COST OPTIMIZATION OF STRUCTURAL SYSTEMS FOR LARGE SPAN SLAB

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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., 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

IndexTerms - Structure Design and Analysis of slab system, Flat Slab System, Grid Slab System, Conventional Slab System, Large span slab.

I. INTRODUCTION

A building is a man-made structure with a roof and walls standing more or less permanently in one place. Buildings come in a variety of shapes, sizes and functions, and have been adapted throughout history for a wide number of factors, from building materials available, to weather conditions, to land prices, ground conditions, specific uses and aesthetic reasons. To better understand the term building compares the list of nonbinding structures. Buildings serve several needs of society – primarily as shelter from weather, security, living space, privacy, to store belongings, and to comfortably live and work. A building as a shelter represents a physical division of the human habitat (a place of comfort and safety) and the outside (a place that at times may be harsh and harmful).

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.
e) Post tension slab

Objective of the study

a) The sole purpose is to make economic structure by using such types of slab and so that overall cost of project wills reduce. The advantages of such types of structure are that it gives better look as well as safety as compare to other.
b) 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.
c) To study comparative costing of various types of slab system.

II. TYPES OF STRUCTURAL SYSTEM IN SLAB

2.1 Flat Slab

A reinforced concrete flat slab is one of the type which is used for long span, it is also called as beamless slab, is a slab supported directly by columns without intermediate beams or wall supports. Flat slab is a type of reinforced concrete construction that transmits the floor or roof load directly on columns without the aid of supporting beams. The flat slab is often thickened close to the supporting columns to provide adequate strength in shear and to reduce the amount of negative reinforcement in the support regions. Columns are flared at top to provide structure economical the portions of the slab near the columns are thickened. In some cases, the section of the column at the top as it meets the floor slab or a drop panel, is enlarged so as to increase, primarily the perimeter of critical section for shear and hence, increasing the capacity of the slab for resisting punching shear and to reduce negative bending moment at the support. Such enlarged or flared portion of Column at their tops are called the column head or the column capital. Flat slabs, now very common in the world, are originally an American development. The first patent for a recognizable reinforced concrete slab was given to C.A.P.Turner in year 1903, flat slab construction were described as "Mush rooms".

2.2 Grid Slab

Building construction is the engineering deals with the construction of building such as residential houses. In a simple building can be define as an enclose space by walls with roof, food, cloth and the basic needs of human beings. In the early ancient times humans lived in caves, over trees or under trees, to protect themselves from wild animals, rain, sun, etc. as the times passed as humans being started living in huts made of timber branches. The shelters of those old have been developed nowadays into beautiful houses. Rich people live in sophisticated condition houses.

Interconnected grid systems are being commonly used or supporting building floors bridge decks and overhead water tanks slabs. A grid is a planar structural system composed of continuous members that either intersect or cross each other. Grids are used to cover large column free areas and have been constructed in number of areas in India and abroad. Is subjected to loads applied normally to its plane, the structure is referred as Grid. It is composed of continuous member that either intersect or cross each other. Grids in addition to their aesthetically pleasing appearance provide a number of advantages over the other types of roofing systems.

2.3 Conventional Slab

A slab is a flat two dimensional planar structural element having thickness small compared to its other two dimensions. It provides a working flat surface or a covering shelter in buildings. It primarily transfers the load by bending in one or two directions. Reinforced concrete slabs are used in floors, roofs and walls of buildings and as the decks of bridges. The floor system of a structure can take many forms such as in situ solid slab, ribbed slab or pre-cast units. Slabs may be supported on monolithic concrete beam, steel beams, walls or directly over the columns. Concrete slab behave primarily as flexural members and the design is similar to that of beams.

2.4 Post Tension Slab

Post-tensioned concrete is a term heard more and more in the construction industry today. This method of reinforcing concrete enables a designer to take advantage of the considerable benefits provided by prestressed concrete while retaining the flexibility afforded by the cast-in-place method of building concrete structures.

