SLABS

Section

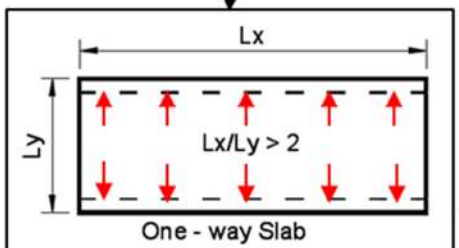
3.5

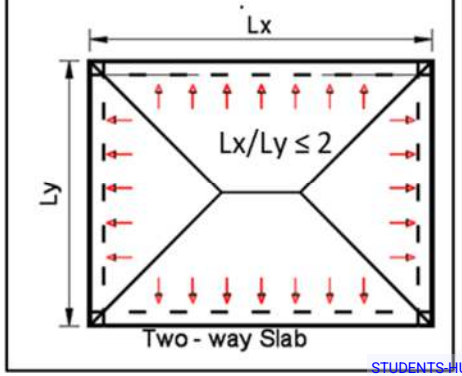
Concrete Slabs

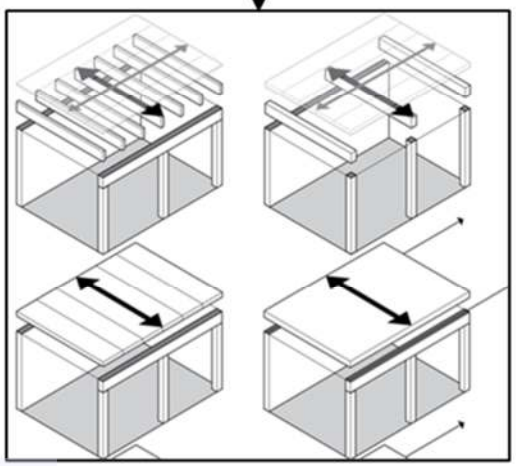
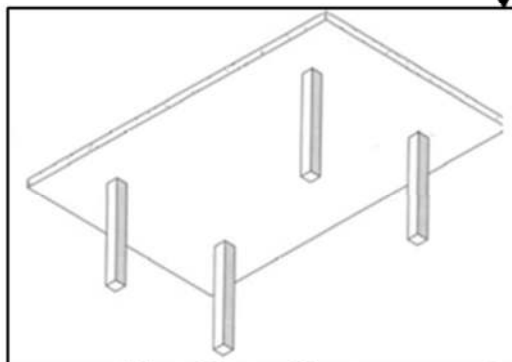
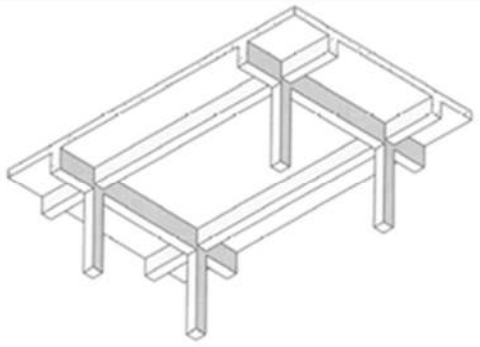
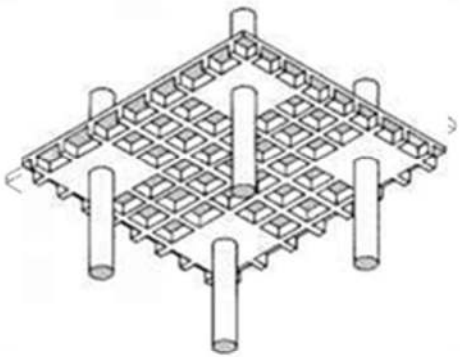
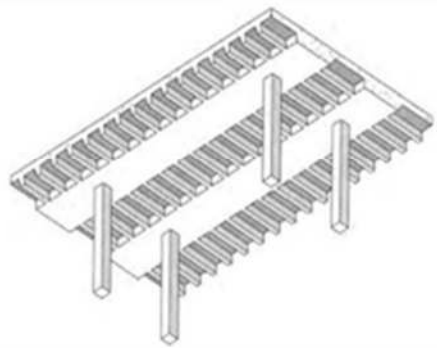
- Concrete slab is a molded layer of plain or reinforced concrete, flat, horizontal (or nearly so), usually of uniform but sometimes of variable thickness, and supported by beams, columns, walls, other framework, or on the ground.
- A suspended slab (or structural slab) spans between supports and must be reinforced to resist bending moments calculated from statics based on the magnitude of load and span. There are one-way slabs, two-way slabs, waffle slabs, flat plates, flat slabs, and many other slab types.
- The floor system (slab) heavily contributes to the building cost, especially in low-rise buildings.
- The need to minimize costs normally favors the use of rectilinear arrangements which require simple patterns of reinforcement and formwork.

