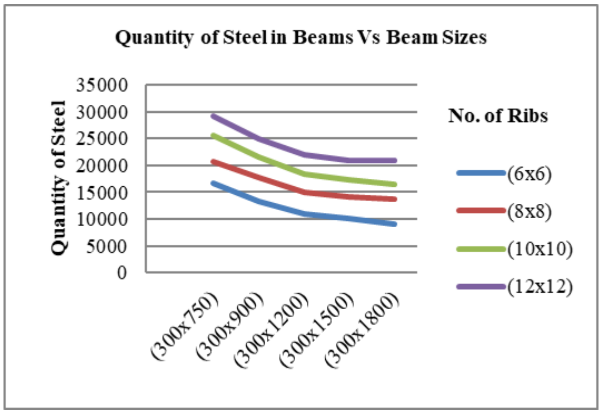
Parametric study:-

Different halls of dimensions (8x8)m, (10x10)m, (15x15)m, (18x18)m, (20x20)m, (25x25)m are selected. First a square grid is tried with centre to centre spacing of rib (0.8 x 0.8)m & increased to (4 x 4)m in the increment of approximately 0.4 to 1m. Keeping the spacing constant, three trial depths are taken. Grid floors of size (25 X 25) m is designed for various parameters of grid slab, spacing of ribs and number of ribs, different sizes of beam depths are taken to work out the quantity of steel and concrete. This investigation is done to work out the cost of steel and concrete from the quantities of steel and concrete available. Further from all the results, the total minimum cost of grid is found and of course the deflection is checked for every case. The cost of each slab is estimated and interaction curves are developed. From this study, it can be concluded that the cost of the grid floor would be minimum if thickness of slab is minimum, number of ribs are minimum and maximum spacing of ribs is maximum.

(ANNEXURE 1)

Table showing Quantity of Steel in Beam Vs Beam Size

	No. of Ribs			
Beam sizes	(6x6)	(8x8)	(10x10)	(12x12)
	Quantity of Steel(Kg)			
(300x750)	16754.30	20754.30	25592.56	29073.40
(300x900)	13310.40	17810.40	21590.20	24919.90
(300x1200)	10936.97	14936.97	18446.50	22044.50
(300x1500)	10001.98	14026.98	17307.20	20988.60
(300x1800)	9097.00	13617.70	16418.70	20961.10

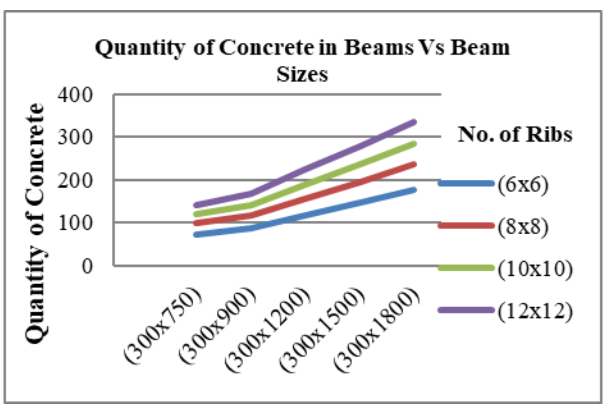


Graph showing Quantity of Steel in Beams Vs Beam Sizes

The above graph shows that, as the depth of the beam increases with the increase in the number of ribs, it is found that, the quantity of steel decreases with the increase in the beam depth. It is found to be minimum when the number of ribs are minimum and when the beam depth is maximum.