Post-tensioning is simply a method of producing prestressed concrete, masonry, and other structural elements. The term prestressing is used to describe the process of introducing internal forces (or stress) into a concrete or masonry element during the construction process in order to counteract the external loads applied when the structure is put into use (known as service loads). These internal forces are applied by tensioning high-strength steel, which can be done either before or after the concrete is placed. When the steel is tensioned before concrete placement, the process is called pretensioning. When the steel is tensioned after concrete placement, the process is called post-tensioning. Because pretensioning requires specially designed casting beds, it is used generally in the precast manufacturing process to make simple shapes that can be trucked to a jobsite. Post-tensioning is done onsite by installing post-tensioning tendons within the concrete form-work in a manner similar to installing rebar.

2.5 Classification of Slab

1) Based of shape: Square, rectangular, circular and polygonal in shape.
2) Based on type of support: Slab supported on walls, Slab supported on beams, Slab supported on columns (Flat slabs).
3) Based on support or boundary condition: Simply supported, Cantilever slab, Overhanging slab, Fixed or Continues slab.
4) Based on use: Roof slab, Floor slab, Foundation slab, Water tank slab.
5) Basis of cross section or sectional configuration: Ribbed slab /Grid slab, Solid slab, Filler slab, Folded plate
6) Basis of spanning directions: One way slab – Spanning in one direction, Two way slab _spanning in two directions

III. ANALYSIS OF THREE DIFFERENT TYPES OF STRUCTURAL SYSTEM OF SLAB USING STAAD PRO.

The analysis of flat, grid and conventional slab structure has been done by using STAAD Pro. software package. The first step is to model geometry of the building. Before analysis all the required elements of the structure needs to be defined earlier like material properties, loads, load combinations, size of members, response spectrum etc. once the analysis has been done we can extract the results like displacement, storey shear, bending moment for comparing the performance of flat, grid and conventional slab building. The following steps are involved in the analysis by STAAD Pro.

Step-1 Defining dimensions of the plan
Step-2 Defining the members and material properties
Step-3 Assigning loads and load combinations
Step-4 Run check model to find errors
Step-5 Run analysis
Step-6 Extract results and discuss

Table 1: Structure Plan Details

- Number of stories G+3
- Height of each storey 3.50 m
- Total height of building 14.0 m
- Number of bay's along X- 5
- Number of bays along Y- 4

Table 2: Structure Element Details

- Columns 800x800, 300x900,
- Beams 600x750, 500x750,
- Flat slab 200mm Flat drop 450mm
- Conventional slab 175mm
- Grid slab 100mm

3.1 Loading Condition

3.1.1 Dead Load

It is taken as according to IS -875 (Part 1): 1987

a) Slab 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

d) Total weight of slab =5.625kN/ m^2

3.1.2 Live Load

It is calculated as per IS-875 (part 2):1987

Live load on floors = 1.5kN/ m^2

3.1.3 Earthquake Load

a) It is calculated as per IS-1893 (part 1): 2002
b) Seismic Definition
c) Earthquake zone – III (Z=0.16)
d) Response reduction factor – 5
e) Importance Factor – 1.5 (Very Important Building)
f) Rock and Soil Site Factor-1 (Medium Soil Building)
g) Type of Structure- 1
h) Damping - 5% (0.05)
i) Soil Type: Medium soil Natural Time Period (Ta) - $0.075h^{0.75}$(Ta = 0.73 sec)
j) Seismic weight of floor on working story's = 4kN/m^3
k) Seismic weight of top floor = 2kN/m^2

IV. RESULTS AND DISCUSSION

4.1 Quantity of Concrete

Table 1: Quantity of Concrete for Conventional slab, Flat Slab and Grid Slab

CONCRETE QUANTITY (m^3)			
Effective 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