Slabs Classification

SLABS CLASSIFICATION

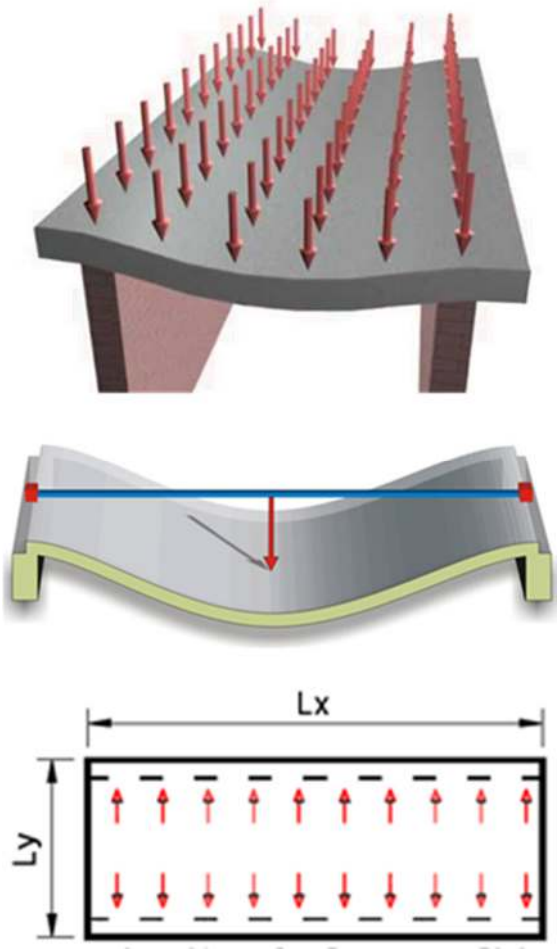
- Load transformation (One-way/ Two way)
  - Geometry
    - 

    - 

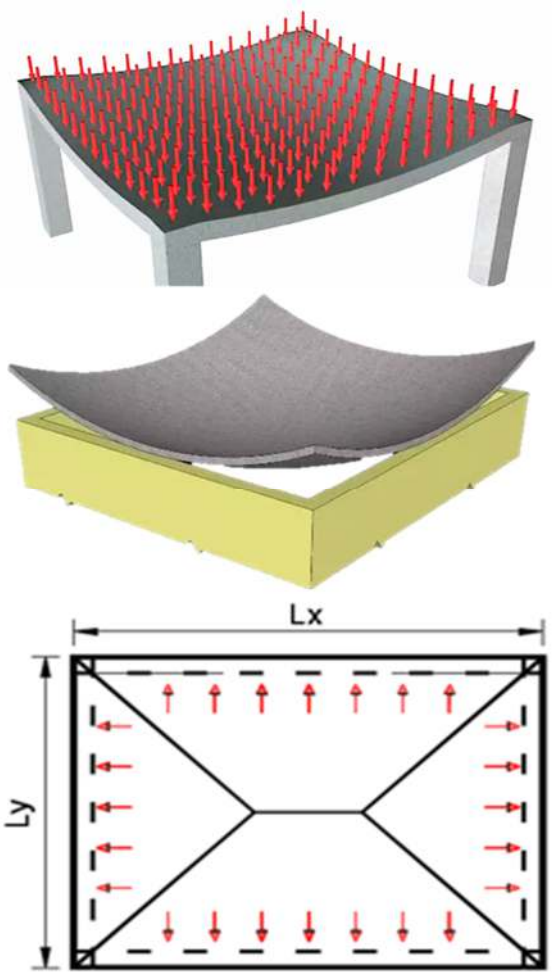
  - Method of construction/ Material
    - 
- Slap Type
  - 
    Flat Plate System
  - 
    Beam-Supported Slab System
  - 
    Waffle Slab System
  - 
    One-way Joist Systems

One-way VS. Two-way slab

One-way slab curves and carry load in one direction. Lx/Ly > 2. Load distributed to the longer edges

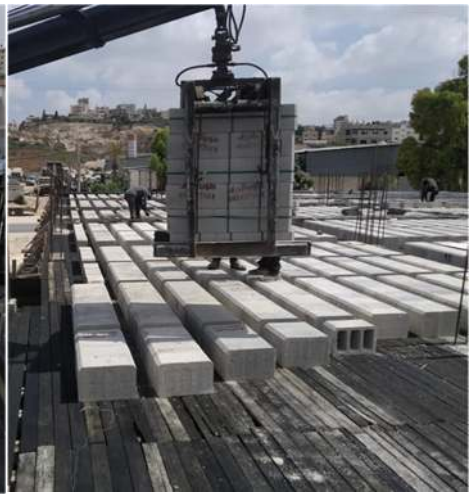


Two-way slab curves and carry load in two directions. Lx/Ly ≤ 2. Load distributed to all edges



One-Way Joist System (rib slab)

