

Research Article

Effect of Depth of Periphery Beams on Behavior of Grid Beams on Grid Floor

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Abstract

By investigating various parameters involved, a solution for optimum structural configuration can be found for the grid floor. The present work includes the parametric investigation in terms of flexural actions such as bending moments and shear force. Spacing of grid beam is one of the important parameters considered for investigations, along with depth of grid beam & depth of periphery beam. Stiffness method is used for analysis which is less time consuming as compare to other analysis methods, where spacing of grid beams i.e. (l/b) is varied for hall size (L/B) with constant ratio. Here the depths of periphery beams (PB) are varied, for considered depth of periphery beams; various depths of grid beams (GB) are varied to arrive at optimum solution.

Keywords: Grid floors, spacing of grids beams, periphery beams (PB), grid beams (GB), stiffness method

1. 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).

Various research papers shows that, the cost of grid floors depends upon various parameters like span and

spacing of grid beams, size of the peripheral & grid beams, span to depth ratio etc.

The present work includes the study on effect of depth of periphery beams and behavior of grid beams on grid slab. For this stiffness method is used for analyzing various spacing of grid beams for a hall size (L/B) with constant ratio. And at the same time various depths of periphery beams and grid beams are considered.

2. Methods of analysis

Grid is highly redundant structural system and therefore, it is statically indeterminate. Rankine-Grashoff method is an approximate method. Plate analogy method is a rigorous method. But both the methods consider simple support conditions. To overcome this limitation of support condition, stiffness method is adopted which can be used for all types of supports.

Stiffness method is an accurate & more suitable to arrive at design moments and shear force. And also it takes less time for analysis. This method is based on matrix formulation of the stiffness of the structure and gives closed form solution. There are various application software's available, in which Stiffness method shows higher value of shear force as compared to other methods discussed. (Dr. S. A. Halkude, S. V. Mahamuni), have carried study for comparison of various methods of analysis. They found that in comparison with other methods, stiffness method is accurate and there is no limitation of support condition.

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3. Problem formulation

3.1 Typical Plan of Grid System

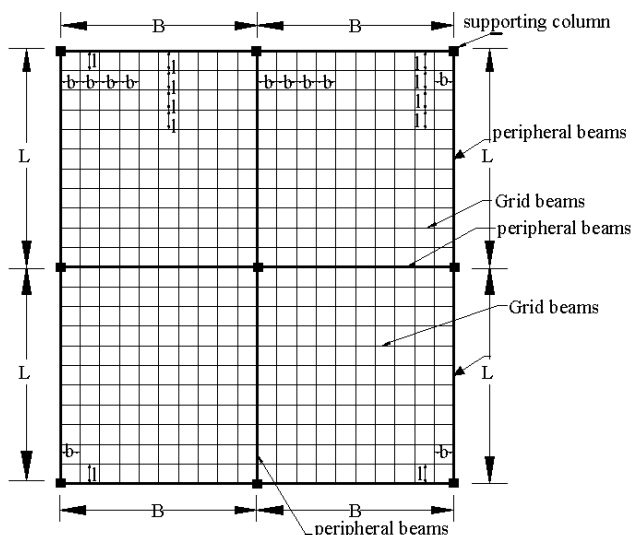


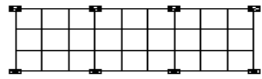
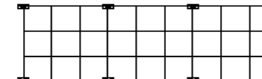
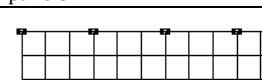
Figure 1 Plan of typical grid system

A grid system is analyzed using any of the methods given above. Above notations are used where, L= length of a typical hall, B= breadth of the hall, l = spacing along length, b = spacing along width

4. Parametric study

Hall considered is of size L= 10m, B = 10m, i.e. L/B =1. This hall is further attached by two similar halls such that No of panels=3, and l/b is varied from 1 to 1.7 at an interval of 0.1.

