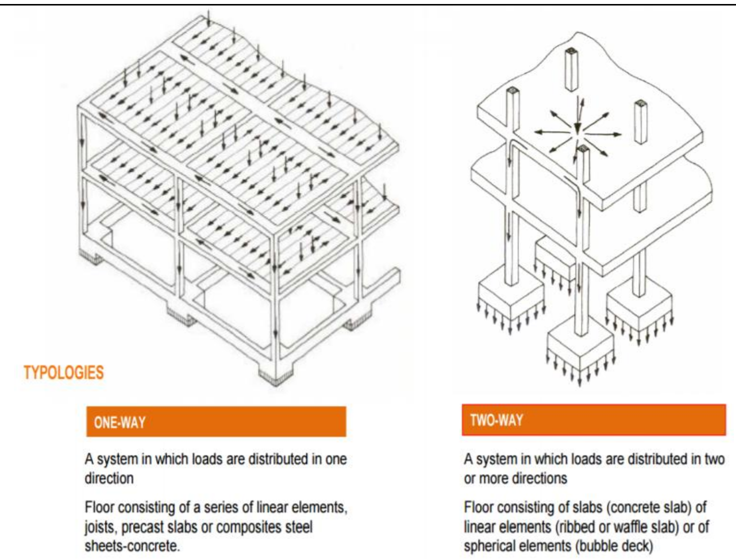
Types of slabs, Design of Slabs and Yield Line Theory

Different floor and roof slab types:

Floor and Roof Slab System 1. One way Slab Supported by Monolithic Concrete Beam 2. One way Slab supported by Steel Beam with shear connectors 3. One way Slab with cold form steel decking as form and reinforcement 4. One way joist floor (also known as ribbed slab) 5. Two way supported by edge beam 6. Flat Slab with column capital or drop panel or both but without any beam. 7. Flat Plate without column capital, drop panel and without any beam. 8. Two way joist with or without beams on the column line.	

ONE-WAY

JOIST SLAB
- CONCRETE:
  - PARTLY PRECAST: REINFORCED JOIST (LATTICE-REINFORCED JOIST)
  - PARTLY PRECAST: PRESTRESSED JOIST
  - PRECAST: SELF-SUPPORTING JOIST
  - SITE-CAST JOIST
- METAL SECTIONS OR PROFILES
- TIMBER

PRECAST CONCRETE FLOOR SLABS:
- PRESTRESSED HOLLOW-CORE SLAB
- RIBBED SLABS, ¶ SECTION OR DOUBLE-T (TT)
- PRECAST PRE-SLABS: LATTICE GIRDER REINFORCED SLAB
- Among others...

COMPOSITE FLOOR SLAB WITH PROFILED STEEL SHEETING

TIMBER FLOORS

TWO-WAY

SLAB
- SOLID REINFORCED CONCRETE SLAB
- SOLID POSTSTRESSED CONCRETE SLAB
- HOLLOW SLABS (LIGHTENED SLABS)

SITE-CAST RIBS (NERVS): WAFFLE-SLAB (OR RIBBED SLAB)

Others : PRECAST PANELS + bubble deck

Direct Design Method

Introduction

ACI318 Code provides two design procedures for slab systems:

13.6.1 Direct Design Method (DDM) For slab systems with or without beams loaded only by gravity loads and having a fairly regular layout meeting the following conditions:

13.6.1.1 There must be three or more spans in each directions.

13.6.1.2 Panels should be rectangular and the long span be no more than twice the short span.

13.6.1.3 Successive span lengths center-to-center of supports in each direction shall not differ by more than 1/3 of the longer span.

13.6.1.4 Columns must be near the corners of each panel with an offset from the general column line of no more 10% of the span in each direction.

13.6.1.5 The live load should not exceed 3 time the dead load in each direction. All loads shall be due gravity only and uniformly distributed over an entire panel.