Rib slab during construction

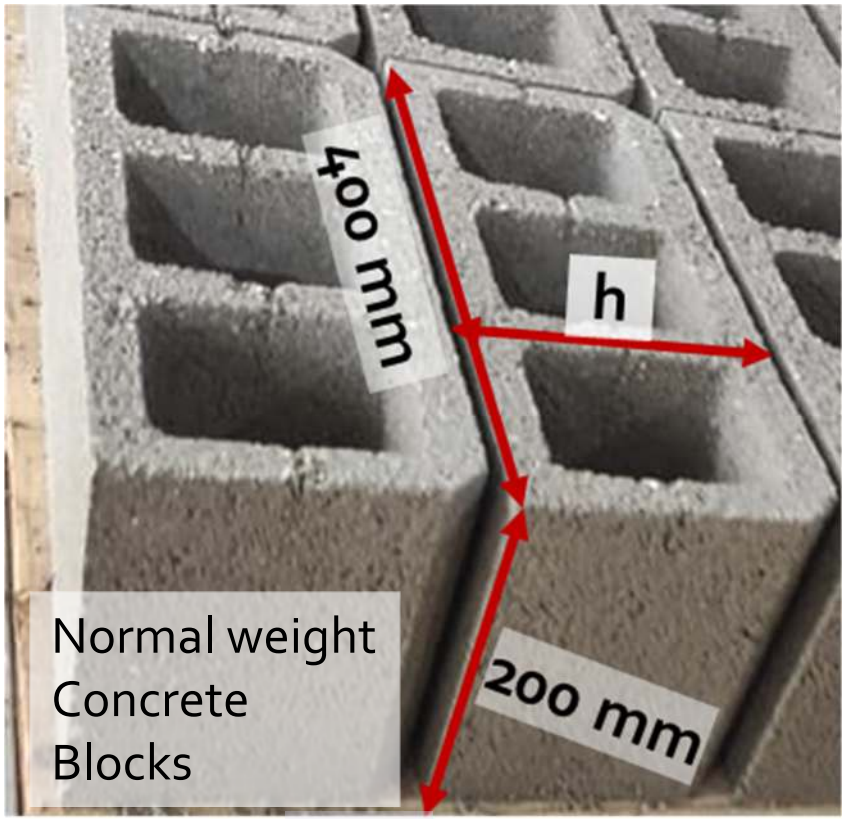


Rib slab from bottom after pouring

A one-way joist system consists of evenly spaced concrete ribs (joists) spanning in one direction, a reinforced concrete slab cast integrally with the joists, and beams spanning between the columns perpendicular to the ribs.

One-Way Joist System (Rib Slab)

- Ribs can be formed using normal weight concrete blocks; light weight blocks (Ytong); Polystyrene concrete blocks; clay block; removable metal or plastic forms.
- Available block size
  - Normal weight concrete blocks: h= 170, 200, 240, 300, 320
  - Ytong blocks: can be fabricated as required