Table 1; Constant parameter; L/B=1, Width (B) =10m, Variable parameters; No. of panels and l/b ratios

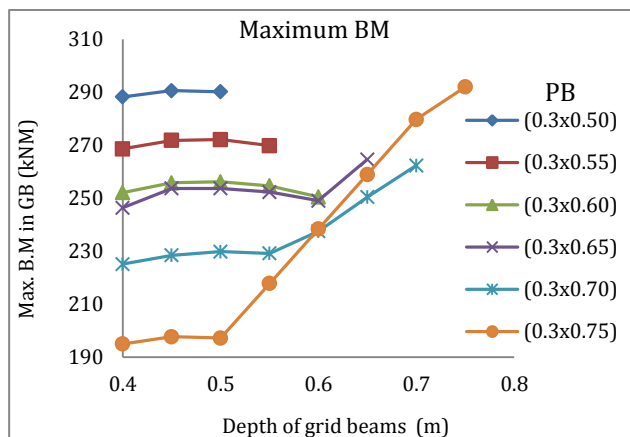
No. of panels	l/b ratios
 3panels	1 to 1.7 varying at an interval of 0.1
 4panels	1 to 1.7 varying at an interval of 0.1
 5panels	1 to 1.7 varying at an interval of 0.1

4.1 Case -I; l/b=1

Here the depths of periphery beams considered are 0.50m to 0.75m varying at an interval of 0.05m. For

considered depth of PB, various depths of GB considered are 0.40m to 0.75m varying at an interval of 0.05m.

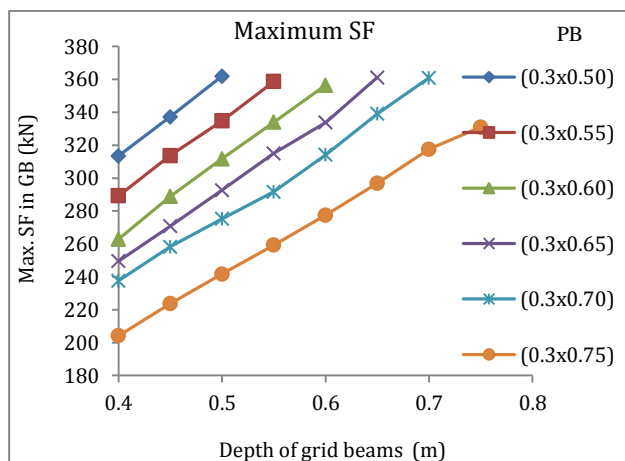
Bending moment



Graph 1 Variation of maximum BM in GB for various depths of GB

From the Graph 1, it is observed that for a given depth of periphery beam, initially no significant change in bending moment in GB is observed up to a depth of GB 0.5m. For grid beam having depth greater than 0.5m, the bending moment in grid beam increases with increasing depth of GB. For a given depth of PB, it is observed that rate of increase of BM in grid beam becomes steeper with increasing depth of PB. For a given depth of GB, bending moment in grid beam decreases with increasing depth of PB.

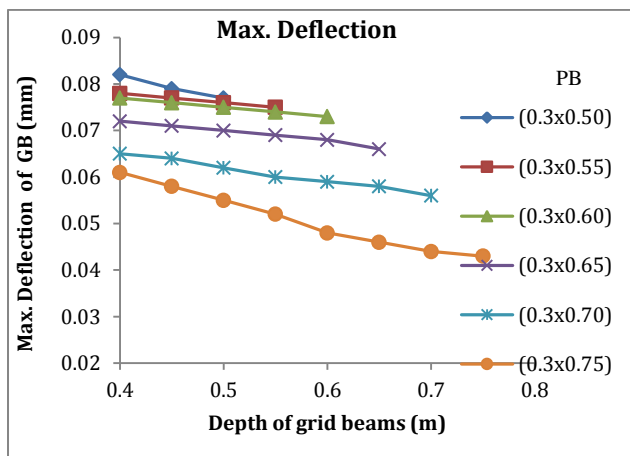
Shear force



Graph 2 Variation of max. SF in GB for various depths

From Graph 2, it is observed that for a given depth of PB the max. Shear force in GB increases linearly with increasing depth of GB. Similar variation is observed for all the depths of PB. However shear force in GB decreases with increase in depth of PB.