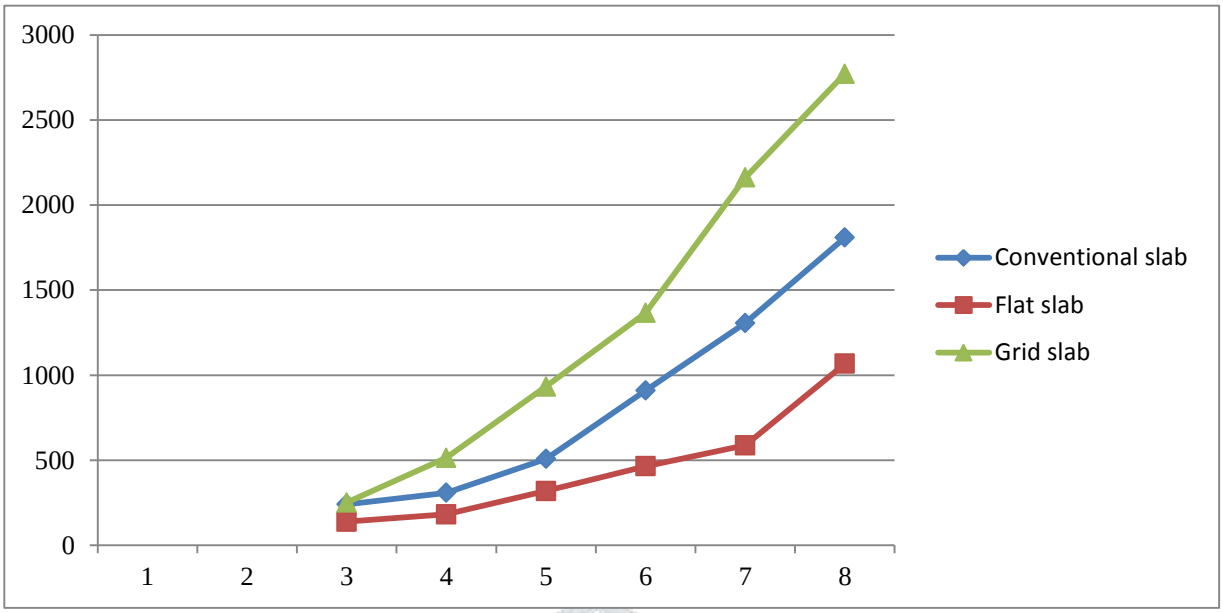

Figure 1: Quantity of Concrete for Conventional Slab, Flat Slab and Grid Slab

- 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.
- 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.

4.2 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 2 and figure 2.

Table 2: Quantity of Steel for Conventional Slab, Flat Slab and Grid Slab

STEEL QUANTITY (IN KGS)			
Span (m)	**Conventional slab**	**Flat slab**	**Grid slab**
1			
2			
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