Normal weight Concrete Blocks

Polystyrene concrete blocks

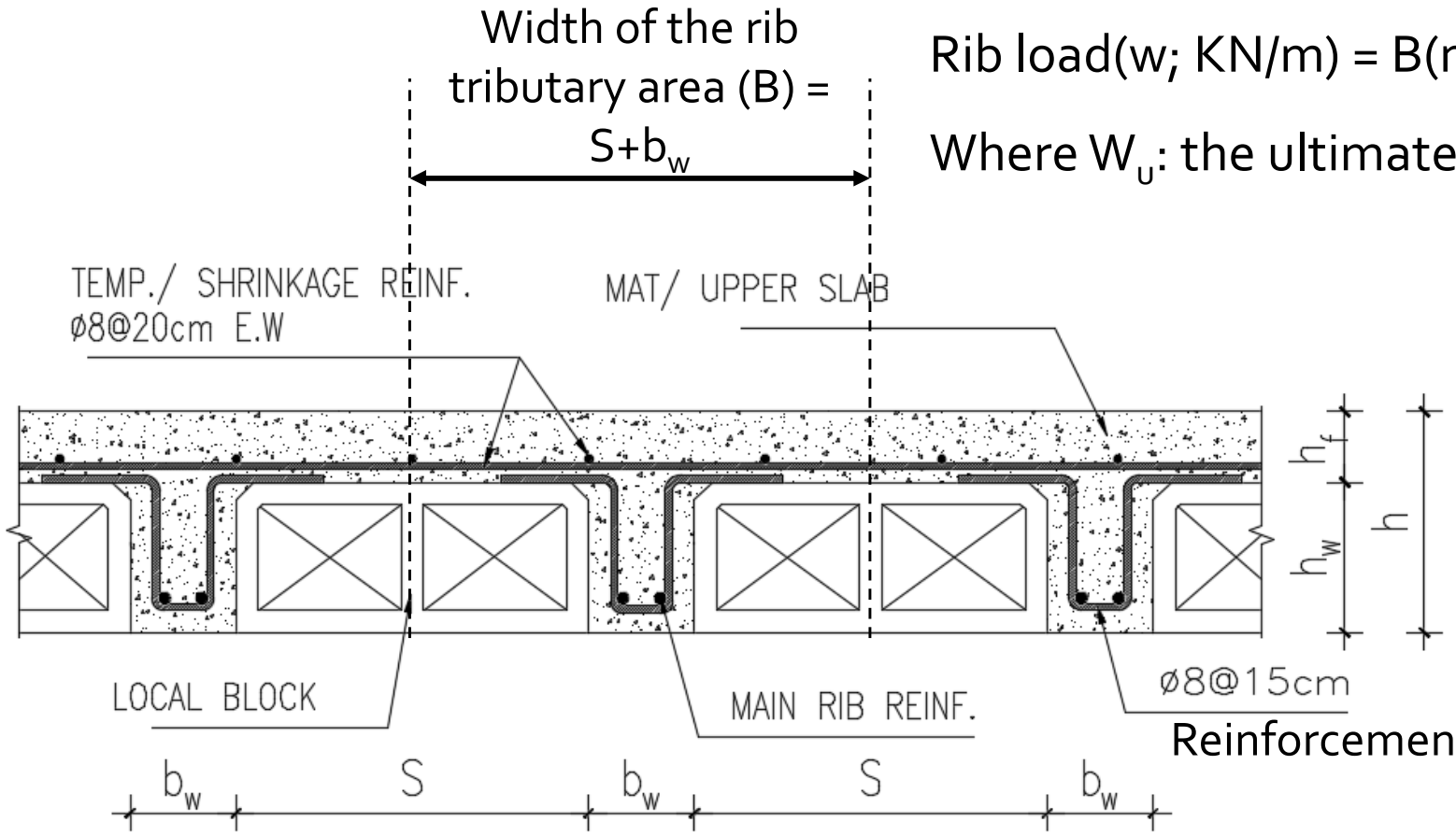
Clay Block

One-Way Joist System (rib slab)

Rib slab requirements ACI -318 (9.8.1)

$b_w \geq 100mm$; $h \leq 3.5\, b_w$; $S \leq 750$ mm; $h_f \geq 40$ mm and $\geq S/12$

Typical section



Rib load(w; KN/m) = B(m) x W_u(KN/m²),

Where W_u: the ultimate load of the slab

One-Way Joist System (rib slab)

Structural Analysis Procedure

- Development of structural models for the ribs. Ribs can be regarded as horizontal elements pined at the center of the supporting beams.
- Establishing rib depth in compliance with serviceability requirements of the design code.
- Distribution of slab loads (both dead and live) to the ribs based on their respective tributary areas.

Serviceability requirements of ACI- 318

Table 9.3.1.1—Minimum depth of nonprestressed beams

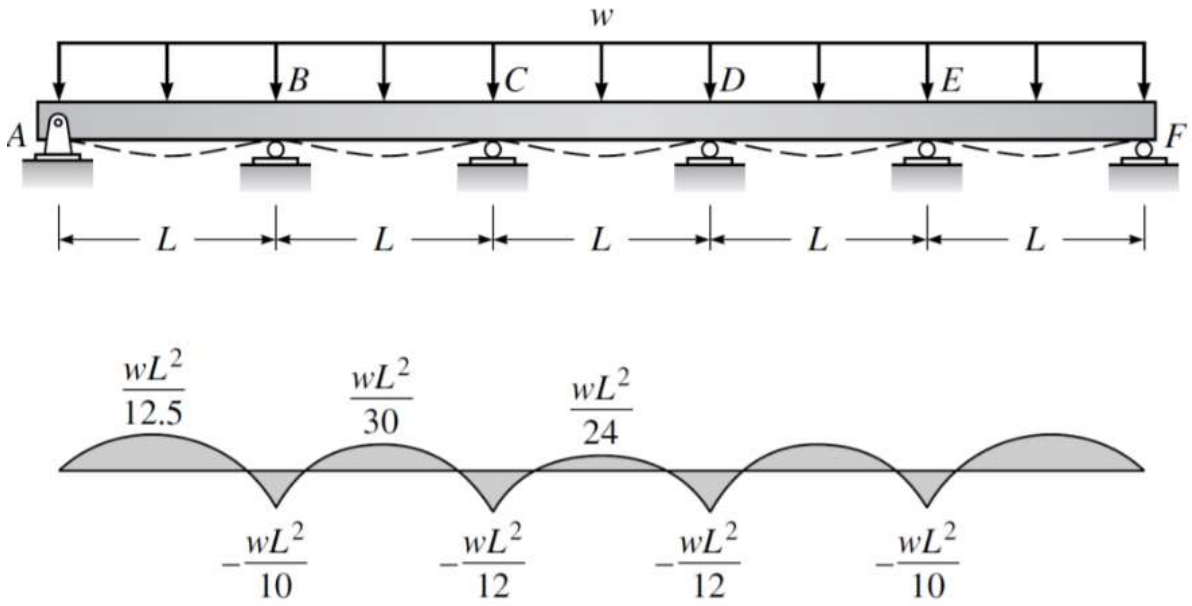
Support condition	Minimum h[1]
Simply supported	$\ell/16$
One end continuous	$\ell/18.5$
Both ends continuous	$\ell/21$
Cantilever	$\ell/8$

[1]Expressions applicable for normalweight concrete and f_y = 420 MPa. For other cases, minimum h shall be modified in accordance with 9.3.1.1.1 through 9.3.1.1.3, as appropriate.

One-Way Joist System (rib slab)

Structural Analysis Procedure

- Computation of moment and shear diagrams for the ribs. These diagrams are used for designing the ribs as either t-shaped or rectangular elements.