Deflection

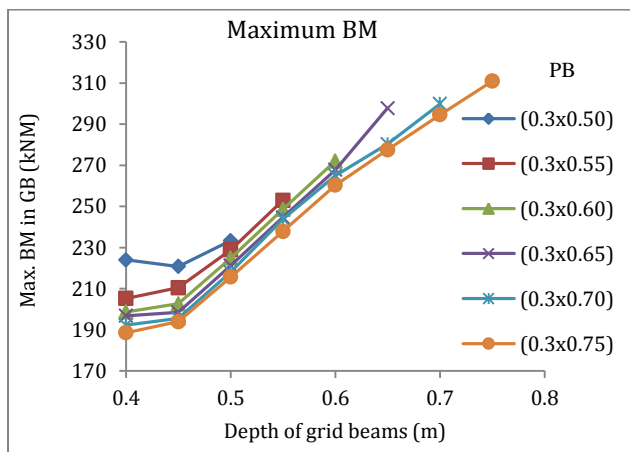


Graph 3 Variation of max. Deflection of GB for various depths

From the Graph 3, it is observed that for a given depth of PB the max. Deflection of GB decreases with increasing depth of GB. This nature of decrease is nearly alike with increase in depth of PB, however deflection decreases. Similar variation is found for (l/b) 1.1 ratios.

4.2 Case -II; l/b=1.2

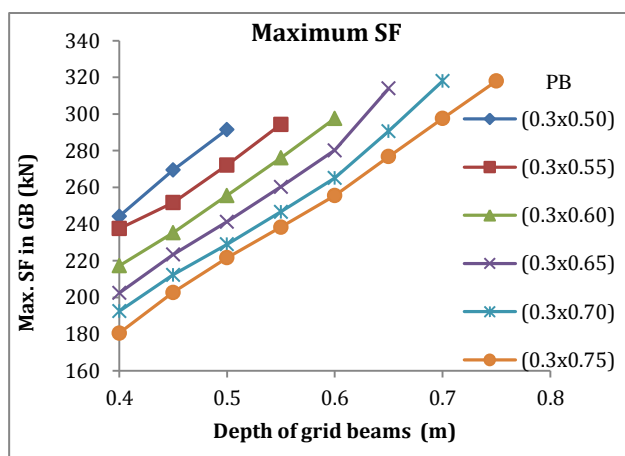
Bending moment



Graph 4 Variation of Max. BM in GB for various depths

From the Graph 4, it is observed that for a given depth of PB, the max. BM in GB increases with increasing depth of GB. The variation is parabolic in nature. The max. Bending moment in GB increases with slower rate initially, and after a certain point, it increases steeply, for given depth of PB. The max. BM in GB remains practically same even though the depth of PB increases. The max. BM in GB decreases with increasing depth of PB for a given depth of GB.

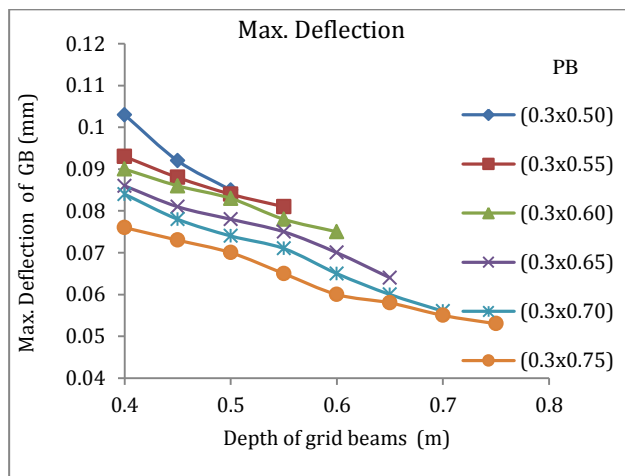
Shear force



Graph 5 Variation of max. SF in GB for various depths

From the Graph 5, it is observed that for a given depth of PB the max. Shear force in GB increases with increasing depth of GB. The variation is alike for all the depths of PB. As the depth of PB increases, the max. Shear force in GB decreases for the given depth of GB.

Deflection



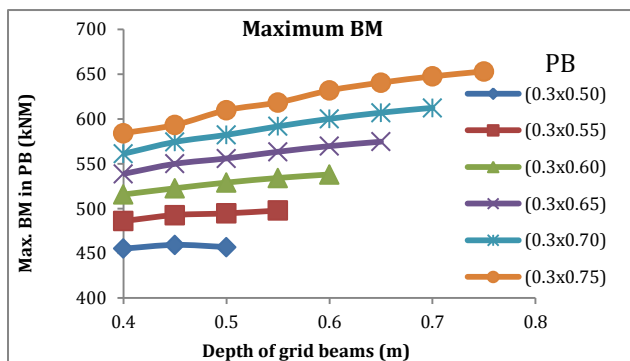
Graph 6 Variation of max. Deflection of GB for various depths

From the Graph 6, it is observed that for a given depth of PB the max. Deflection of GB decreases with increasing depth of GB. This nature of decrease in deflection of GB is nearly alike with increase in depth of PB, however deflection decreases.

