Comparative Analysis and Design of Flat and Grid Slab System With Conventional Slab System

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Abstract – Structural Engineering is a branch of Civil Engineering where the study is done to know how the structure behave when building is constructed at real environment and to identify the various forces like axial force and shear force, bending moment and displacement etc. acting on the structure. When the analysis come to complex structure or multi-story structure the manual calculation will be difficult to perform and hence there is various software available to perform these calculations, this software are STAAD Pro V8i, ANSYS, ETAB, SAP-2000 etc. In the present study, "Comparative analysis and design of flat slab and grid slab system with conventional slab system" comparison of parameter like quantity of concrete, quantity of steel, cost of the structure, bending moment, shear force and displacement of flat slab system and grid slab system with conventional slab system. In this study, slab system design and analysis for G+10 building for seismic zone III and having medium soil condition by using STAAD Pro V8i and these slab system analyzed for different plan area or grid size/ spacing of the column. The analysis and design of slab system is done as per IS 456-2000 and IS 1983-2002. Design of the slab system is done for different spacing/ grid size of column to find out which grid size of the column or plan area which slab is economical.

Keywords- Structure Design and Analysis of slab system, Flat Slab System, Grid Slab System, Conventional Slab System, STAAD Pro V8i.

1. Introduction

The flat slab arrangement of structure is one in which the beam is used in the conventional procedures of construction through away with the directly rests on column as well as the load from the slabs is directly conveyed to the columns and then to the footing. Drops or columns are generally provided using column heads or capitals. Floor systems consisting of flat slabs are very famous in countries where cast-in place building is prime form of construction because of numerous advantages in terms of architectural flexibility, use of space, easier formwork, and shorter creation time. Flat slabs are being used chiefly in office buildings due to reduced formwork cost, fast excavation, and easy establishment. That's why it's crucial to think what you're getting into (or under) so you can maximize the comeback on your investment. Grid floor systems comprising of beams move apart at regular intervals in perpendicular directions, monolithic with slab.

1.1. Types of Structure

Slabs are plate elements creating floor and roofs of building in addition to carrying loads primarily by flexure. Inclined slabs may be used as ramps for multi-story car parks. A staircase can be considered be an inclined slab. A slab may be decorated by beams or walls and may utilize as the flanges of a Tor L-beam. Besides, a slab may be simply supported or continuous over one more supports and is categorized according to the mode of support:

a) One way slabs spanning in one direction
b) Two way slabs spanning in two directions
c) Flat slabs sleeping directly on columns with no beams and
d) Grid floor with ribbed slabs.

One way slab are those held continuously on the two reverse sides so that the loads are supported along one direction only. The route in which the load is carried in one way slabs is called the span. It may be in the long or short direction. One way slab are frequently made to span in the shorter direction since the analogical bending moments and shear forces are the minimum. The main reinforcement is placed the span direction. Steel is also placed in the transverse direction, to divide any unevenness that may arise in loading and for temperature and shrinkage effects in that path. This steel is called distribution steel or secondary reinforcement placed it usually the minimum specified by the code. The secondary reinforcement is placed usually the minimum stated by the code for such reinforcement.
Two way slab are those slabs that are held continuously on all four sides and also of such dimension that the loads are transfer to supports along both directions.

Flat slab are those multi span slabs which relaxed on column without beams. Flat slab is demarcated as one sided or two-sided support arrangement with shear load of the slab being concentrated on the supporting columns and a square slab called 'drop panels
Grid floor systems comprising of beams spaced at regular intervals in at right angles directions, monolithic with slab.

1.2. Objective

The following are the objective of the present study:

1) To design various form of slab system for example conventional slab, flat slab and grid slab for the given plan area and their comparative study.
2) To study comparative costing of various types of slab system.

2. Literature Review

Amit A. Sathwane studied that the among flat slab , flat slab with drop and grid slab which is economical for the nexus point opposite to vidhan bhavan and beside NMC office. The analysis of flat slab, flat slab without drop and grid slab done both manually by IS 456-2000 and by STAAD PRO V8i. It is found in the study that flat slab with drop is economical then rest of other considered slab for the nexus point. It is also revealed in the study that concrete required for grid slab is more than the flat slab with and without drop and steel required for the flat slab without drop is more than the flat slab with drop and grid slab.

Navjot Kaur Bhatia (June 2016) studied that dynamic performance of flat slab and grid slab in compare to conventional slab. In the study of the project the writer perform the dynamic analysis for seismic and wind forces of multistory reinforced concrete building with different plan like square, hexagonal, orthogonal for flat slab , grid slab and conventional slab. The above analysis done for different story like 10, 20 and 30 and also for the different earthquake zone as per the Indian standard code of practice is 1893 – 2002. They made the relation between earthquake responses and intensities. It is revealed from the study that the performance and structural behavior of flat slab & grid slab is superior in compare to conventional slab. It is show in term of deflection and cost of material.

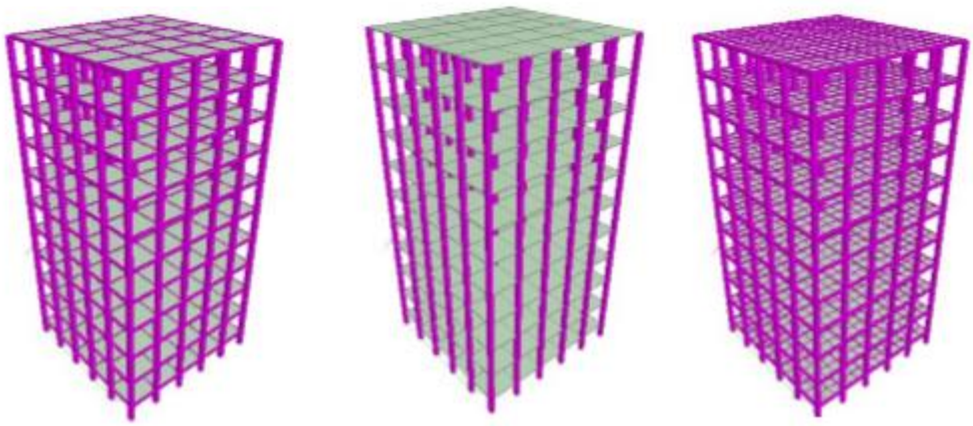
D. Ramya (October 2015) analyzed the multi-story (G+10) building by both STAAD PRO V8i and ETABS software. In the study comparison between these two software is done to find out which give economy of multi storied (G+10) building. It is show that in the study STAAD PRO is much simple to work with as compare to ETABS software. It is also show that quantity of steel given by the ETABS is 9.25% less than by STAAD Pro when analyzed G+10 multistory building. The quantity of concrete show by both the software's is found same for multistory building. In the study it is revealed that the most economical section given by ETABS.

K.N.Mate (June 2015) analyzed the flat slab .Flat slab system is simple structure of RCC which provide long clear space, a good height, simple formwork and no delay time in construction. It is shown that why the flat slab is more feasible and flexible in comparison to other slab. This study includes complete analysis and design of flat slab as per Indian code of practices IS456:2000. Flat slab is more flexible and economical as compare to conventional slab. This paper guide us how to select drop, panel width, thickness of slab and detailing of reinforcement.