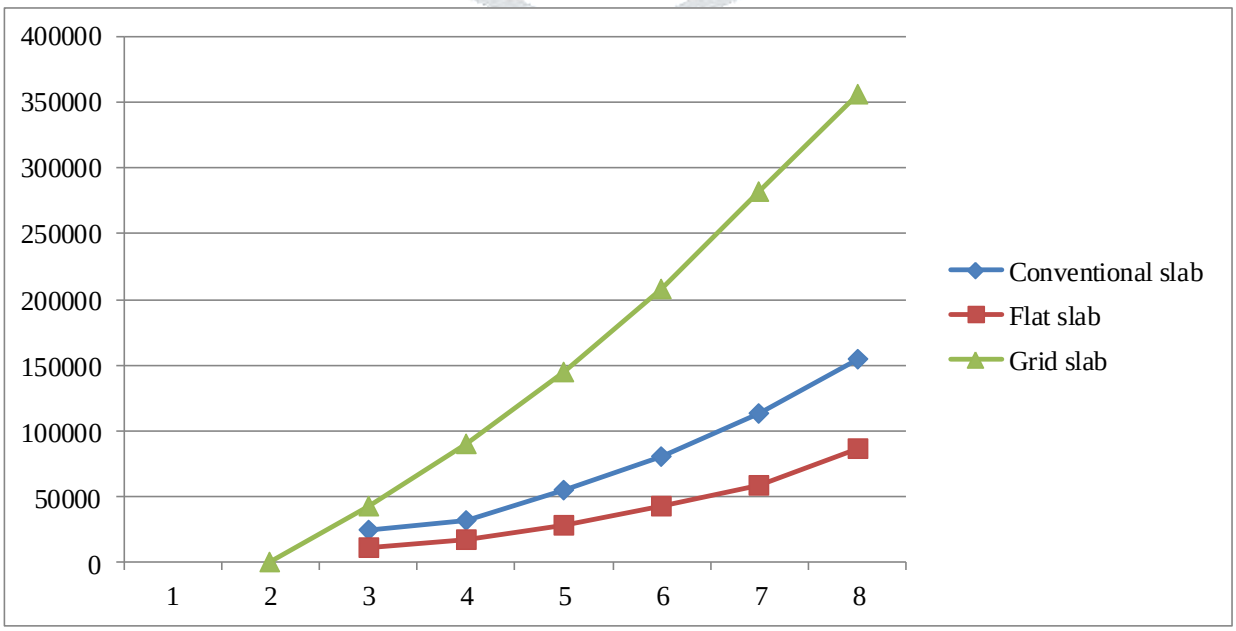

Figure 2: Quantity of Steel for Conventional Slab, Flat Slab and Grid Slab

- 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.
- 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.

4.3 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 3 and in figure 3.

Table 3: 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

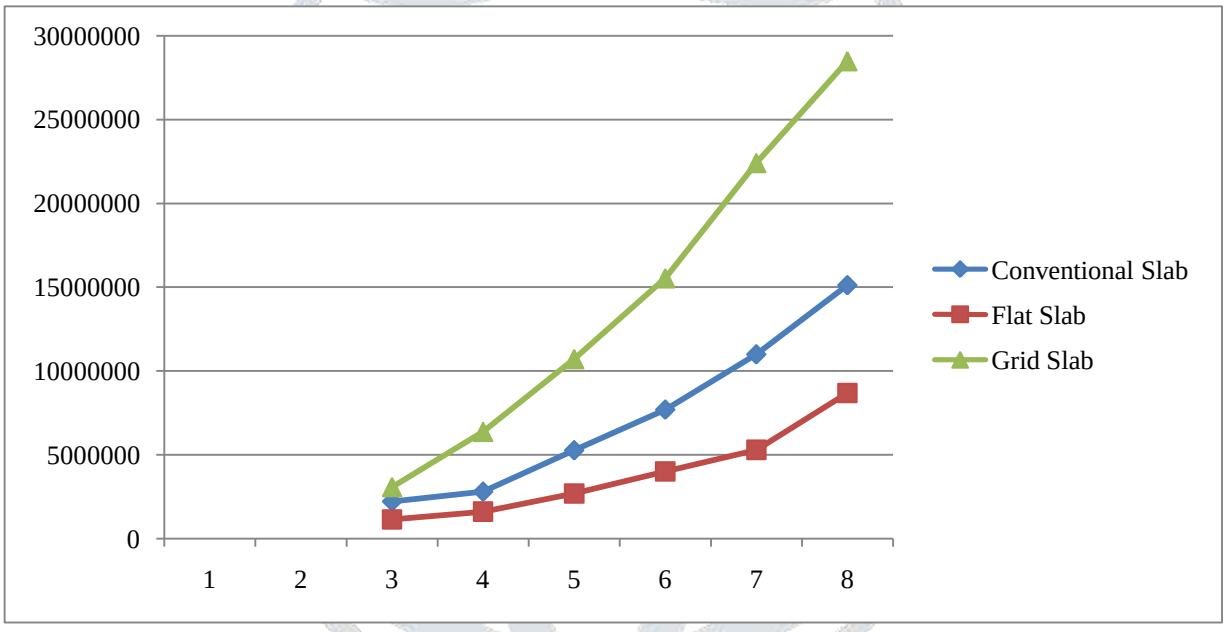

Figure 3: Cost of Structure for Conventional Slab, Flat Slab and Grid Slab

- The cost of structure for flat slab multi story building is found to be least for all spans / grid size of the structure and for the gird or coffered slab multi story building is found to be most for all spans/ gird size of the structure.
- 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.
- 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.
- 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.
- 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

V. 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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