For a ratio above (l/b) 1.2 and upto (l/b) 1.4, it is found that the bending moment in grid beams goes on increasing; shear force was found to be minimum for (l/b) 1.2 ratios. For (l/b) 1.3 to 1.4, shear force is found to be increasing.

4.3 Case -II; $l/b=1.4$

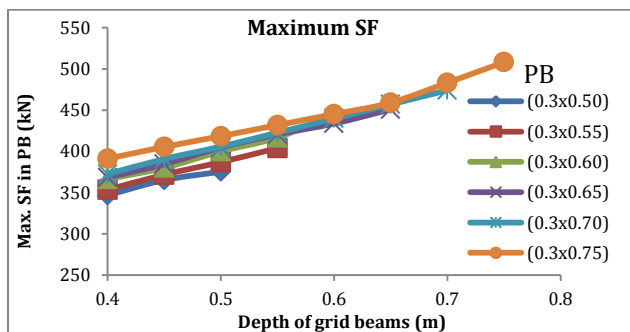
Bending moment



Graph 7 Variation of max. BM in PB for various depths

From the Graph 7, it is observed that for a given depth of PB, the max. bending moment in PB is increasing with increase in depth of GB. In this case it is observed that the max. bending moment in PB goes on reducing with increasing depths of PB for a given depth of GB.

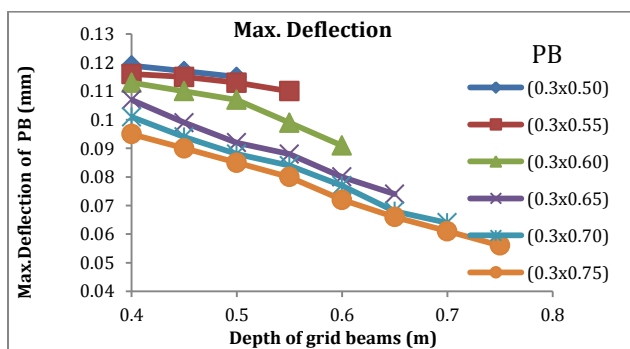
Shear force



Graph 8 Variation of max. SF in PB for various depths

From the Graph 8, it is observed that for a given depth of PB, the max. shear force in PB increases with increase in depth of GB. It is also observed that shear force decreases by a very negligible amount, even though the depth of PB is increased.

Deflection

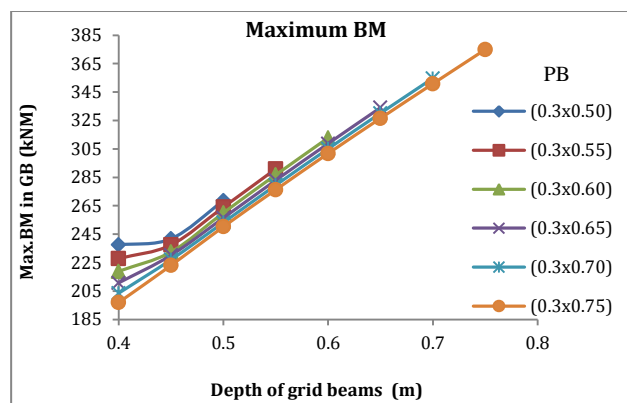


Graph 9 Variation of max. Deflection of PB for various depths of GB for a constant width

From the Graph 9, it is observed that for a given depth of PB, the deflection of PB is decreasing. With increase in depth of PB, the max. Deflection of PB is decreasing. With increasing depth of GB similar trend is observed for all the depths of PB.

4.4 Case-III; $l/b=1.6$

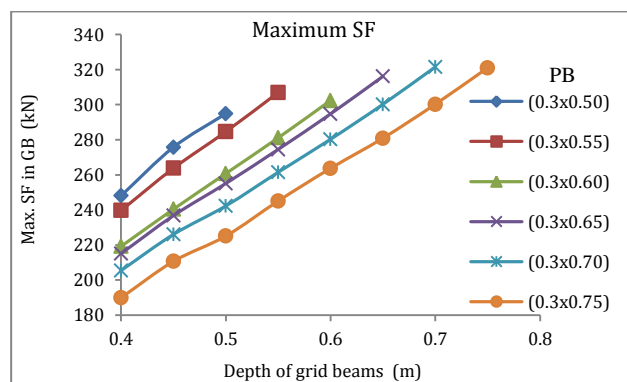
Bending moment



Graph 10 Variation of max. BM in GB for various depths

From the Graph 10, it is observed that for a given depth of PB, the max. bending moment in GB increases with increasing depth of GB. Initially the variation is parabolic in nature for smaller depths of PB. Later as the depth of PB increases above 0.60m, the nature of variation is found to be a straight line with increase in depth of GB. It is also observed that as the depth of PB increases max. bending moment in GB increases with steeply, for given depth of GB.