13.6.1.6 If there are beams, there must be beams in both directions, and the relative stiffness of the beam in the two directions must be related as follows:

$$0.2 \le \frac{\alpha_1 l_2^{\,2}}{\alpha_2 l_1^{\,2}} \le 5.0$$

where

$$\alpha = \frac{E_{cb} I_b}{E_{cs} I_s}$$

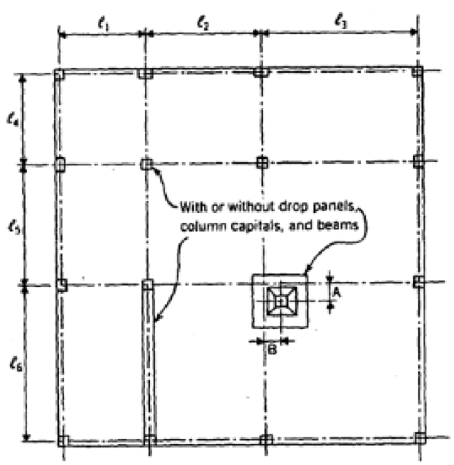
is the ratio of flexural stiffness of beam sections to flexural stiffness of a width of slab bounded laterally by center lines of adjacent panels (if any) on each side of the beam.

1. Three continuous spans in each direction, minimum.
2. Rectangular panels with aspect ratio ≤ 2.0. e.g., $\frac{\ell_6}{\ell_1} \le 2.0$.
3. Span lengths differ by $\frac{1}{3}$ or less of longer span. e.g., $\frac{\ell_5}{\ell_6} \ge 0.67$.
4. Column offset a maximum at 10%. e.g., $A \le 0.1\,\ell_6$.

5A. Gravity loads only, uniformly distributed, not lateral loads.

5B. Live load ≤ 3 × dead load.

6. Beam stiffness: $0.2 \le \frac{\alpha_1 \ell_2^2}{\alpha_2 \ell_1^2} \le 5.0$.
7. No moment redistribution as permitted by ACI Code Section 8.4.



In the Direct Design Method, the Static moment, M_0, is calculated for each panel. This moment is then divided between positive and negative moment regions using arbitrary moment coefficients and the positive moments are adjusted to reflect pattern loadings. In the Elastic Frame Method, all of this is accomplished by frame analyses.

Equivalent frame method may be used in those cases where:

• slab layout is irregular and those not comply with the restrictions stated previously in Direct Design Method
• where horizontal loading is applied to the structure
• where partial loading patterns are significant because of the nature of the loading
• high live load/dead load ratios.

Slab Analysis methods:

1. Elastic theory
2. Elastic-plastic analysis
   – Finite element analysis (FEA)
3. Approximate methods of analysis
   a. Direct design method
   b. Equivalent frame method
   c. Assignment of moments

4. Limit analysis (essentially Plastic analysis)
   – Yield Line Theory- – Lower & upper bound analysis

Yield Line Theory

Define yield line theory.

The theory is based on the principle that:
Work done in yield lines rotating = work done in loads moving
The yield line theory is largely based upon the yield lines that develop in any reinforced concrete slab (rectangular, circular, square or any other geometrical shape in plan) before its final collapse. This stage reaches under loads approaching collapse load or ultimate load that the slab can carry. The collapse loads, movements and shears can be calculated from the crack pattern developed in slab, under idealized support conditions and only uniformly distributed loads.
Yield Line Design demands familiarity with failure patterns, i.e. knowledge of how slabs might fail. This calls for a certain amount of experience, engineering judgement and confidence, none of which is easily gained. Yield Line Design tends to be a hand method. This may be seen as both an advantage and disadvantage. Each slab has to be judged on its merits and individually assessed. The method allows complex slabs to be looked at in a simple way, and, in an age of computers, it gives an independent method of analysis and verification. This is especially important for those who are becoming disillusioned with the reliance placed on Finite Element Analysis. They see a need to impart greater understanding and remind designers that reinforced concrete does not necessarily behave in an elastic manner.

