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Choice of Type of R C Slab Floors for Construction of Multi-Storied Buildings.

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***Abstract:*— In construction of a multi-storey building while assessing the structural cost, it is evident that the bulk of the expenses is utilised for the floor slab construction. Hence the overall budget of a structure depends on the efficiency and expenditure of the floor slab system. Efficacy of the design and structural layout depends upon the quality of the material used, where as the actual cost of the structure may depends on factors such as speed of construction, availability of labour, competitive tendering, local market conditions, and equipment and cost of construction finance. Choice of the floor is very important for a building to meet the needs of major financial occupiers in today's market. In this paper, the different types of RC slab floor systems and their advantages and disadvantages are discussed.**

***Index Terms* :-- Flat slab, One-way, Precast slab, Ribbed slab,Two-way ,Waffle slab.**

I. INTRODUCTION

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

1.2 Importance of Slabs in Buildings

In multi-storied buildings slabs are important load bearing structural elements. A very high proportion of the total volume of concrete used for the construction of buildings is mainly used for the attainment of slabs (Table1). Optimal design is required since slabs have crucial impact on the total cost of the construction.

Table 1 - Percentage of the total concrete volume used for load bearing structural elements in buildings.

Structural element or load bearing member	Percentage of total volume of concrete
Foundations and ground supported slabs	15-25%
Bearing walls	3-6%
Columns	5-7.5 %
Floor Slabs with Beams	50-65%
Others	5-10%

1.3 Classification of Slabs

Slabs are mainly classified on the basis of many aspects such as-

i) Shape: Square, rectangular, circular and polygonal in shape.

ii) Support or boundary conditions: Simply supported, Cantilever slab, Overhanging slab, Fixed or Continues slab. on columns (Flat slabs).

iii) Type of supports: Slab supported on walls, Slab supported on beams, Slab supported on columns with or without drops and column heads (Flat slabs).

iv)Stressing steel reinforcement – Conventional reinforced concrete slab, Prestressed slabs.

v) Cross section or sectional configurations: Solid slab, Ribbed slab /Grid slab/Waffle slab, Filler slab, Folded plate, Precast Slabs and Composite Precast slabs.

vi) Spanning directions :

One way slab – Spanning in one direction.

Two way slab -Spanning in two direction.

vii) Utility: Roof slab, Floor slab, Foundation slab/slabs-on-ground or slabs-on-grade, Water tank slab.

1.4 Choice of Type of Slab Floor

There are many factors that influences the choice of type of slab for a particular floor. Predominantly economy of construction is a significant factor having geographical variables. Other factors includes the design loads, required spans, serviceability requirements, and strength requirements.

In the assessment of the structural cost of a multi-storey building, large proportion of the budget is assigned mainly for the floor slab construction. The efficiency and economy of the floor slab system affects overall economy of a structure. The quality of the material used indicates the competence of the structural layout and the design. The structural design that has proved to be competitive in one region may not always be competitive in another, since the actual cost bearing of the structure depends on factors such as speed of construction, local market conditions, competitive tendering, availability of labour and equipment and cost of construction finance.

There are some considerations for the choice of floor design that we have to keep in mind for a building to meet the needs of major financial occupiers in today's market:

i. The cost of concrete, reinforcement, formwork and workmanship expenses required in construction of cast-in-place concrete floors.

ii. The need for long spans to provide floor space uninterrupted by cores and columns.

iii. A maximum floor-to-floor height which allows adequate space for services and ducts, balanced against planning pressure to limit overall building height.

iv. An adaptable floor structure which can accommodate future tenant alterations with maximum speed and minimum disruption.

The types of floors and the reasons for choosing them are given below.

1.5 Cast-in-place reinforced concrete floor systems

A concrete slab can be cast in two ways: It could either be prefabricated or cast in situ

Prefabricated concrete slabs are cast in a factory and then transported to the site ready to be lowered into place between steel or concrete beams.

The cast-in place concrete are most commonly used for construction of structural element such as foundation, columns, beams and floors. On the behaviour of structural actions floors can be classified as two way or one way slabs.