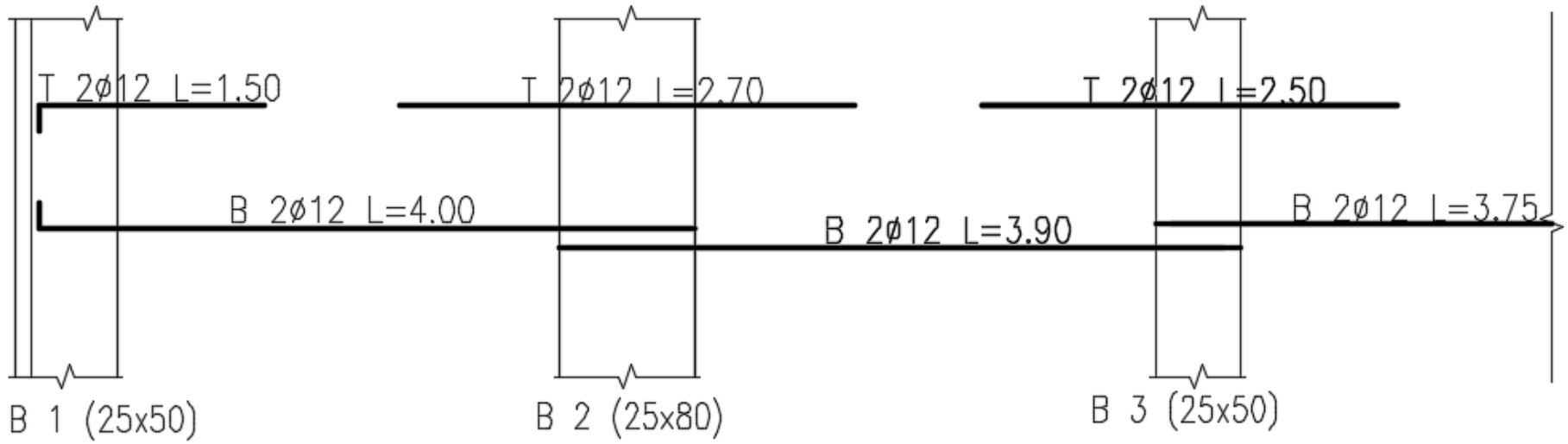


Typical deflected shape and moment diagram of a continuous rib of equal spans

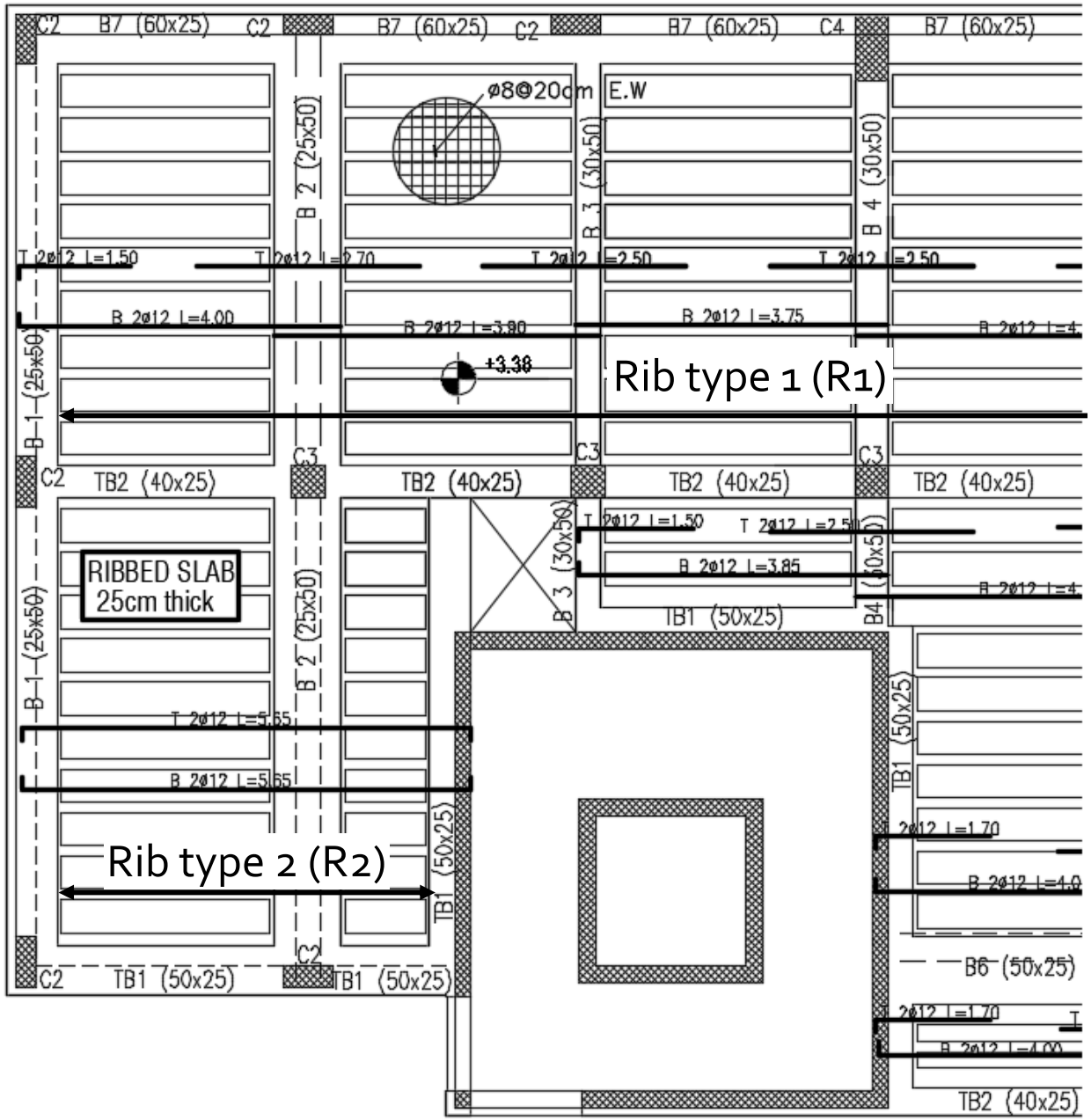
One-Way Joist System (rib slab)