Table shows Quantity of concrete in Beam Vs Beam Sizes

	No. of Ribs			
Beam sizes	(6x6)	(8x8)	(10x10)	(12x12)
	Quantity of Concrete (m3)			
(300x750)	73.18	97.92	118.50	139.87
(300x900)	87.82	117.51	142.20	167.94
(300x1200)	117.11	156.69	189.61	223.81
(300x1500)	146.38	195.85	237.00	279.74
(300x1800)	175.67	235.04	284.42	335.70

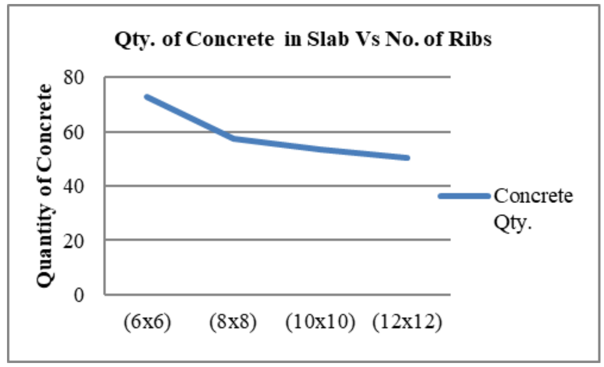


Graph showing Quantity of concrete in Beam Vs Beam Sizes

The above graph shows that, as the depth of the beam increases with the increase in the number of ribs, it is found that, the quantity of steel increases with the increase in the beam depth. It is found to be minimum when the number of ribs is minimum and when the beam depth is minimum.

Table shows Quantity of Concrete in slab Vs No. of ribs

Spacing of ribs(m)	No. of ribs	Quantity of Concrete(m3)
(2.083x2.083)	(6x6)	72.64
(2.5x2.5)	(8x8)	57.18
(3.15x3.15)	(10x10)	53.24
(4.166x4.166)	(12x12)	50.35

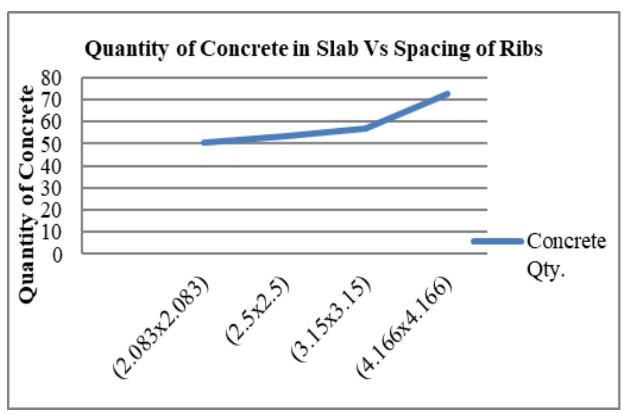


Graph showing Quantity of Concrete in slab Vs No. of ribs

The above graph shows that, as the spacing of the ribs increases with the increase in the number of ribs, it is found that, the quantity of concrete decreases with the increase in the spacing of the rib. It is found to be minimum when the number of ribs is maximum and spacing of ribs is maximum.

Table shows Quantity of Concrete in Slab Vs Rib spacing

Spacing of ribs(m)	Quantity of Concrete(m3)
(2.083x2.083)	50.35
(2.5x2.5)	53.24
(3.15x3.15)	57.18
(4.166x4.166)	72.64

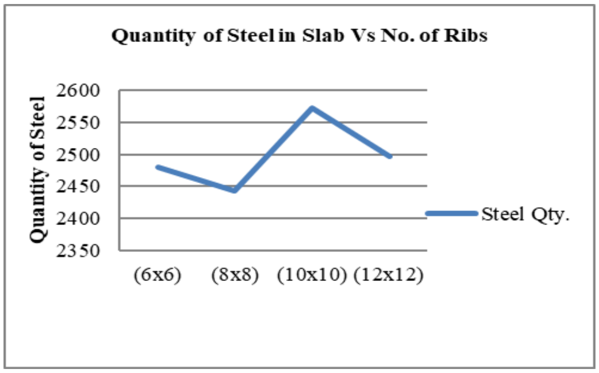


Graph showing Quantity of Concrete in Slab Vs Rib spacing

The above graph shows that, as the spacing of the ribs increases, it is found that, the quantity of concrete increases with the increase in the spacing of the ribs. It is found to be minimum when the spacing of the ribs is minimum.