1.5.1 Two Way Slabs Floors

A two-way slab is a structure where a rectangular slab is supported on all the sides and the longer span-to-shorter span ratio is less than two. It spans in both the orthogonal directions and are supported by beams all around or by rectangular column grids where the load will be carried in both the directions. Where the two way slab is directly supported on columns are called flat slabs, total load will be carried in each direction therefore main reinforcement is provided in both directions for two way slabs.

Rectangular two-way slabs can be differentiated into the following types.

Flat plates**:** Flat plates shown in Figure 1a, does not have any beams, drop panels or column capitals. There can be edge beams called as spandrel beams that are designed for torsion.

The key feature of the dropless floor is its Flush soffit which requires only simple formwork and is very easy to construct. This floor has a minimum overall depth that allows great flexibility for locating horizontal services. Flat Plate floor system are economical for spans 5m to 7.5 m and lighter loading to control shear in the vicinity of the column supports and the need to control long-term deflection limits.

Flat slabs: Flat slabs have drop panels and /or column capitals and not the beams. In some structures there may be peripheral beams at the outer edges.Drop panels give extra strength and stiffness in the column region and minimizes the amount of concrete at mid-span. As per IS 456:2000, the drop when provided shall be in rectangular in plan, and have a length in each direction not less than one third of panel length in that direction. Thickening of the slab near the column with *drop panels* (Figure 1b & d)or flaring the top of the column to form a *column capital* (Figure 1c & d)provides the shear transfer to the column.Nowadays column capitals as shown in Figure 1c &d are rarely seen due to the high construction cost. The R C flat slabs are used for loads of 5 kPa and for spans of 6m to 9m.

The main feature that differentiates flat plates from flat slabs is that flat plate does not contain both column capitals or drop plates on the other hand flat slab contain any one of these or both. The advantages and disadvantages of two way Flat Slabs are given in Table 2. In flat plate/slab design, the longer spans is used to find depth of slab and slab deflection.

Table 2 -The advantages and disadvantages of two way Flat Slabs.

Advantages	Disadvantages
1. i. Flexibility in room layout 2. ii. Saving in building height 3. iii.Shorter construction time 4. iv.Ease of installation of MEP services 5. v. Use of prefabricated welded mesh 6. vi. Buildable score	1. i.Larger amount of *in situ* concrete require than other flooring systems, resulting in a heavier floor. 2. ii.Can have deflection and vibration issues, especially for longer spans, requiring additional reinforcement

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Figure 1a. Flat Plate Slab resting directly on Column (Source https://www.nexus.globalquakemodel.org)

Figure 1b. Flat Slab with Drop Panels

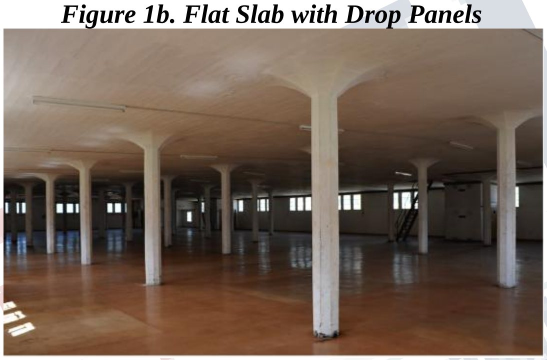

Figure 1c. Flat slab with column head (Source https://en.wikipedia.org)

Figure 1d. Flat slab with drop panel and column head (Source http://civildigital.com)

Figure 1. Types of Flat Slab (Source

Two-way slabs with beams: The main feature of these slabs is the beams are provided in orthogonal directions between the columns. The slab is either supported by the beams or by wide and shallow/band beams (Figure 2). In two way slab-beam design, the shorter spans is used to find depth of slab and slab deflection.

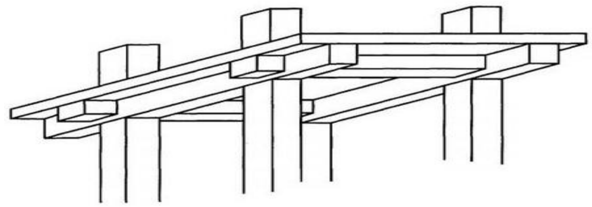

Figure 2.Two-way slabs with beams(www.dailycivil.com)

Two Way Waffle slabs : The column supports directly the Ribbed floors consisting of equally spaced ribs. It is of two types, the one is ribbed slab (Figure 5) which is one way spanning system and the another one is waffle slab (Figure 3) which is two-way ribbed system. The shear transfer of loads from the slab to the columns requires a solid drop panel and load bearing walls for shear and moment resistance.