3. Methodology and Problem Formulation

3.1. Modelling of building frames

A RCC structure is primarily composed of beams, columns, slabs and foundation and this whole system behave as a one unit and transfer load finally to the footing. Normally the flow of load in the building is from slab to beam, beam to column and finally to footing. In the current study we have taken different type of floors for different grid size and for this purpose we have utilized the STAAD Pro V8i software. The different types of floors taken are conventional slab, flat slab, and grid slab having same elevation.



(i) Conventional Slab system **(ii) Flat Slab system** **(iii) Grid Slab system**

Figure No. 1: Different type of slab system

3.2 Methodology

The process of analysis and design of structure performed on STAAD–Pro V8i in accordance with IS -1893:2002 and IS-456:2000 is shown through Flow Chart below.

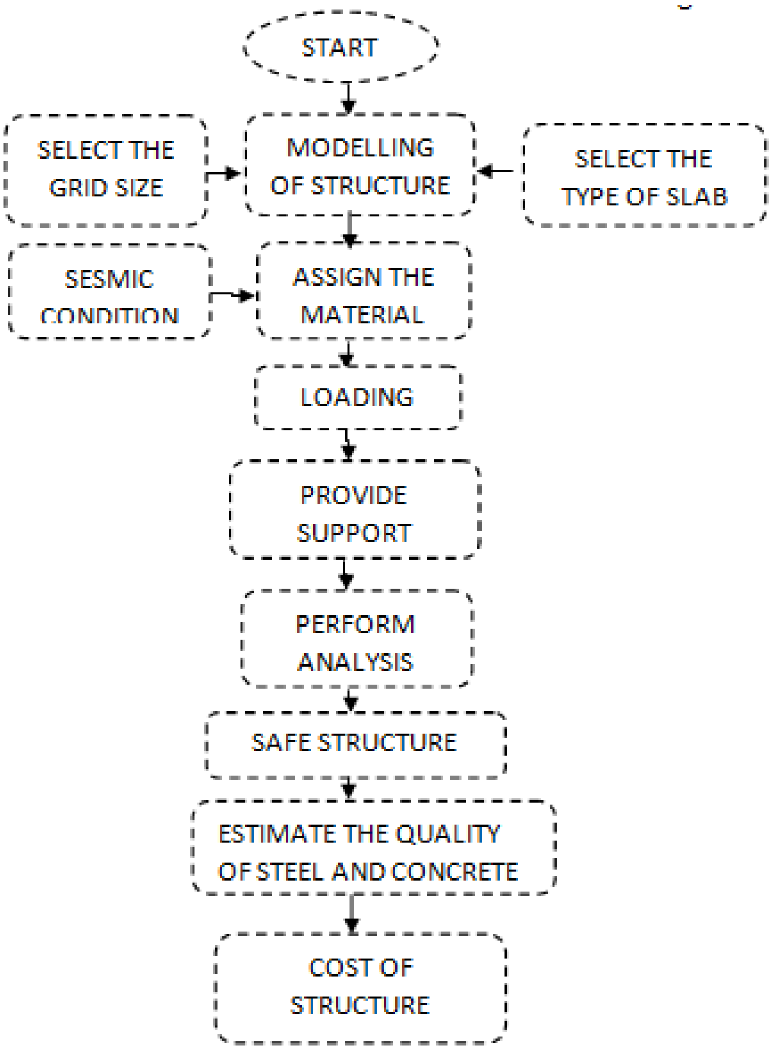


Table 1: Building Specification

S. No	MATERIAL SPECIFICATION	
1	Grade of Concrete, M-25	F_{ck} = 25N/mm2
2	Grade of Steel, Fe-415	F_y = 415N/mm2
3	Density of Concrete	Y'c = 25KN/m3
4	Cost of Steel bars	Rs 45/Kg
5	Cost of Concrete	Rs 4500/m3

Table No.2: Building Specifications for Case Number I

S. NO.	SPECIFICATIONS	DIFFERENT TYPES OF SLAB SYSTEM		
		Conventional Slab	**Flat Slab**	**Grid Slab**
1	Plan Dimension	15m X 15m	15m X 15m	15m X 15m
2	Length of Grid in x- direction	3m	3m	3m
3	Length of Grid in z- direction	3m	3m	3m
4	Floor to Floor height	3m	3m	3m
5	No. of Stories	10	10	10
6	Plinth Level	1.5m	1.5m	1.5m
7	Slab Thickness	0.125 m	0.125 m	0.125m
8	Size of Beam	0.2 m x 0.15 m	-	0.2 m x 0.2 m
9	Size of Column	0.4 m x 0.4 m	0.35 m x 0.35 m	0.35m x 0.35 m
10	Size of Grid	-	-	0.1 m x 0.1 m
11	Spacing of Grid	-	-	1 m
12	Grade of Concrete	M-25	M-25	M-25
13	Grade of Steel	Fe-415	Fe-415	Fe-415

Table No.3: Building Specifications for Case Number II

S.NO.	SPECIFICATIONS	DIFFERENT TYPES OF SLAB SYSTEM		
		Conventional Slab	**Flat Slab**	**Grid Slab**
1	Plan Dimension	20m X 20m	20m X 20m	20m X 20m
2	Length of Grid in x- direction	4m	4m	4m
3	Length of Grid in z-direction	4m	4m	4m
4	Floor to Floor height	3m	3m	3m
5	No. of Stories	10	10	10
6	Plinth Level	1.5m	1.5m	1.5m
7	Slab Thickness	0.15 m	0.15 m	0.15 m
8	Size of Beam	0.2 m x 0.2 m	-	0.25 m x 0.2 m
9	Size of Column	0.45 m x 0.45 m	0.45 m x 0.45 m	0.5 m x 0.5 m
10	Size of Grid	-	-	0.15 m x 0.1 m
11	Spacing of Grid	-	-	1 m
12	Grade of Concrete	M-25	M-25	M-25
13	Grade of Steel	Fe-415	Fe-415	Fe-415

Table No.4: Building Specifications for Case Number III

S. NO.	SPECIFICATIONS	DIFFERENT TYPES OF SLAB SYSTEM		
		Conventional Slab	**Flat Slab**	**Grid Slab**
1	Plan Dimension	25m x 25m	25m x 25m	25m x 25m
2	Length of Grid in x-direction	5m	5m	5m
3	Length of Grid in z-direction	5m	5m	5m
4	Floor to Floor height	3m	3m	3m
5	No. of Stories	10	10	10
6	Plinth Level	1.5m	1.5m	1.5m
7	Slab Thickness	0.175 m	0.175 m	0.175 m
8	Size of Beam	0.25 m x 0.2 m	-	0.25m x 0.22m
9	Size of Column	0.63 m x 0.63 m	0.55 m x 0.55 m	0.65m x 0.65m
10	Size of Grid	-	-	0.15m x 0.15m
11	Spacing of Grid	-	-	1 m
12	Grade of Concrete	M-25	M-25	M-25
13	Grade of Steel	Fe-415	Fe-415	Fe-415