Table shows Quantity of Steel in Slab Vs No. of Ribs

No. of ribs	Quantity of Steel(Kg)
(6x6)	2480.60
(8x8)	2442.17
(10x10)	2571.90
(12x12)	2496.32

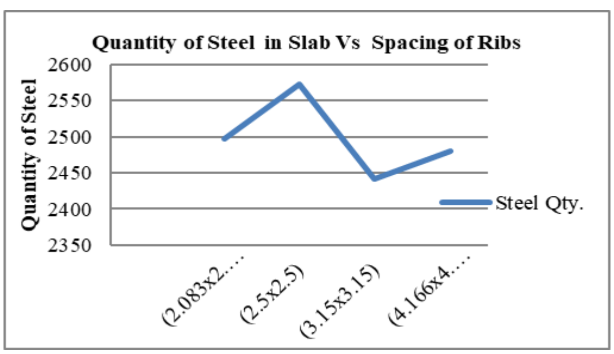


Graph showing Quantity of Steel in Slab Vs No. of Ribs

The above graph shows that, as the number of ribs are increasing, it is found that, the quantity of steel decreases with the increase in the number of ribs and then there is a increase in the quantity of steel as number of ribs are increased.

Table shows Quantity of Steel in Beam Vs Spacing of Ribs

Spacing of ribs(m)	Quantity of Steel(Kg)
(2.083x2.083)	2496.32
(2.5x2.5)	2571.90
(3.15x3.15)	2442.17
(4.166x4.166)	2480.60

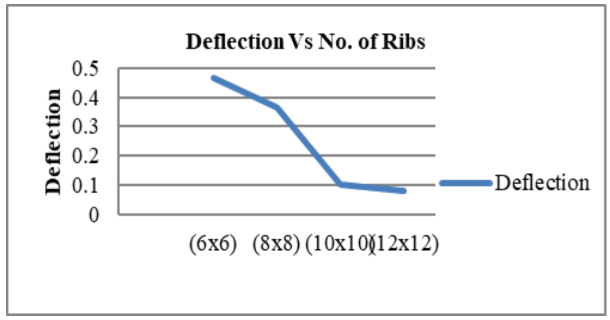


Graph showing Quantity of Steel in Beam Vs Spacing of Ribs

The above graph shows that, as the spacing of the ribs is increased, there is a increase in the quantity of steel for a particular spacing of the ribs and again there is a decrease in the quantity of steel with the increase in the spacing of ribs.

Table shows Number of ribs Vs Deflection

No. of ribs	Deflection
(6x6)	0.468
(8x8)	0.367
(10x10)	0.100
(12x12)	0.081

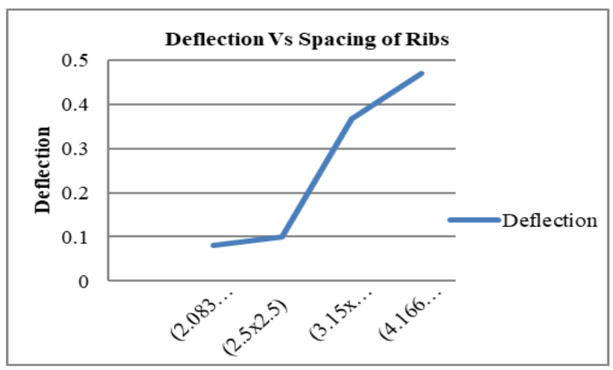


Graph showing Number of ribs Vs Deflection

The above graph shows that, as the number of ribs increases,it is found that, there is a decrease in the deflection.

Table shows Spacing of Ribs Vs Deflection

Spacing of ribs(m)	Deflection
(2.083x2.083)	0.081
(2.5x2.5)	0.100
(3.15x3.15)	0.367
(4.166x4.166)	0.468



Graph showing Spacing of Ribs Vs Deflection

The above graph shows that, as the spacing of the ribs increases, it is found that there is increase in the deflection.