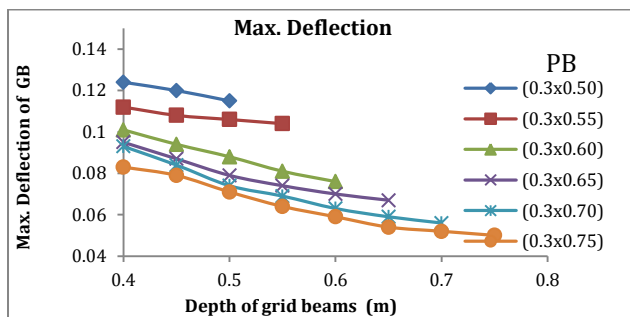
Shear force



Graph 11 Variation of max. SF in GB for various depths

From the Graph 11, it is observed that for this case the variation of max. shear force in GB is observed to be the same as in case of $l/b = 1.3$. The variation remains linear with steeper slope. It means the max. shear force in GB is increasing linearly with increasing depth of GB, for given depth of PB. However as the depth of PB increases, there is a decrease in max. SF in GB.

Deflection

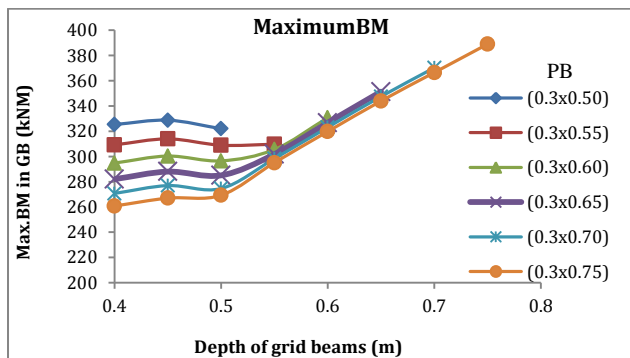


Graph 12 Variation of max. Deflection of GB for various depths

From the Graph 12, it is observed that for a given depth of PB the max. deflection of GB decreases with increasing depth of GB. This nature of decrease in deflection of GB is nearly alike with increase in depth of PB, however deflection decreases.

4.5 Case -2; l/b=1.7

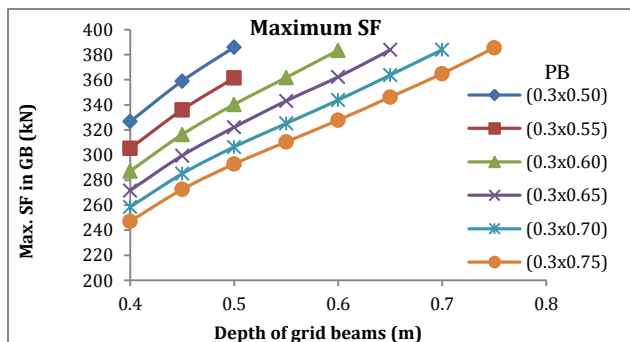
Bending moment



Graph 13 Variation of max. BM in GB for various depths

From the Graph 13, it is observed that the nature of variation in max. bending moment in GB is observed to be the same as that of for the previous case. The rate of decrease in max. bending moment in PB is almost same as the rate of increase in max. bending moment.

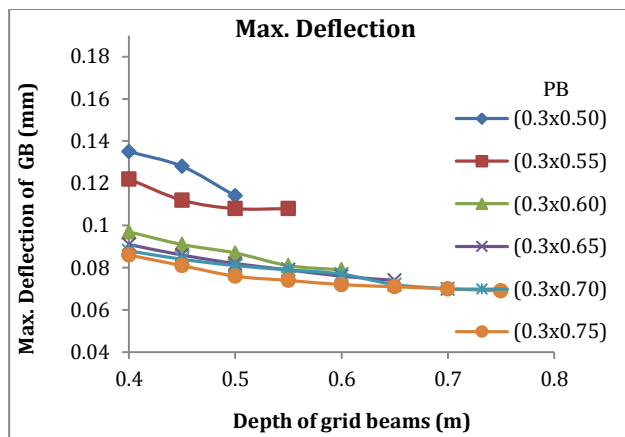
Shear force



Graph 14 Variation of max. SF in GB for various depths

From the Graph 14, it can be observed that for this case, the variation of max. shear force in PB is observed to be the same as previous case. The variation remains linear with similar slope. It means the max. shear force is increasing linearly with increasing depth of GB, for given depth of PB.

