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Comparative Analysis of Waffle Slab of Different Configuration & Deflection Check by Manual Method & Software-Based Method

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Abstract—*Waffle slab or sometimes is called ribbed slab may be a reinforced concrete slab containing square grids or rectangular grids with deep sides. In this study comparative analysisof waffle slab of different configuration & deflection check by manual method & software-based method. A reinforced concrete floor is to be designed to cover a floor area of size 18m by 24m.The different configuration include span to depth ratio, width of rib, c/c spacing of rib, thickness of slab, overall depth of ribs. The span to depth ratio considered is 20&26. The c/c spacing of rib is varied from0.75,1.00,1.25,1.50m.The thickness of slab and therefore the width of rib is constant and are adequate to 0.125m and 0.200m respectively. According to this configuration 24 models is to be generated. The deflection developed on grid floorhave been predicted by manual method andcompared to software-based method. After study the result analyzed the best model and check the deflection value within the permissible limit as per IS 456:2000.*

Introduction

Waffle slab system or ribbed slab system consists of beams spaced at regular interval in perpendicular directions, monolithic with slab. In these kinds of slab, a mesh or secondary beam or grid of beams running in both the directions is that the most structure, and thus the slab is consisting of minimum 65mm thickness as per code. In waffle slab the Grids (beams) are found to be very efficient in transferring the load. Normally the sizes of grids in waffle slab running in perpendicular directions or both dir. are generally kept the same. Waffle slab consist of two type: with solid heads and with band beam. With solid head at column joints for shear requirements and with band beam along centerline of columns to possess uniform depth. Waffle slab is highly economical as compared with conventional slab system. The load bearing system it can take up higher amount of dead and live load with compromising the structural integrity. Waffle slab is best of theatre, show rooms and halls, where it is necessary to have large column-void spaces or spans. In the aesthetics the waffle slab proved to be attractive both structurally and aesthetically.

Analysis

Three method are available foranalysis of waffle slab are:

- Rankine – Grashoffmethod (approximate method)
- Rigorous analysis (Timoshenko's plate theory)
- Stiffness method.

Rankine Grashoff's method (approximate method):

Deflections of the ribs:

$\delta=(5q1a4/384EI) =(5q2b4/384EI)$

$q1a4=q2b4$

$q1=q(b4/a4+b4)$ and$q2=q(a4/a4+b4)$

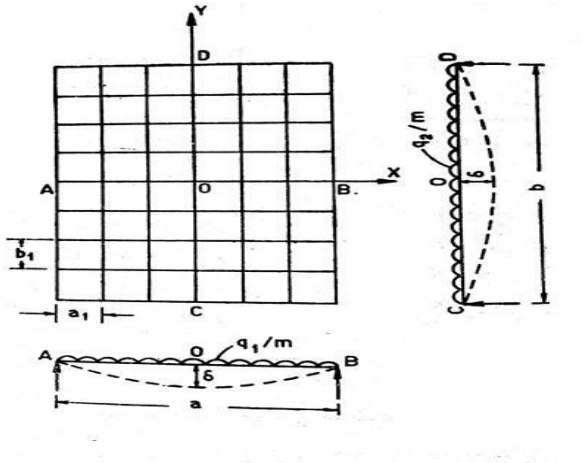


Figure 1: Deflection of the waffle slab

Bending moment in Mx and Myat center of grid

Mx=(q1b1a2/8) and My=(q2a1b2/8)

Shear force Qx and Qy

Qx=(q1b1a/2) and Qy=(q2a1b/2)

Rigorous analysis (Timoshenko's plate theory):

The vertical deflection 'a' at any point of the grid shown in Fig.

expressed as:

$$\mathbf{a} = \frac{16q}{\pi^6}\left[sin\left(\frac{\pi x}{ax}\right) + \left(sin\frac{\pi y}{by}\right) / \frac{Dx}{ax^4} + \frac{2H}{ax^2+by^2} + \frac{Dy}{by^2}\right]$$

Where:q= total udl per unitarea

ax&by=Length of plate in x and y directions

Dx& Dy=Flexural rigidity per unit length along x & y direction

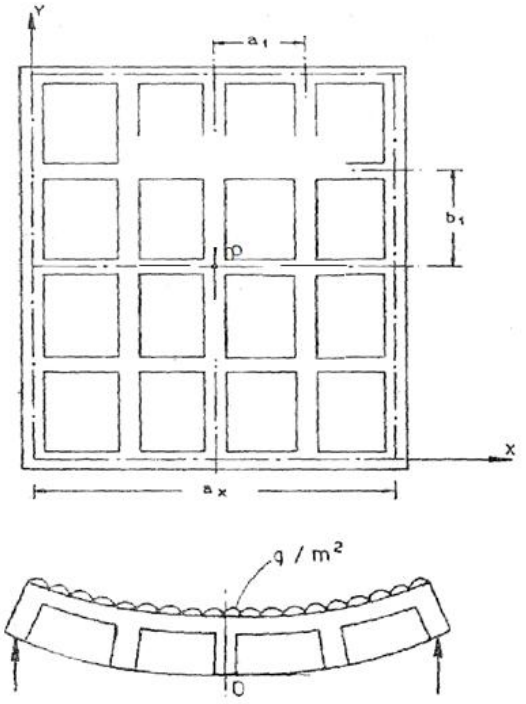


Figure 2: Deflection characteristics of grid floor

If axand by are the spacings of the ribsin x and y directions respectively, then we have therelations,