Table No.5: Building Specifications for Case Number IV

S.NO.	SPECIFICATIONS	DIFFERENT TYPES OF SLAB SYSTEM		
		Conventional Slab	**Flat Slab**	**Grid Slab**
1	Plan Dimension	30m X 30m	30m X 30m	30m X 30m
2	Length of Grid in x-direction	6m	6m	6m
3	Length of Grid in z-direction	6m	6m	6m
4	Floor to Floor Height	3m	3m	3m
5	No. of Stories	10	10	10
6	Plinth Level	1.5m	1.5m	1.5m
7	Slab Thickness	0.20 m	0.20 m	0.20 m
8	Size of Beam	0.3 m x 0.2 m	-	0.30 m x 0.30 m
9	Size of Column	0.77 m x 0.77 m	0.64m x 0.64m	0.75 m x 0.75 m
10	Size of Grid	-	-	0.15 m x 0.1 m
11	Spacing of Grid	-	-	1 m
12	Grade of Concrete	M-25	M-25	M-25
13	Grade of Steel	Fe-415	Fe-415	Fe-415

Table No.6: Building Specification for Case Number V

S.NO.	SPECIFICATIONS	DIFFERENT TYPES OF SLAB SYSTEM		
		Conventional Slab	**Flat Slab**	**Grid Slab**
1	Plan Dimension	35m X 35m	35m X 35m	35m X 35m
2	Length of Grid in x-direction	7m	7m	7m
3	Length of Grid in z-direction	7m	7m	7m
4	Floor to Floor height	3m	3m	3m
5	No. of Stories	10	10	10
6	Plinth Level	1.5m	1.5m	1.5m
7	Slab Thickness	0.25 m	0.25 m	0.25 m
8	Size of Beam	0.3 m x 0.25 m	-	0.35 m x 0.35 m
9	Size of Column	0.92 m x 0.92 m	0.72 m x 0.72 m	1.0 m x 1.0 m
10	Size of Ribs	-	-	0.20 m x 0.15 m
11	Spacing of Ribs	-	-	1.4 m
12	Grade of Concrete	M-25	M-25	M-25
13	Grade of Steel	Fe-415	Fe-415	Fe-415

Table No.7: Building Specifications for Case Number VI

S.NO.	SPECIFICATIONS	DIFFERENT TYPES OF SLAB SYSTEM		
		Conventional Slab	**Flat Slab**	**Grid Slab**
1	Plan Dimension	40m X 40m	40m X 40m	40m X 40m
2	Length of Grid in x-direction	8m	8m	8m
3	Length of Grid in z-direction	8m	8m	8m
4	Floor to Floor height	3m	3m	3m
5	No. of Stories	10	10	10
6	Plinth Level	1.5m	1.5m	1.5m
7	Slab Thickness	0.30 m	0.30 m	0.30 m
8	Size of Beam	0.35 m x 0.25 m	-	0.40 m x 0.35 m
9	Size of Column	1.09 m x 1.09 m	0.97 m x 0.97 m	1.1 m x 1.1 m
10	Size of Ribs	-	-	0.2 m x 0.15 m
11	Spacing of Ribs	-	-	1.33 m
12	Grade of Concrete	M-25	M-25	M-25
13	Grade of Steel	Fe-415	Fe-415	Fe-415

3.3. Loading Condition

The loads considered during design and analysis of multistoried building for grid size 3x3 having plan area 225m^2 and loading calculation for other case changes as plan area changes due to change in depth of the slab.

1. **Dead load** : It is taken as according to IS -875 (Part 1) : 1987
   a) Plate load = Density of concrete x Slab thickness
   = 25kn/m^3 x 0.125m = 3.125kn/m^2
   b) Masonry load on plate = 1kn/m^2
   c) Floor finishing = 1.5kn/m^2
   Total weight of slab =5.625kn/m^2

2. **Live Load**: It is calculated as per IS-875 (part 2) :1987
   Live load on floors = 1.5kn/m^2

3. **Earthquake load**: It is calculated as per IS-1893 (part 1): 2002
   Seismic Definition
   Earthquake zone – III (Z=0.16)
   Response reduction factor – 5
   Importance Factor – 1.5 (Very Important Building)
   Rock and Soil Site Factor-1 (Medium Soil Building)
   Type of Structure- 1
   Damping - 5% (0.05)
   Soil Type: Medium soil
   Natural Time Period (T_a) - 0.075h$^{0.75}$ (T_a = 0.73199 sec)
   Seismic weight of floor on working story's = 4kn/m^3
   Seismic weight of top floor = 2kn/m^2

4. Result and Inferences

4.1. Results

1) Quantity of Concrete:

Quantity of concrete required in several type of slab with different type of grid size/ span is observed as follow in table no. 8 and figure no. 2:

Table No. 8: Quantity of Concrete for Conventional slab, Flat Slab and Grid Slab

Concrete quantity (meter cube)			
Span (m)	Conventional slab	Flat slab	Grid slab
1			
2			
3	240.8	138.9	251.1
4	308.8	181.4	514.5
5	508	318.5	932.9
6	910	464.5	1365.5
7	1306.3	587.9	2162
8	1809.3	1067	2771.5

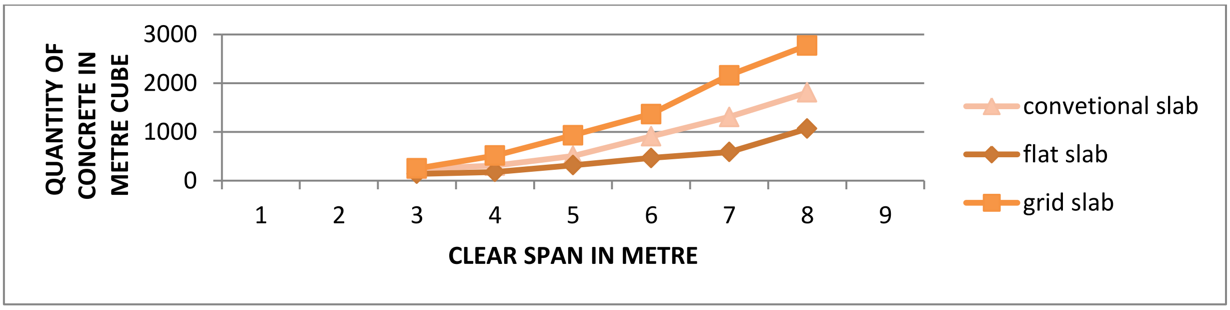


Figure No.2: Quantity of Concrete for Conventional Slab, Flat Slab and Grid Slab

2) Quantity of steel:

Quantity of steel required in different type of slab system with different type of grid size/ span is observed as follow in table no. 9 and figure no.3:

Table No. 9: Quantity of Steel for Conventional Slab, Flat Slab and Grid Slab

STEEL QUANTITY (IN KGS)			
Span (m)	Conventional slab	Flat slab	Grid slab
3	25194.9	11526.2	43006.5
4	31362	17667.3	89929.2
5	55601.9	27995.6	144527.3
6	80018.1	42674.2	208414.3
7	113680.3	58831.2	281588.1
8	155064.1	86300.8	355648.1

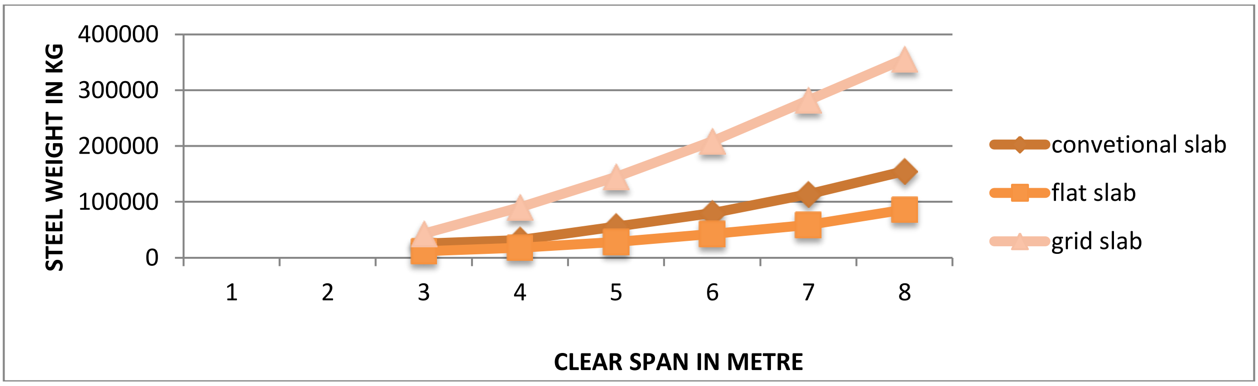


Figure No.3: Quantity of Steel for Conventional Slab, Flat Slab and Grid Slab

3) Cost of structure:

The cost of structure is mainly dependent on the quantity of concrete and steel. As the quantity of concrete and steel is vary, the cost of structure is changed. The cost of structure of model with different slab system is shown in the following table no. 10 and in figure no. 4:

Table No. 10: Cost of Structure for Conventional Slab, Flat Slab and Grid Slab

COST OF THE STRUCTURE (RUPEES)			
Span (m)	Conventional Slab	Flat Slab	Grid Slab
1			
2			
3	2217370.5	1143729	3065242.5
4	2800890	1611328.5	6362064
5	5270035.5	2693052	10701778.5
6	7695814.5	4010589	15523393.5
7	10993963.5	5295654	22400464.5
8	15119734.5	8685036	28475914.5

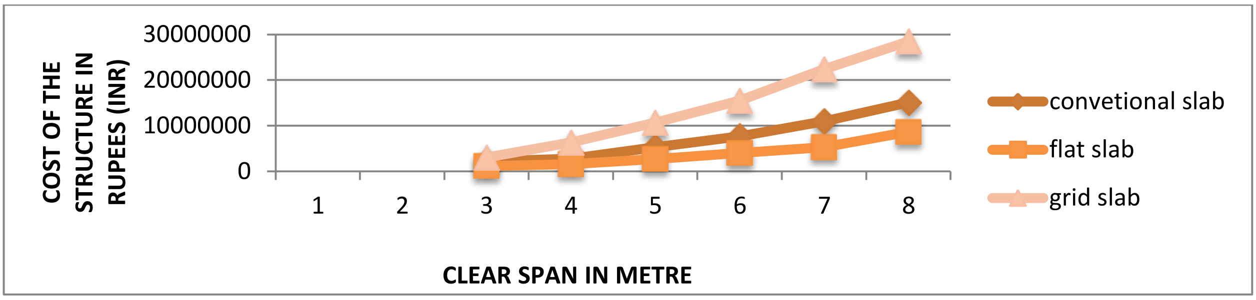


Figure No.4: Cost of Structure for Conventional Slab, Flat Slab and Grid Slab

The cost of structure per meter square of model with different slab system is shown in table no. 11 and figure no.5:

Table No. 11: Cost per Meter Square for Conventional Slab, Flat Slab and Grid Slab

COST PER METRE SQUARE(RUPEES)			
Span (m)	Conventional slab	Flat Slab	Grid Slab
1			
2			
3	985.498	508.324	1362.33
4	700.23	402.83	1590.52
5	843.2	430.8	1712.28
6	855.1	445.62	1724.82
7	897.47	432.3	1828.6
8	944.98	542.81	1779.74

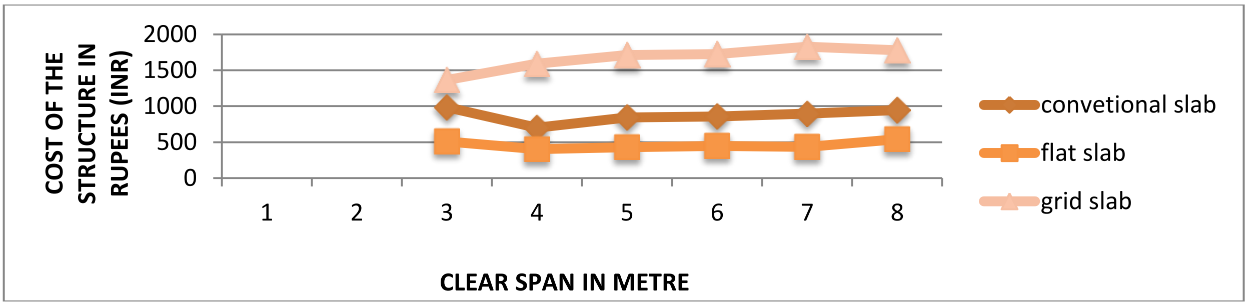


Figure No.5: Cost per Meter Square for Conventional Slab, Flat Slab and Grid slab

4) Maximum Displacement:

1) Maximum Displacement in X-Direction for different problem in earthquake zone III is shown in table no.12 and figure no.6.