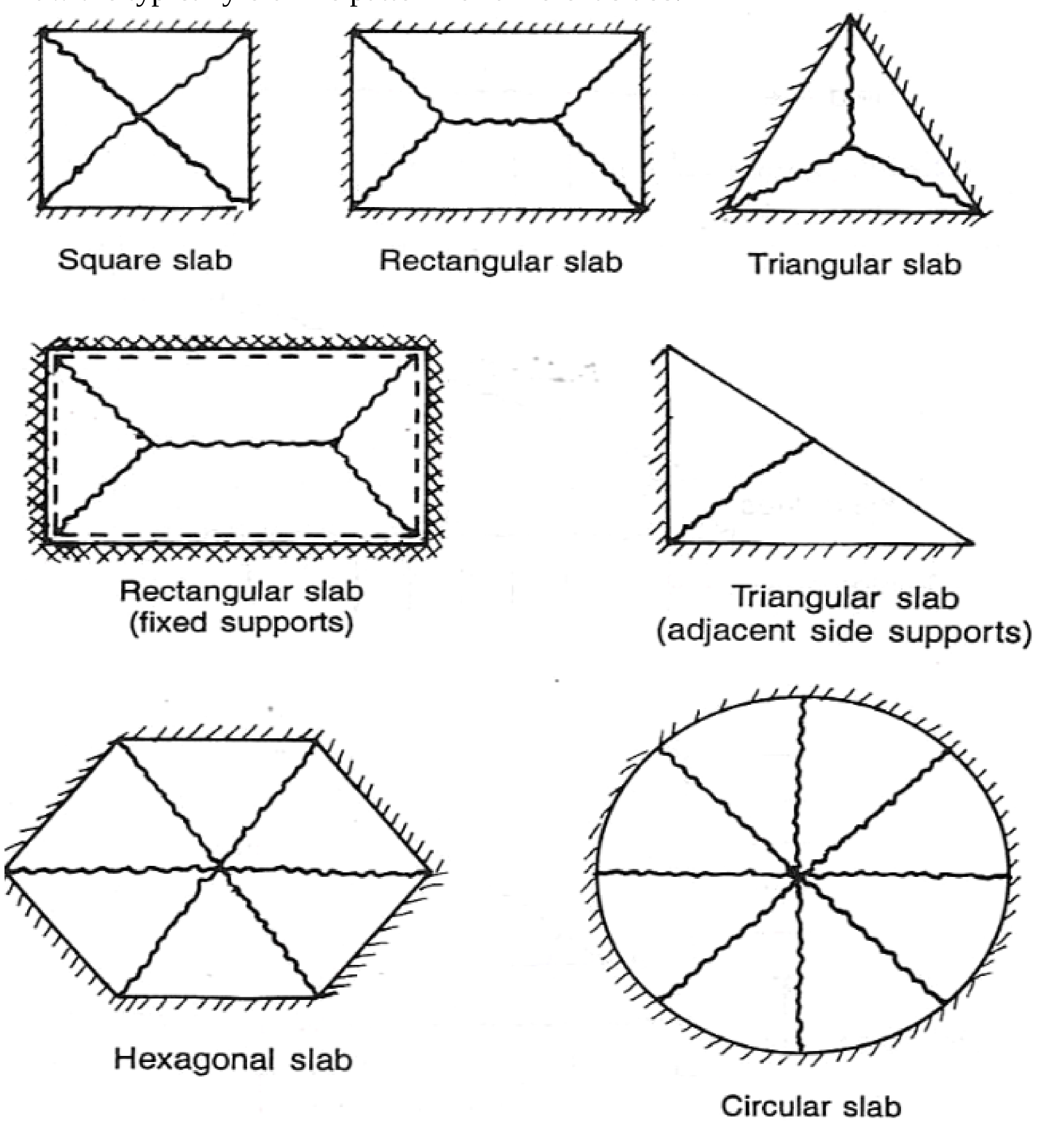
Yield Line Analysis: Yield line theory permits prediction of the ultimate load of a slab system by postulating a collapse mechanism which is compatible with the boundary conditions. Slab sections are assumed to be ductile enough to allow plastic rotation to occur at critical section along yield lines.
1.Postulate a collapse mechanism compatible with the boundary conditions
2.Moment at plastic hinge lines $\approx$ *Ultimate moment of resistance of the sections*
3.Determine the ultimate load

4.Redistributions of bending moments are necessary with plastic rotations.

What are the characteristic features of yield lines?

- *Yield lines end at the supporting edges of the slab*
- *Yield lines are straight*
- *A yield line or yield line produced passes through the intersection of the axes of rotation of adjacent slab*
- *Axes of rotation generally lie along lines of supports and pass over any columns.*

Draw the typical yield line pattern for different slabs.



Typical yield line patterns in reinforced concrete slabs.