Typical Reinforcement

- Typical Rib is reinforced by bottom reinforcement at mid of the span and top reinforcement at supports (main beams), as shown below.
- Usually, the rib slab is reinforced for flexural stresses only (shear reinforcement is not required).
- Mat is reinforced each way (parallel and perpendicular to the ribs) by temp/shrinkage reinforcement.



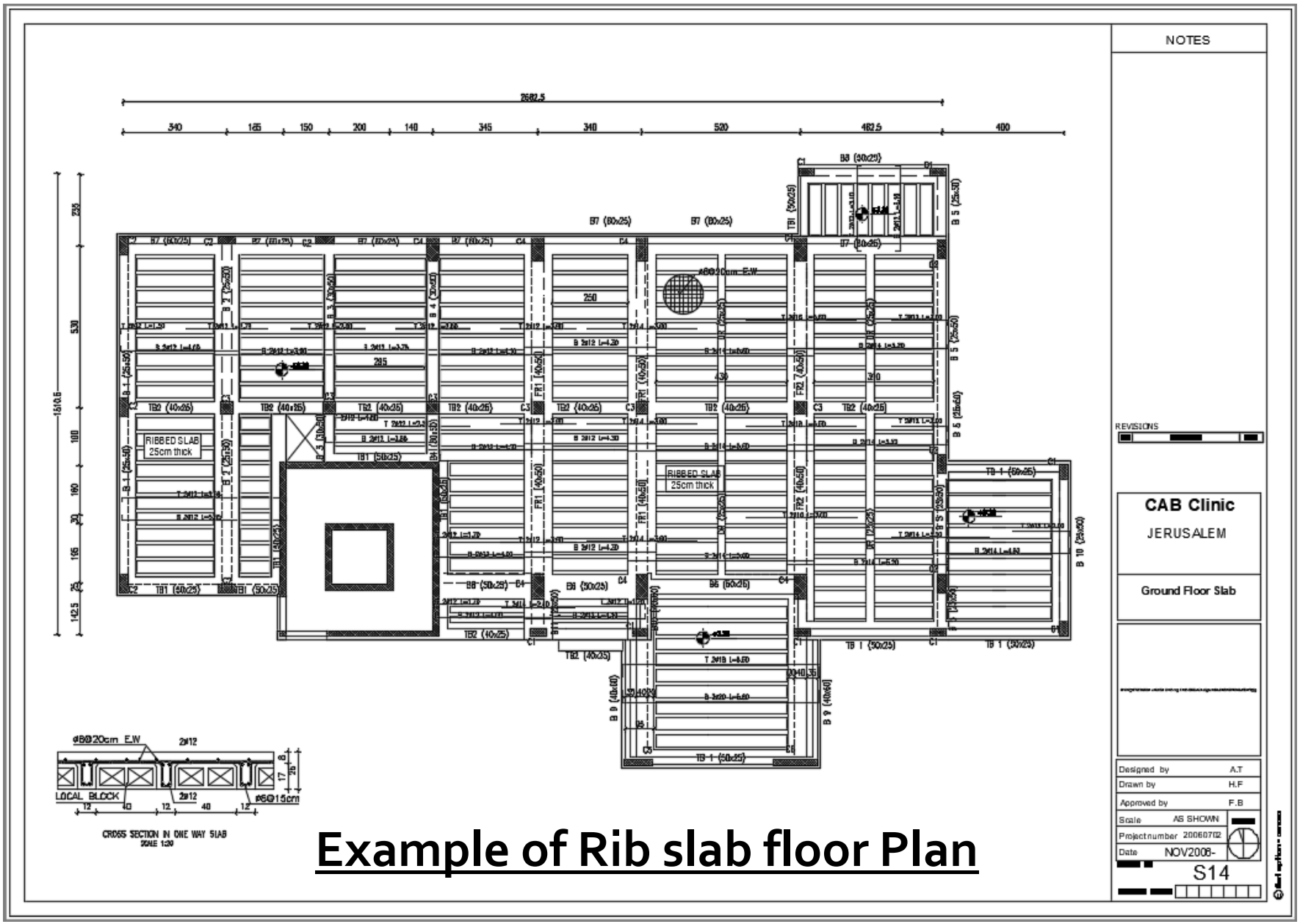
One-Way Joist System (rib slab)



How to draw rib slab?