Table No. 12: Maximum Displacement (mm) in X-Direction

Maximum Displacement (mm) in X Direction						
Different types of slab system	Case no. 1	Case no.2	Case no.3	Case no.4	Case no.5	Case no.6
Conventional slab	56.219	74.39	72.989	82.952	66.673	59.353
Flat slab	48.557	44.649	46.624	50.745	47.947	56.256
Grid slab	68.103	132.902	135.62	123.474	119.24	86.232

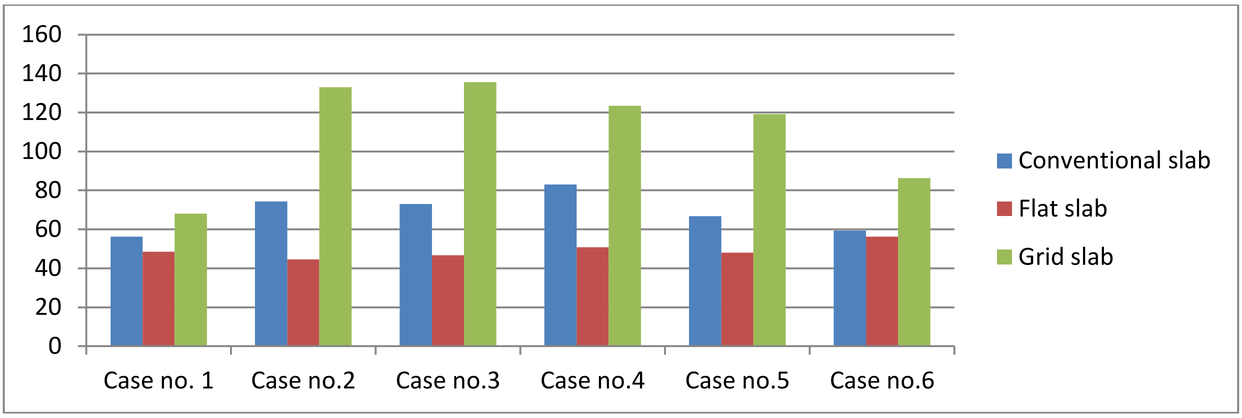


Figure No.6: Maximum displacement (mm) in X-Direction

Table No.13: Story No. and Node No. at which Maximum Displacement in X-Direction

Story No. and Node No. at which Maximum Displacement in X Direction						
Different types of slab system	Case no. 1	Case no.2	Case no.3	Case no.4	Case no.5	Case no.6
Conventional slab	10&397	10&427	10&397	10&397	10&397	10&397
Flat slab	10&397	10&427	10&397	10&397	10&427	10&397
Grid slab	10&517	10&2429	10&3094	10&3760	10&3094	10&4005

Here 00 story stands for plinth level or ground floor

2) Maximum Displacement in Y-Direction for different problem in earthquake zone III is shown in table no. 14 and figure no. 7.

Table No.14: Maximum Displacement (mm) in Y-Direction

Maximum Displacement (mm) in Y Direction						
Different types of slab system	Case no. 1	Case no.2	Case no.3	Case no.4	Case no.5	Case no.6
Conventional slab	0.753	1	0.811	0.835	0.768	0.744
Flat slab	0.667	0.64	0.602	0.615	0.701	0.523
Grid slab	1	1.756	1.741	1.826	2.158	1.679

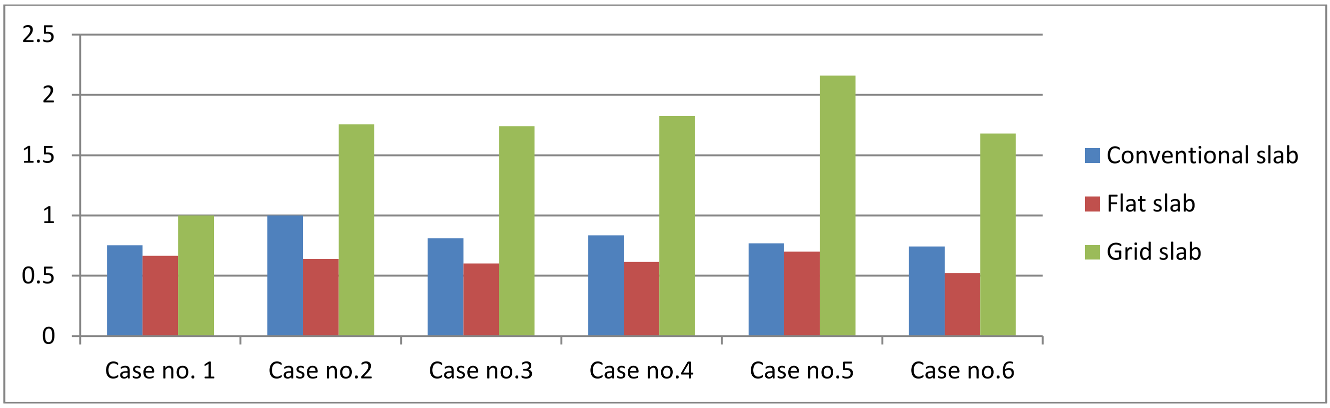


Figure No.7: Maximum displacement (mm) in Y-Direction

Table No. 15: Story No. and Node No. at which Maximum Displacement in Y-Direction

Story No. and Node No. at which Maximum Displacement in Y Direction						
Different types of slab system	Case no. 1	Case no.2	Case no.3	Case no.4	Case no.5	Case no.6
Conventional slab	10&409	10&421	10&403	10&403	10&421	10&403
Flat slab	10&403	10&421	10&403	10&403	10&411	10&403
Grid slab	09&1665	09&2246	03&1400	03&1637	03&1396	03&1892

3) Maximum Displacement in Y-Direction for different problem in earthquake zone III is shown in table no. 16 and figure no.8.

Table No. 16: Maximum Displacement (mm) in Z-Direction

Maximum Displacement (mm) in Z Direction						
Different types of slab system	Case no.1	Case no.2	Case no.3	Case no.4	Case no.5	Case no.6
Conventional slab	56.219	74.39	72.989	82.952	66.673	59.353
Flat slab	48.557	44.649	46.624	50.745	47.947	56.256
Grid slab	68.104	133.857	135.714	123.537	119.24	86.232

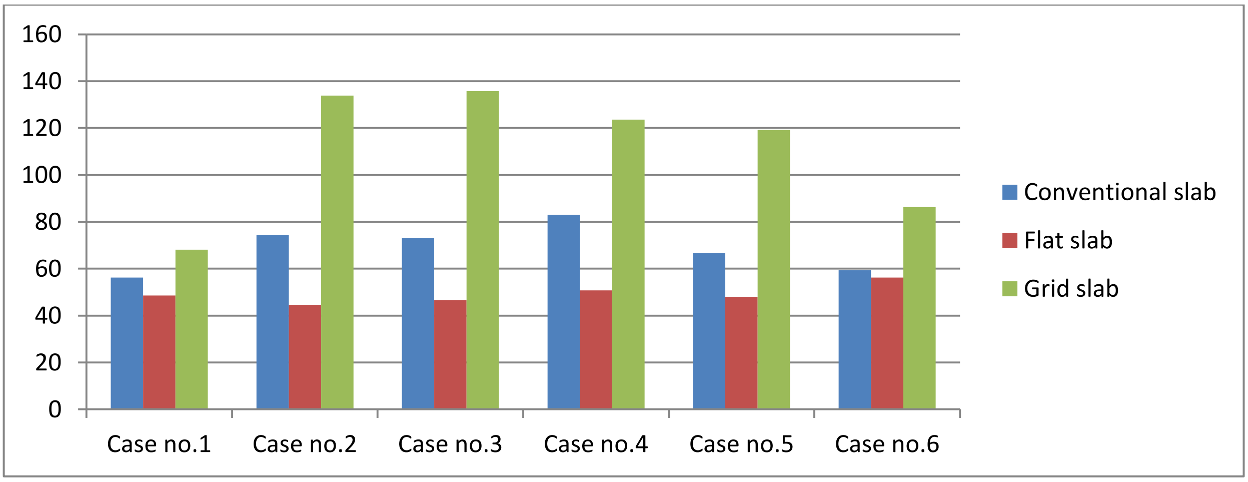


Figure No.8: Maximum displacement (mm) in Z-Direction

Table No.17: Story No. and Node No. at which Maximum Displacement in Z-Direction

Story No. and Node No. at which Maximum Displacement in Z Direction						
Different types of slab system	Case no. 1	Case no.2	Case no.3	Case no.4	Case no.5	Case no.6
Conventional slab	10&397	10&402	10&397	10&397	10&397	10&397
Flat slab	10&397	10&402	10&397	10&397	10&402	10&397
Grid slab	10&517	10&2468	10&3146	10&3825	10&3146	10&3920