Main drawback of this structure is its formwork costs and the low fire rating therefore not recommended usually. To attain a 2-hour fire rating, 120-mm-thick slab with a minimum rib thickness of 125 mm for continuous ribs is essential. A rib thickness of greater than 125 mm is usually required to accommodate tensile and shear reinforcement. Ribbed slabs are appropriate for medium to heavy loads and spans from 7.5m to 12m. The advantages and disadvantages of two way Waffle/Ribbed slabs are given in Table 3.

Table 3- The advantages and disadvantages of two way Waffle/Ribbed slabs.

Advantages:	**Disadvantages:**
1. i.Savings on weight and materials 2. ii.Long spans 3. iii.Attractive soffit appearance if exposed 4. iv.Economical when reusable formwork pans used v.Vertical penetrations between ribs are easy	1. i.Depth of slab between the ribs may control the fire rating 2. ii.Requires special or proprietary formwork 3. iii.Greater floor-to-floor height 4. iv. Large vertical penetrations are more difficult to handle

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Figure 3a. Reinforcement Details.
(Source http://recentpastnation.org)

Figure 3b. Waffle / Ribbed Slabs
(Source http://www.designboom.com)

Figure 3c. Waffle / Ribbed Slabs
(Source http://www.worldarchitecturenews.com)

Figure 3d. Waffle Slab with Column head.
(Source http://sketchucation.com)
Figure 3. Two-Way Ribbed slabs /Grid slabs/Waffle slabs

1.5.2 One-way slabs

A one-way slab is a structure where a rectangular slab is supported by two parallel sides only by beams and other two edges are free (Figure 4). The structural action is only along the direction perpendicular to the beams as it is supported on two opposite side only. Total load is distributed in the direction perpendicular to the supporting beam. In one way slab design, the spans between beams is used to find depth of slab, structural response like bending moments, shear force and slab deflection. This type of slabs are economical when these slabs are supported along longer directions.

The slab is also considered as one way slab spanning in shorter direction when a slab is supported on all the four sides and the ratio of longer span (ly) to shorten span (lx) is greater than two. In this type of slabs, the shorter span is used to find structural response.

In one way slabs, the main reinforcement is provided along the span i.e. along the plain of bending and distribution/temperature steel is provided in other orthogonal direction. For fast construction the one-way spanning solid slab between the beams facilitates the use of table forms.

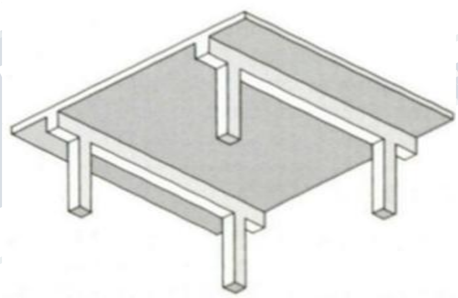

Figure 4a. One Way slabs supported on two parallel beams. (Source http://www.arch.ttu.edu)

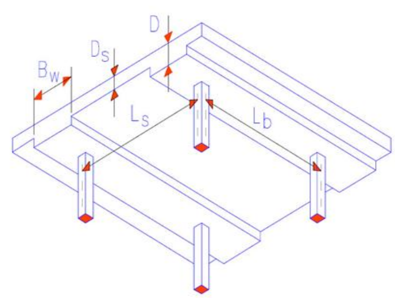

Figure 4b. One Way slabs supported on two parallel band beams. (Source http://www.vhptsystem.com)
Figure 4. Types of One-Way slabs supported by opposite beams

One Way Slabs supported by series of beams (One Way Ribbed slabs)

The quantity of concrete and reinforcement, and consequently the weight of the floor can be reduced by providing series of ribs to the soffit of the floor slab (Figure

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5).. The ribs should be positioned away from the column lines while flying form panels are used. The deeper and stiffer floor permits longer spans to be used. Standard modular, re-usable formwork minimises complexity of formwork. Ribbed slab floors are very much compliant for a range of service openings .