Deflection



Graph 15 Variation of max. Deflection of GB for various depths

From the Graph 15, it is observed that for a given depth of PB, the deflection of PB is decreasing. With increase in depth of PB, the max. Deflection of PB is decreasing. With increasing depth of GB similar trend is observed for all the depths of PB.

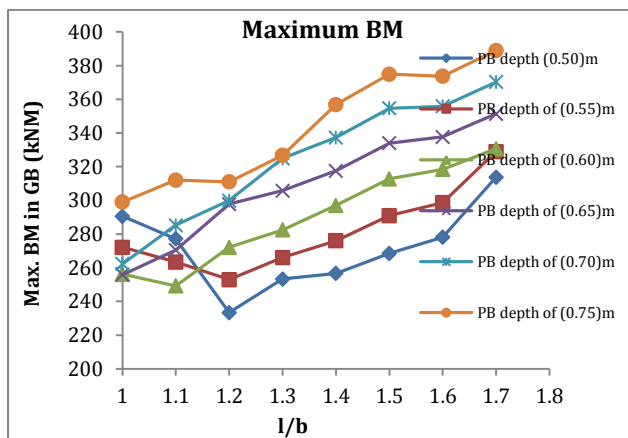
4.6 Various max. flexural actions for L/B=1, No of panel=3, for l/b=1.0 to 1.7

After analyzing such combinations and looking towards the variations, it can be observed that the variations in BM, and SF in PB are similar for all l/b ratio. It is also found that variations in BM, and SF in GB are alike. Now, the variations of max. flexural actions can be compared with the l/b ratios of grid dimensions for different depths of PB.

Table 2 Comparison of Max. BM in GB for various depths of PB

PB Depth (m) l/b	0.5	0.55	0.6	0.65	0.7	0.75
1	290.6	272.1	256.1	255.9	262.3	299
1.1	277.1	263.3	249.2	270.57	285.31	312.1
1.2	233.3	252.9	272.1	297.78	299.91	310.9
1.3	253.3	266.1	282.4	305.8	324.9	326.8
1.4	256.6	276	297	317.5	337.3	356.9
1.5	268.5	290.9	312.7	334	354.7	374.9
1.6	278.1	298.6	318.4	337.6	355.8	373.6
1.7	313.7	328.9	330.6	351.3	370.2	389

Bending moment



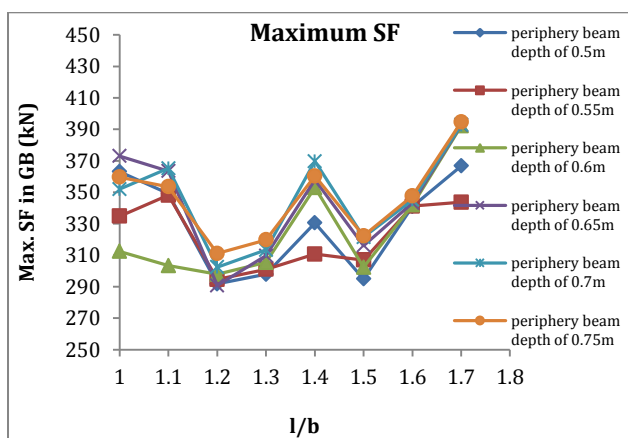
Graph 16 Variation of Max. BM of GB for various l/b

From this Graph 13, it is observed that for initial depth of PB up to 0.60m, variation of BM in grid is not consistent with depth of GB. However with increasing depth of PB, the nature of the max. BM in GB becomes more consistent i.e. with increasing depth of PB the variation of BM in GB tend to becomes linear.