5) Maximum Force:

1) Maximum Force in X-direction for different problem in earthquake zone III are shown in table no. 18 and figure no.9.

Table No. 18: Maximum Force (KN) in X-Direction

Maximum Forces (KN) in X Direction						
Different types of slab system	Case no.1	Case no.2	Case no.3	Case no.4	Case no.5	Case no.6
Conventional slab	1865.234	1571.84	6439.446	10253.367	15181.477	22496.518
Flat slab	1627.723	3168.701	5498.654	8285.55	10168.366	18869.828
Grid slab	2176.246	4372.087	7566.49	10585.092	17818.301	24305.295

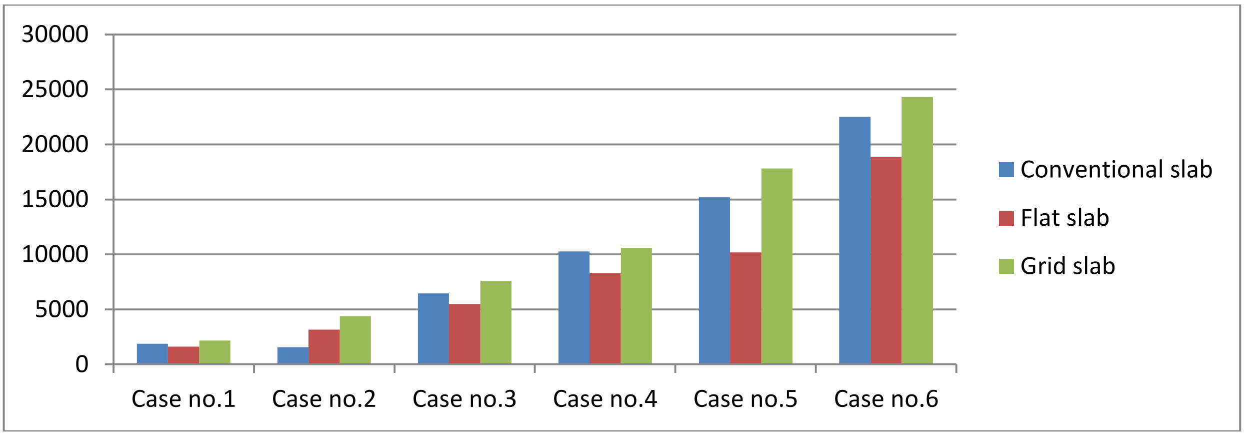


Figure No.9: Maximum Force (KN) in X-Direction

Table No. 19: Story No. and Node No. at which Maximum Force in X-Direction

Story No. and Node No. at which Maximum Force in X Direction						
Different types of slab system	Case no. 1	Case no.2	Case no.3	Case no.4	Case no.5	Case no.6
Conventional slab	00&15	00&22	00&15	00&22	00&15	00&22
Flat slab	00&15	00&22	00&15	00&22	00&15	00&22
Grid slab	00&15	00&15	00&15	00&22	00&9	00&22

Here 00 story stands for plinth level or ground floor

2) Maximum Force in Y-direction for different problem in earthquake zone III are shown in table no.20 and figure no.10.

Table No. 20: Maximum Force (KN) in Y-Direction

Maximum Forces (KN) in Y Direction						
Different types of slab system	Case no.1	Case no.2	Case no.3	Case no.4	Case no.5	Case no.6
Conventional slab	43.125	88.919	177.319	316.813	485.666	751.-403
Flat slab	29.603	48.998	96.699	166.787	293.804	407.388
Grid slab	47.585	191.314	336.258	477.947	916.703	1091.633

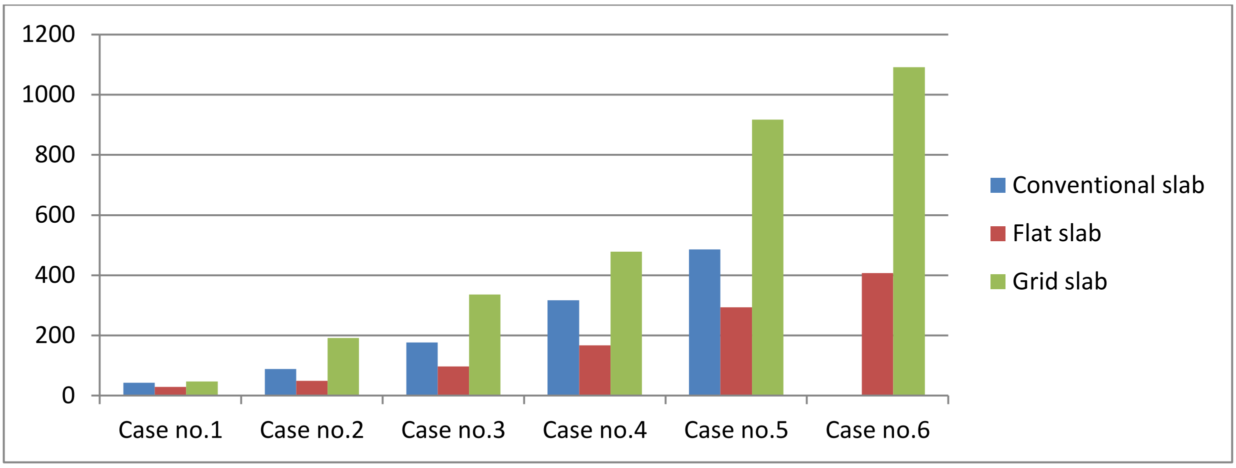


Figure No.10: Maximum Force (KN) in Y-Direction

Table No.21: Story No. and Node No. at which Maximum Force in Y-Direction

Story No. and Node No. at which Maximum Force in Y Direction						
Different types of slab system	Case no. 1	Case no.2	Case no.3	Case no.4	Case no.5	Case no.6
Conventional slab	03&119	02&101	03&119	03&119	03&137	03&119
Flat slab	03&119	04&173	04&155	03&119	03&137	03&131
Grid slab	04&275	04&299	04&358	03&419	04&359	03&437

3) Maximum Force in Z-direction for different problem in earthquake zone III are shown in table no. 22 and figure no.11.