- Draw the beams in each direction to create the slab panels and determine the desirable direction of the ribs.
- Fil the panels by the appropriate number of ribs, maintaining continuity.
- Add reinforcement of each rib type.

One-Way Joist System (rib slab)



Example of Rib slab floor Plan

One-Way Joist System (rib slab)

Advantages of one-way rib slab

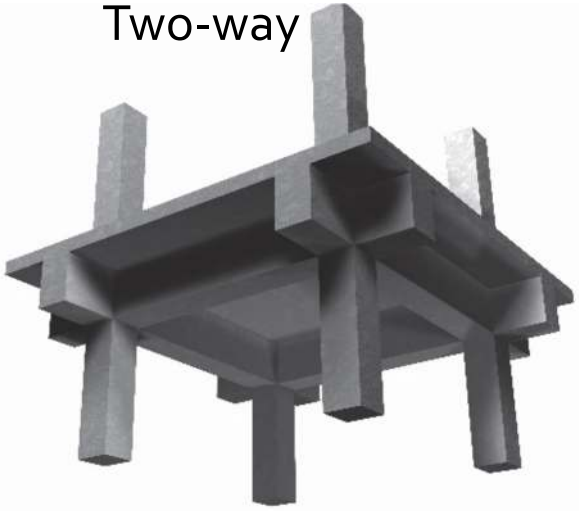
1. Reduce slab weight. The filler (blocks or molds) is lighter than solid concrete.
2. Flexible. It can behave as a one or two-way slab based on the proposed direction of the ribs. Usually, engineers consider the one-way design for spans up to 5m.
3. Preferable by the architects, especially when the ribs supporting beams are made hidden (have the same depth as the slab).
4. The system may have better sound and heat insulation compared with solid slabs.
5. The system materials and components are widely available in the local market. Furthermore, local engineers, contractors, and technicians are experienced in the system's design and construction methods.

Beam-Supported Slab System

- The slab system supported on beams was the original slab system in reinforced concrete. Usually reinforced in two directions and cast integrally with supporting beams and columns.
- The slap panels can act as a one-way or two-way slap based on panel dimensions or supporting conditions.
- A principal advantage of concrete slab-and-beam systems is the rigid frame action made possible by the column-beam interaction.

One-way

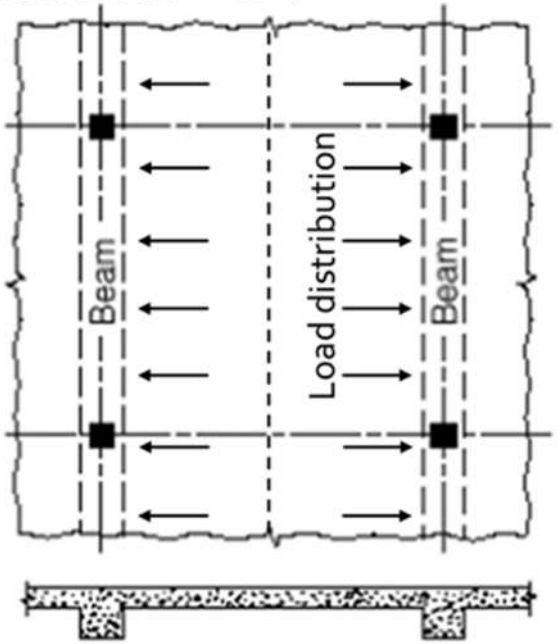
Two-way

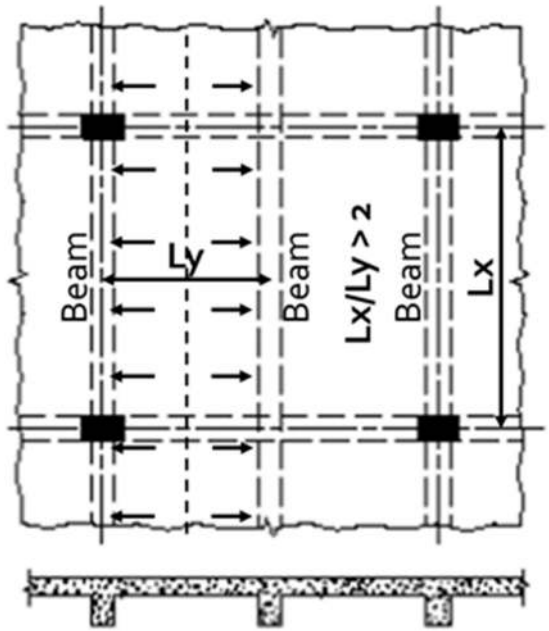


- The principal disadvantages are the increased cost of formwork and greater construction depth, mainly when mechanical ductwork must run below the beam structure.