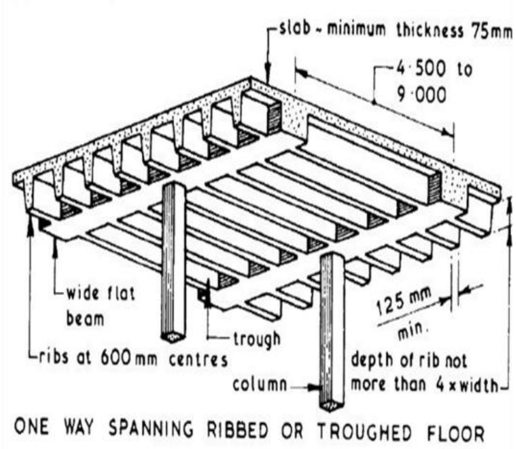

Figure 5. One Way Spanning Ribbed Slab (Source http://www.slideshare.net)

1.6 Precast concrete floor systems

Precast slabs are of two types: Precast solid slabs (Figure 6a) and Precast hollow core slabs(Figure 6b) both offers the advantage of off-site manufacture,with a reduction in site labour and site formwork. The prestressed slab offers the additional benefits of longer spans and higher load capacity. The hollow core slab is a very common type of precast floor (Figure 6 b). A flush soffit is formed by relatively light weight units. A shear key between units ensures load sharing and the construction is commonly capable of developing diaphragm action without the need for a structural topping. The precast units are easily removable and can accommodate a wide range of floor openings.

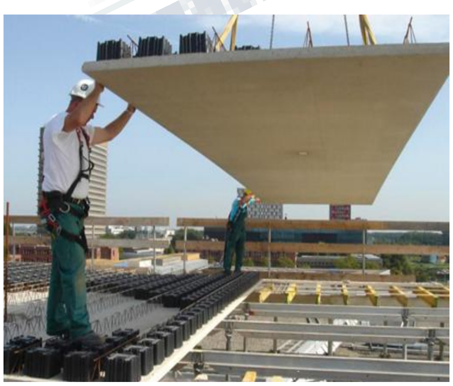

Figure 6a. Precast Solid Slab

Figure 6b. Precast Hollow Core Slab(Source http://www.jpcarrara.com)
Figure 6. Precast Slab

1.7 Preliminary sizing of Non-prestressed concrete members:

Preliminary member sizes must be assumed before analyzing the floor system by the designers. It is ensured that the deflection requirements of respective Section of Building codes and Standards (Table4) are fulfilled by determining the thickness of the slab and/ or beam.

Table 4– Sections/Clauses for Span to Depth Ratio or Minimum thickness for Non prestressed concrete members to ensure deflection criteria by various Building codes and Standards.

Sr. No.	Building Code and Standard	Section/Clause for Span to Depth Ratio				Deflection limitation	Remark
		Beam	One-Way Slabs	Two Way Slabs			
				Slab-Beam	Flat Slab		
1	ACI 318-14	9.3.1	7.3.1	8.3.1.2	8.3.1.1	24.2	Note1
2	BS 8110-1:1997	3.4.6	3.4.6	3.4.6	3.7.1..6, 3.7.8, 3.4.6	Section 3 of BS 8110-2:1985	Note2
3	CSA A23.3-04	9.8, 13.2.6	9.8	13.2.5	13.2.3 13.2.4	9.8.5.3	Note1
4	Eurocode 2	7.4.2	7.4.2	7.4.2	7.4.2	7.4	Note2
5	IS 456:2000	23.2.1	24.1	24.1	31.2.1	23.2	Note2
6	NZS 3101:Part1: 2006	2.4.3a	2.4.3a	2.4.3c	2.4.3b	NA	Note1

Note1: Overall depth of member is considered

Note2 : Effective depth of member is considered

1.8 Conclusion

The overall budget of a building structure depends on the efficiency and expenditure of the floor slab system. The choice of the floor is very important for a building to meet the needs of major financial occupiers in today's market. While making the choice of floor system for long spans, the factors like buildability, aesthetics, sustainability, health and Safety, cost, buildingservices integration and adaptability shall be considered. In this paper, the different types of RC slab floor systems and their advantages and disadvantages are discussed.

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