Table No.22: Maximum Force (KN) in Z-Direction

Maximum Forces (kn) in Z Direction						
Different types of slab system	Case no.1	Case no.2	Case no.3	Case no.4	Case no.5	Case no.6
Conventional slab	43.125	88.919	177.319	316.813	485.666	751.403
Flat slab	29.603	48.998	96.699	166.787	293.804	407.388
Grid slab	45.395	194.587	336.766	474.458	917.896	1091.633

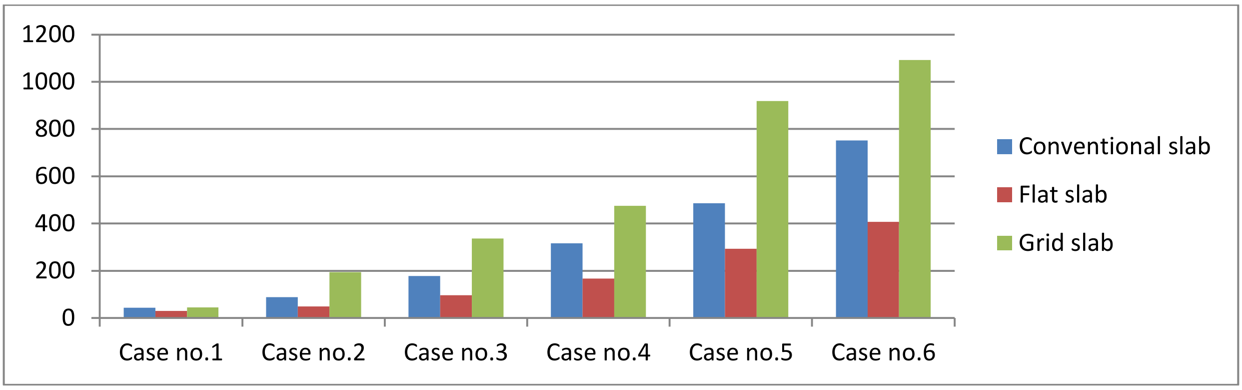


Figure No.11: Maximum Force (KN) in Z-Direction

Table No.23: Story No. and Node No. at which Maximum Force in Z-Direction

Story No. and Node No. at which Maximum Force in Z Direction						
Different types of slab system	Case no. 1	Case no.2	Case no.3	Case no.4	Case no.5	Case no.6
Conventional slab	03&116	02&83	03&116	03&116	03&119	03&116
Flat slab	03&119	04&155	04&152	03&116	03&119	03&118
Grid slab	04&272	04&296	04&356	03&416	04&356	03&419

6) Maximum Bending Moment:

1) Maximum Bending Moment in X-direction for different problem in earthquake zone III are shown in table no.24 and figure no.12.

Table No.24: Maximum Bending Moment (KN-M) in X-Direction

Maximum Moment (KN-M) in X Direction						
Different types of slab system	Case no. 1	Case no.2	Case no.3	Case no.4	Case no.5	Case no.6
Conventional slab	0.108	0.177	1.051	3.349	6.768	14.126
Flat slab	0.047	0.073	0.287	0.848	1.431	7.845
Grid slab	2.599	9.247	19.248	25.168	47.394	49.736

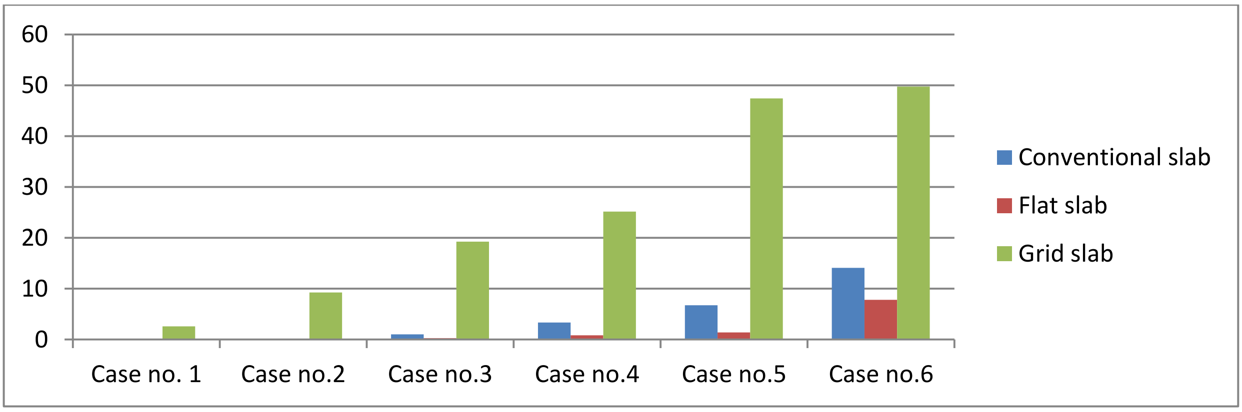


Figure No.12: Maximum Bending Moment (KN-M) in X-Direction

Table No.25: Story No. and Node No. at which Maximum Bending Moment in X-Direction

Story No. and Node No. at which Maximum Bending Moment in X Direction						
Different types of slab system	Case no. 1	Case no.2	Case no.3	Case no.4	Case no.5	Case no.6
Conventional slab	03&169	10&1331	10&336	10&391	10&366	10&391
Flat slab	01&67	01&67	10&361	10&391	10&366	10&391
Grid slab	03&289	03&355	03&415	03&445	03&385	03&1927

2) Maximum Bending Moment in Y-direction for different problem in earthquake zone III are shown in table no.26 and figure no.13.

Table No.26: Maximum Bending Moment (KN-M) in Y-Direction

Maximum Moment (KN-M) in Y Direction						
Different types of slab system	Case no1	Case no.2	Case no.3	Case no.4	Case no.5	Case no.6
Conventional slab	67.494	142.645	337.545	735.517	1161.793	1921.964
Flat slab	44.731	74.329	152.157	286.535	480.914	1101.54
Grid slab	70.79	325.123	681.8	1033.427	2550.399	2822.585