DISCUSSIONS AND CONCLUSIONS

The quantity of the steel and the concrete is found for various sizes of the grid floor, slab thickness, number of ribs and rib spacing, and following are the results.

Variation of results:-

Cost of grid floor:-

1. It is found that, as the thickness of slab increases, total cost of concrete and steel decreases and hence total cost of grid floor decreases.
2. As the spacing of grid increases, total cost of concrete and steel decreases and hence total cost of grid floor decreases.
3. It is found that as the beam depth increases for a particular spacing, total cost of concrete increases whereas total cost of steel decreases as the beam depth increases and hence cost of grid floor increases.

As the spacing of the ribs increases it is found that-

1. The quantity of concrete in slab increases. For a smaller spacing of ribs, Quantity of steel in slab decreases for a slight increase in spacing of rib and again decreases for further increase in spacing of rib and then finally it is found that there is again increase in the steel quantity for larger spacing of rib.
1. Quantity of steel in beam decreases with increase in the spacing of rib and is found to be minimum for a greater spacing of rib.

As the number of the ribs increases it is found that-

1. Quantity of concrete in slab decreases.
2. On the other hand, the quantity of concrete in beam goes on increasing and is found to be minimum for greater spacing of ribs and minimum number of ribs.
3. For minimum number of ribs, the quantity of steel in slab is maximum and goes on decreasing when the number of ribs is increased and further if the number of ribs is increased, the quantity of steel increases and again decreases for further increase in number of ribs.

As the beam depth goes on increasing for a particular spacing of ribs and number of ribs, it is found that-

1. The quantity of concrete in slab increases.
   Quantity of concrete in beam decreases as the spacing of ribs increases.
2. For a smaller spacing of ribs, Quantity of steel in slab decreases for a slight increase in spacing of rib and again decreases for further increase in spacing of rib and then finally it is found that there is again increase in the steel quantity for larger spacing of rib.
3. Quantity of steel in beam decreases with increase in the spacing of rib and is found to be minimum for a greater spacing of rib.
4. Quantity of steel in beam goes on increasing as the number of ribs increases.

As the beam depth goes on increasing for a particular spacing of ribs and number of ribs, it is found that-

1. Quantity of concrete in slab is the same, even when the beam depth is increased.
   At the same time, quantity of steel in slab is constant even when the beam depth is increased.
   At the same time, quantity of steel in slab is constant even when the beam depth is increased.
2. Quantity of concrete in beam goes on increasing when the beam depth is increased with respect to decrease in number of ribs and spacing of ribs.
3. Quantity of steel in beam decreases as the beam depth is decreased and is found to be maximum for smaller depth of beam and maximum number of ribs and minimum spacing of ribs. Also quantity of steel in beam is found to be minimum for lesser number of ribs and greater spacing of ribs.

Deflection

1. Deflection is found to be decreasing, as the number of ribs is increasing.
2. Deflection goes on increasing as the spacing increases. It is found to be minimum for a smaller spacing of ribs and maximum for a larger spacing of ribs.
3. Deflection is found to be decreasing as the beam depth increases. It is found to be maximum for lesser depth of beam, minimum number of ribs and greater is the spacing of ribs.
4. Also deflection is found to be minimum, when the number of ribs is maximum, spacing of ribs is minimum and beam depth is minimum.