Table 3 Comparison of max. shear force in GB for various depths of PB

PB Depth (m) l/b	0.5	0.55	0.6	0.65	0.7	0.75
1	361.9	358.6	356.5	346.6	360.9	330.9
1.1	349.7	348.6	348.3	363.9	370.1	353.5
1.2	291.5	294.3	297.5	313.9	317.96	317.9
1.3	300.9	302.4	297.5	310.1	314.8	310.5
1.4	360.5	361.4	353.9	364.8	367.6	361
1.5	294.8	306.9	302.3	316.1	321.4	321
1.6	341	341.2	341.9	343.1	345.1	347.7
1.7	386	384.5	383.5	383.8	384	385.5

Shear force



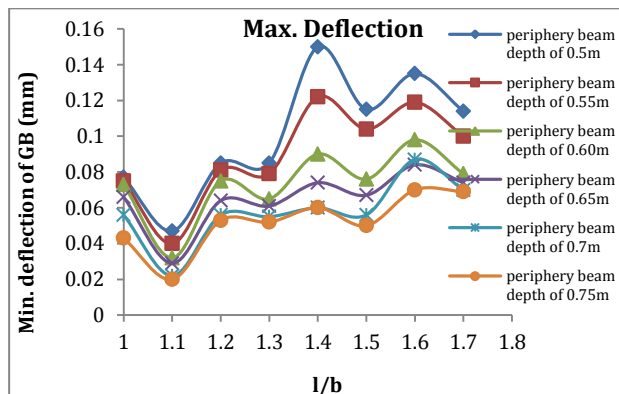
Graph 17 Variation of max. SF of GB for various l/b

Nature of variation of shear force of GB observed is as shown in Graph 17, It is observed that up to l/b 1.2, the shear force of GB decreases. For l/b =1.2 to 1.4, there is slight increase in shear force. The max. shear force of GB is observed for l/b=1.4 for all depths of PB.

Table 4 Comparison of Max. Deflection in GB for various depths of PB

PB Depth (m) l/b	0.5	0.55	0.6	0.65	0.7	0.75
1	0.077	0.075	0.073	0.066	0.056	0.043
1.1	0.047	0.04	0.032	0.029	0.022	0.02
1.2	0.085	0.081	0.075	0.064	0.056	0.053
1.3	0.085	0.079	0.065	0.061	0.055	0.052
1.4	0.15	0.122	0.09	0.074	0.06	0.056
1.5	0.115	0.104	0.076	0.067	0.056	0.05
1.6	0.135	0.119	0.098	0.084	0.087	0.07
1.7	0.114	0.1	0.079	0.074	0.07	0.069

Deflection



Graph 18 Variation of min. deflection of GB for various l/b

For a given depth of PB, the nature of variation in deflection is as seen in the Graph 18. The minimum deflection of GB for all the depths of PB is observed to be at l/b=1.1 and max. deflection of GB is observed for l/b=1.4 for all depths of PB. With increasing depth of PB the variation in deflection of GB is getting minimized

5. Conclusions

From the observations conclusions are drawn which will be helpful in understanding seismic structural behavior. These various conclusions are as presented below.

5.1 Spacing of grid beams

1) It is found that, BM in GB decreases mildly up to 1.2. For (l/b) higher than 1.2 and up to 1.7, BM in GB goes on increasing with increase in l/b ratio.

- 2) It is found that shear force in GB decreases for (l/b) 1.2. For (l/b) above 1.2, SF in GB increases linearly with increasing l/b ratio till (l/b) 1.7.
- 3) It is found that the deflection of GB is found to be maximum for (l/b) 1.4.

5.2 Effect of various flexural actions with respect to depth variations of PB

- 1) It has been observed that, for given depth of PB, the max. BM in GB goes on decreasing with increasing depth of grid beams. After attaining a minimum value of BM in GB, BM in GB further increases with increasing depth of grid beam.
- 2) Shear force in GB decreases with increase in depth of PB up to 0.6m and the increase is mild. For a depth of PB above 0.6m, shear force in GB increases steeply.
- 3). Deflection in GB decreases with increase in depth of PB. The deflection in GB is minimum when depth of grid beams is equal to depth of PB.

5.3 Effect of flexural actions on 3 panels, 4 panels and 5 panels

- 1 It is observed that, there is no significant change in BM in PB and in GB with increase in number of panels. When depth of PB is equal to depth of GB, it is observed that, initially BM in PB decreases for a smaller depth of PB.
- 2 Shear force in GB decreases with increase in PB. However, it is observed that there is not much variation in shear force in GB due to increasing number of panels.
- 3 Obviously the deflection in PB and GB decreases with increase in depth of PB and the same thing is observed by increasing the number of panels.

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