Bending moment in Mx and My

$$Mx=-Dx(\delta 2a/\delta x2)$$

$$My =-Dy(\delta 2a/\delta y2)$$

Shear force Qx and Qy

$$Q\ x = -\ \delta/\delta\ x[Dx(\delta 2a/\delta x2) + C2/a1(\delta 2a/\delta\ x\ \delta\ y)]$$

$$Q\ y = -\ \delta/\delta\ y[Dy(\delta 2a/\delta y2) + C1/b1(\delta 2a/\delta\ x\ \delta\ y)]$$

Torsional moment in Txy and Tyx

$$Txy = Cx(\delta 2a/\delta\ x\ \delta\ y)$$

$$Tyx = Cy\ (\delta 2a/\delta\ x\ \delta\ y)$$

Cx=C1/b1& Cy =C2/a1

Cx& Cy = torsional rigidity per unit length along x and y dir.

Stiffness Method: Software-based method or stiffness method is based on matrix formulation of the stiffness of the different kind of structure and provides closed form solution. By using this method, the analysis is usually done by considering fixed (rigid supports) also. Different types of application software's are available to carry out analysis by stiffness method.This type of work while analyzing both dir. Grid or grid floor frame by stiffness method, the simple supports are considered at very short or closer distance so on simulate the support conditions almost like Rankine Grashoff's method (approximate method) and Rigorous analysis (Timoshenko's plate theory). Here ETABS.18 software is employed.

Geometrical Properties and Material Properties:

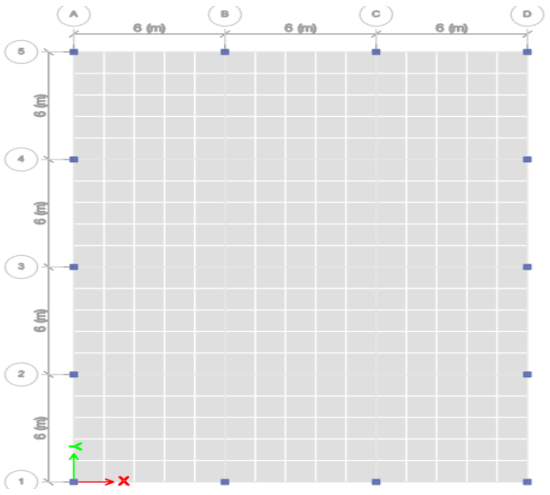
Table 1: Geometrical properties

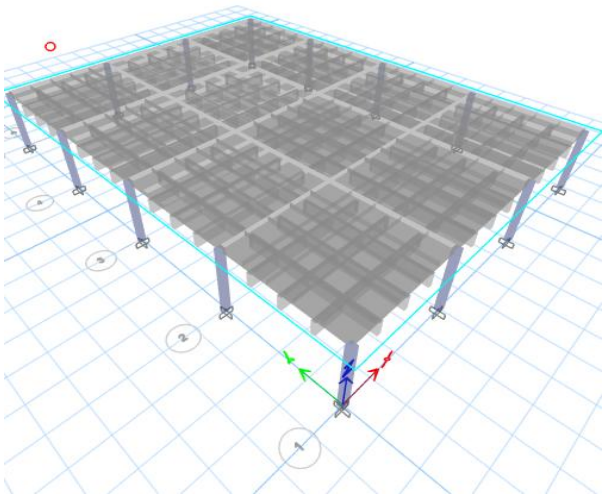
S.NO.	STRUCTURAL PART	DIMENSION
1	Size of grid	18*24m
2	No. of grid line in x& y-direction	4&5
3	Spacing in x& y-direction	6 m
4	Floor to floor height	4m
5	No. of story	SINGLE
6	Thickness of slab	125mm
7	Width of rib	200 mm
8	Overall depth of rib	900& 692 mm
9	Spacing of ribs	750,1000,1200 &1500mm
10	Column	300*300mm

Table 2: Material properties

S NO.	MATERIAL	GRADE
1	Concrete	M20
2	Rebar	Fe 415

Model



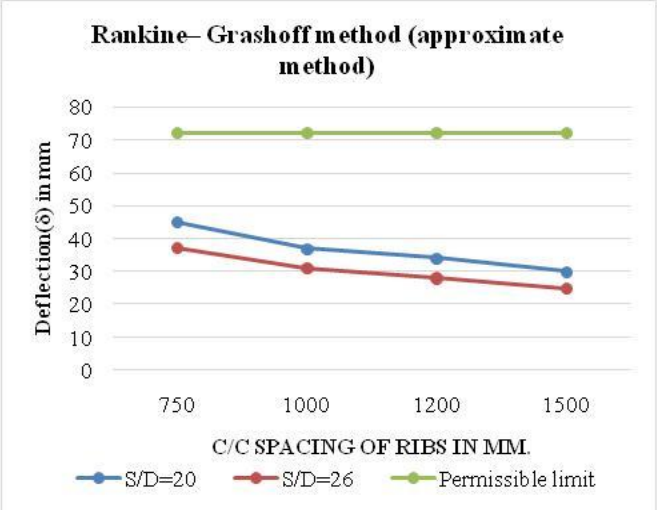


Model: Plan view,3D view

Result

Table 4: Deflection check by Rankine– Grashoff method (approximate method)