(ANNEXURE 1)

Table shows variation of cost of concrete & steel with increase in spacing of grid

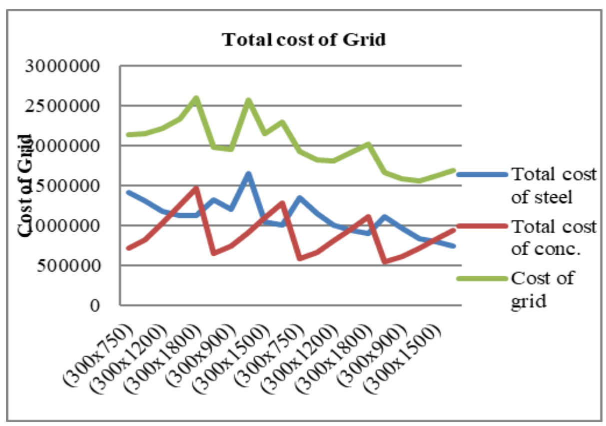
Hall dimension (25X25)m

Slab thk. (mm)	Spacing (m)	No. of ribs	Column Sizes	Beam sizes	Quantity of slab		Quantity of Beam		Deflection
					Conc. (m3)	Steel (kg)	Conc. (m3)	Steel (kg)	<L/250
110	(2.083x2.083)	(12x12)	(450x1000)	(300x750)	50.35	2496.32	139.87	29073.4	0.081
				(300x900)	50.35	2496.32	167.94	24919.9	0.066
				(300x1200)	50.35	2496.32	223.81	22044.5	0.05
				(300x1500)	50.35	2496.32	279.74	20988.6	0.043
				(300x1800)	50.35	2496.32	335.7	20961.1	0.045
110	(2.5x2.5)	(10x10)	(450x1000)	(300x750)	53.24	2571.9	118.5	25592.6	0.1
				(300x900)	53.24	2571.9	142.2	21590.2	0.06
				(300x1200)	53.24	2571.9	189.61	18446.5	0.082
				(300x1500)	53.24	2571.9	237	17307.2	0.013
				(300x1800)	53.24	2571.9	284.42	16418.7	0.007
115	(3.15x3.15)	(8x8)	(450x1000)	(300x750)	57.18	2442.17	97.92	20754.3	0.367
				(300x900)	57.18	2442.17	117.51	17810.4	0.22
				(300x1200)	57.18	2442.17	156.69	14937	0.1
				(300x1500)	57.18	2442.17	195.85	14027	0.05
				(300x1800)	57.18	2442.17	235.04	13617.7	0.01
135	(4.166x4.166)	(6x6)	(450x1000)	(300x750)	72.64	2480.6	73.18	16754.3	0.468
				(300x900)	72.64	2480.6	87.82	13310.4	0.279
				(300x1200)	72.64	2480.6	117.11	10937	0.192
				(300x1500)	72.64	2480.6	146.38	10002	0.063
				(300x1800)	72.64	2480.6	175.67	9097	0.036

Table shows total cost of grid floor

Span (25X25)m

Spacing (m)	Beam Sizes mm	Total cost of steel	Total cost of conc.	Cost of grid
(2.083x2.083)	(300x750)	1419334	722874	2142208
	(300x900)	1315979	829540	2145519
	(300x1200)	1177959	1041846	2219805
	(300x1500)	1127315	1254380	2331695
	(300x1800)	1125956	1467028	2592984
(2.5x2.5)	(300x750)	1327025	652612	1979637
	(300x900)	1208984	742672	1951656
	(300x1200)	1653140	922830	2575970
	(300x1500)	1050707	1102942	2153649
	(300x1800)	1011776	1283108	2294884
(3.15x3.15)	(300x750)	1345694	589380	1935074
	(300x900)	1153594	663822	1817416
	(300x1200)	1002684	812706	1815390
	(300x1500)	948019	961514	1909532
	(300x1800)	905345	1110436	2015781
(4.166x4.166)	(300x750)	1115275	554116	1669391
	(300x900)	974916	609748	1584664
	(300x1200)	836043	721072	1557116
	(300x1500)	792364	832276	1624639
	(300x1800)	748683	943480	1692163



Graph showing Total cost Vs Beam sizes

The above graph shows that as the beam depth increases for a particular spacing, total cost of concrete increases where as total cost of steel decreases as the beam depth increases and hence cost of grid floor increases.

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