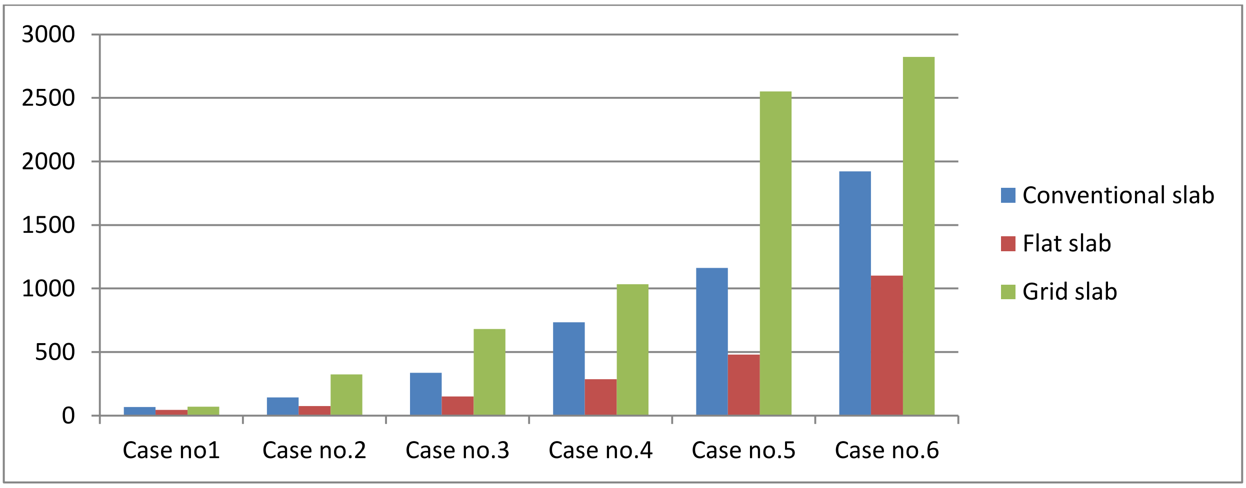


Figure No.13: Maximum Bending Moment (KN-M) in Y-Direction

Table No.27: Story No. and Node No. at which Maximum Bending Moment in Y-Direction

Story No. and Node No. at which Maximum Bending Moment in Y Direction						
Different types of slab system	Case no. 1	Case no.2	Case no.3	Case no.4	Case no.5	Case no.6
Conventional slab	01&62	01&235	00&27	00&27	00&22	00&21
Flat slab	04&191	04&191	01&62	01&62	01&65	00&21
Grid slab	02&218	01&236	00&20	00&21	00&20	00&22

Here 00 story stands for plinth level or ground floor

3) Maximum Bending Moment in Z-direction for different problem in earthquake zone III are shown in table no.28 and figure no.14.

Table No.28: Maximum Bending Moment (KN-M) in Z-Direction

Maximum Moment (KN-M) in Z Direction						
Different types of slab system	Case no. 1	Case no.2	Case no.3	Case no.4	Case no.5	Case no.6
Conventional slab	67.494	142.645	337.545	735.517	1161.793	1921.964
Flat slab	44.731	74.329	152.157	286.535	480.914	1101.54
Grid slab	70.79	323.406	681.482	1033.787	2550.399	2822.585

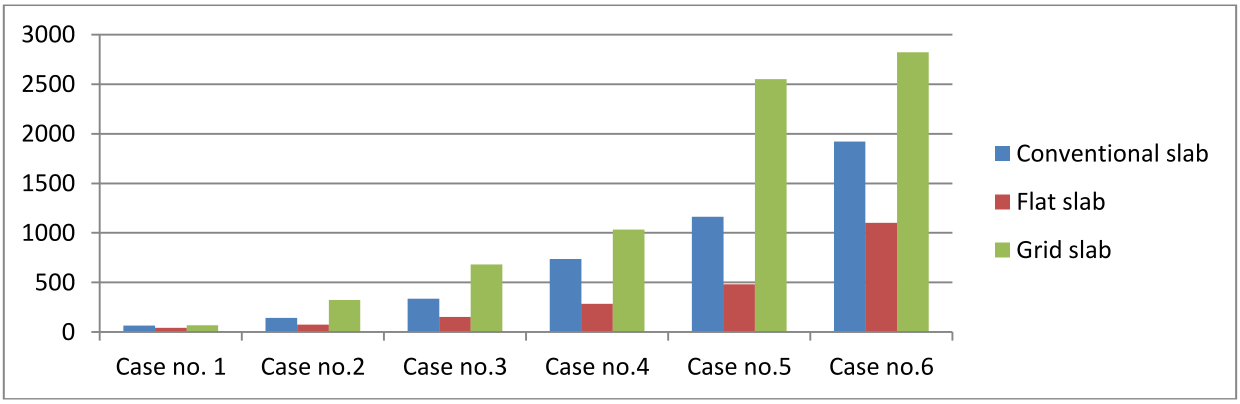


Figure No.14: Maximum Bending Moment (KN-M) in Z-Direction

Table No.29: Story No. and Node No. at which Maximum Bending Moment in Z-Direction

Story No. and Node No. at which Maximum Bending Moment in Z-Direction						
Different types of slab system	Case no. 1	Case no.2	Case no.3	Case no.4	Case no.5	Case no.6
Conventional slab	01&192	01&235	00&17	00&17	00&22	00&16
Flat slab	04&206	04&206	01&47	01&47	01&65	00&16
Grid slab	02&203	01&226	00&10	00&17	00&10	00&22

Here 00 story stands for plinth level or ground floor

4.2. Discussion and Inferences

The analysis of slab system shows the following inferences:

1) The quantity of concrete required for grid slab multi story building is maximum and for the flat slab multi story building is minimum for the same span/ grid size. But when we talk about the conventional slab system the quantity of concrete required more than the flab slab multi story building.
2) It is also seen that the quantity of concrete is increase with increase span / grid size of the structure for the same slab system. The quantity of concrete is least for smaller span of the structure and it is most for larger span of the structure.
3) The quantity of steel required for grid slab multi story building is maximum and for the flat slab multi story building is minimum for the same span/ grid size. But when we talk about the conventional slab system the quantity of steel required more than the flat slab multi story building.

4) It is also observed that the quantity of steel is increase with increase span/ grid size of the structure for the same slab system. The quantity of steel is least for smaller span of the structure and it is most for the larger span of the structure.
5) The cost of structure for flat slab multi story building is found to be least for all span / grid size of the structure and for the gird or coffered slab multi story building is found to be most for all span/ gird size of the structure.
6) The cost per meter square for all considered slab system is found to be changes with span/ grid size of the structure. In this case also cost per meter square is found to be least for flat slab system and most for grid slab system.
7) The maximum displacement is found to be most for grid slab system for same plan area of the structure and it is followed by conventional slab system and least for flat slab system in all direction of the structure.
8) The maximum force is found to be most for grid slab system and followed by conventional slab system and least for flat slab system for same plan area of the structure in all direction of the structure. It is seen in study that maximum force changes with change in plan area of the structure or found to be increase with increase span/grid size of the structure.
9) The maximum bending moment is also found to be most for grid slab system and followed by conventional slab system and least for flat slab system for same plan area of the structure in all direction of the structure. The same trend seen for maximum bending moment as that of shear force i.e. increases with the span/grid size of the structure.

5. Conclusion

Considering all the above inference made on analysis of all considered slab system multi story building, we finally conclude that the flat slab is most economical for all span consider in the analysis. In flat slab system it is found from the study that maximum displacement, maximum force and maximum bending moment in x, y and z direction is minimum but in case of grid slab system maximum displacement, maximum force and maximum bending moment is found to be maximum. The quantity of steel and concrete required for flat slab system is minimum but for the grid slab system is maximum.

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