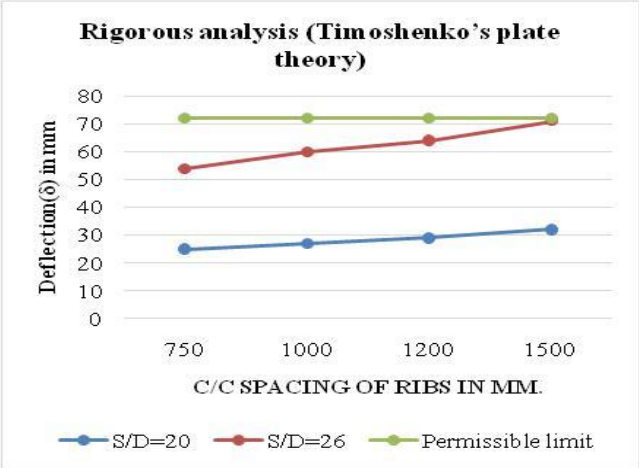
Span/ Depth	C/C spacing of ribs in mm	Rankine– Grashoff method	PERMISSIBLE LIMIT AS PER IS 456:2000
		Deflection(δ) in mm	For long term deflection (L/250)
20	750	45	72
	1000	37	72
	1200	34	72
	1500	30	72
26	750	37	72
	1000	31	72
	1200	28	72
	1500	25	72



Graph 1: Deflection in rankine– grashoff method (approximate method)

Table 4: Deflection check by Rigorous analysismethod (manual method)

Span/ Depth	C/C spacing of ribs in mm	Rigorous analysis (Timoshenko's plate theory)	PERMISSIBLE LIMIT AS PER IS 456:2000
		Deflection(δ) in mm	For long term deflection (L/250)
20	750	25	72
	1000	27	72
	1200	29	72
	1500	32	72
26	750	54	72
	1000	60	72
	1200	64	72
	1500	71	72

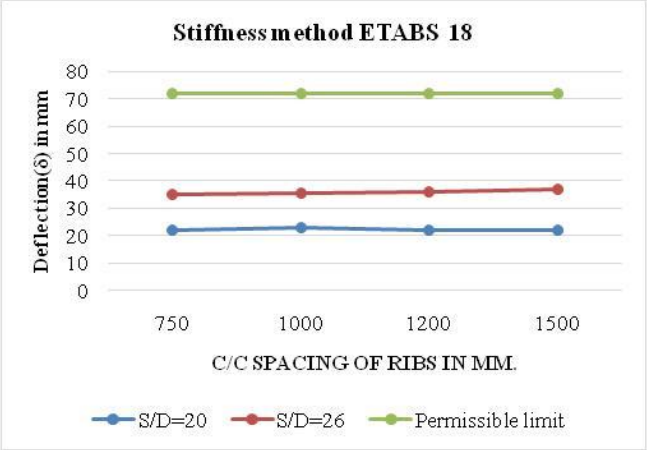


Graph 2: Deflection in Rigorous analysis (Timoshenko's plate theory)

Table 4: Deflection check by Stiffness method ETABS18(software-based method)

Span/ Depth	C/C spacing of ribs in mm	Stiffness method ETABS 18	PERMISSIBLE LIMIT AS PER IS 456:2000
		Deflection(δ) in mm	For long term deflection (L/250)
20	750	22.16	72
	1000	22.94	72

	1200	21.93	72
	1500	22.14	72
26	750	35.30	72
	1000	35.59	72
	1200	36.06	72
	1500	37.03	72



Graph 3: Deflection in Stiffness method ETABS 18

Conclusion

1. The spacing of grid beam and span-depth ratio influence the deflection and bending moment.
2. The load carrying capacity is to be increaseswhen spacing of ribs isdecreases or the load carrying capacity is decreases when spacing of ribs is increases.
3. The spacing of ribs is decreases the mid span deflection is decreases.
4. The depth of the ribs increases mid span deflection is decreases.
5. According to Rankine–Grashoffmethod (approximate method) when span-depth ratio and spacing of ribs is increases deflection is decreases.
6. According to Rigorous analysis (Timoshenko's plate theory) and stiffness method when span-depth ratio and spacing of ribs is increases deflection is increases.
7. So, it is found that Rigorous analysis (Timoshenko's plate theory) and stiffness method are given perfectresult ascompared to Rankine–Grashoffmethod (approximate method).

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