One-way solid slab

- The one-way slab is a plate with uniform thickness supported by concrete/ masonry-bearing walls, or more typically, cast integrally with parallel supporting beams, which, in turn, are supported by girders, bearing walls, or columns.
- The thickness of the slab is initially determined in compliance with serviceability requirements of the design code.
- They are suitable for light to moderate load conditions over relatively short spans of 2 to 5.5 m.



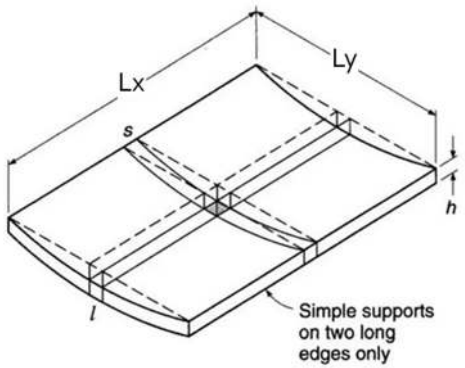


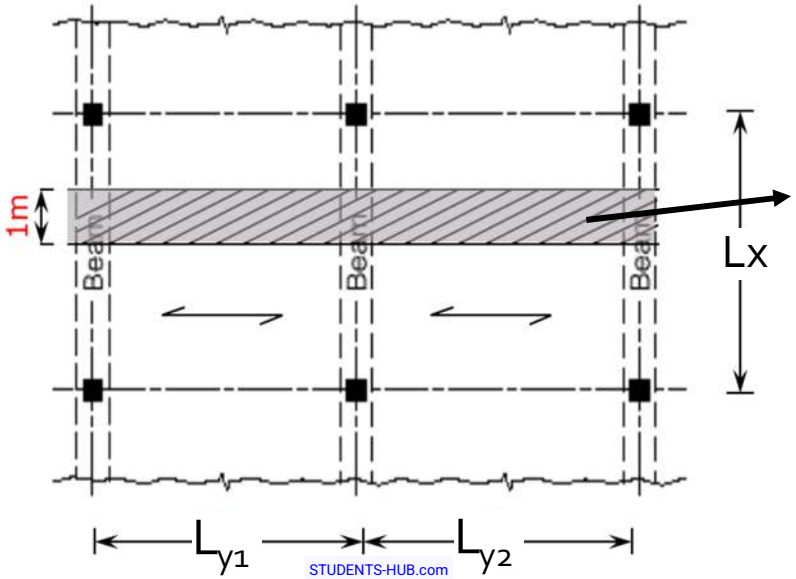
One-way solid slab

- Serviceability requirements of ACI-318 is shown in the table.
- The deflected shape of a uniformly loaded one-way solid slap panel is shown in the figure below. The shape indicates that slap loads are mainly distributed to the long sides of the slap panel.

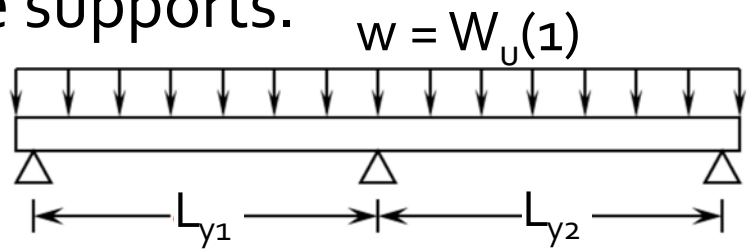
Table 7.3.1.1—Minimum thickness of solid nonprestressed one-way slabs

Support condition	Minimum $h^{[1]}$
Simply supported	$\ell/20$
One end continuous	$\ell/24$
Both ends continuous	$\ell/28$
Cantilever	$\ell/10$



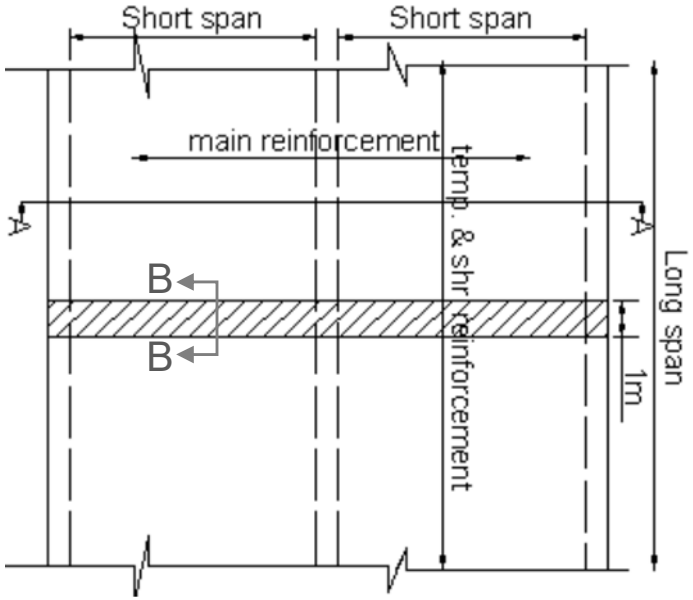


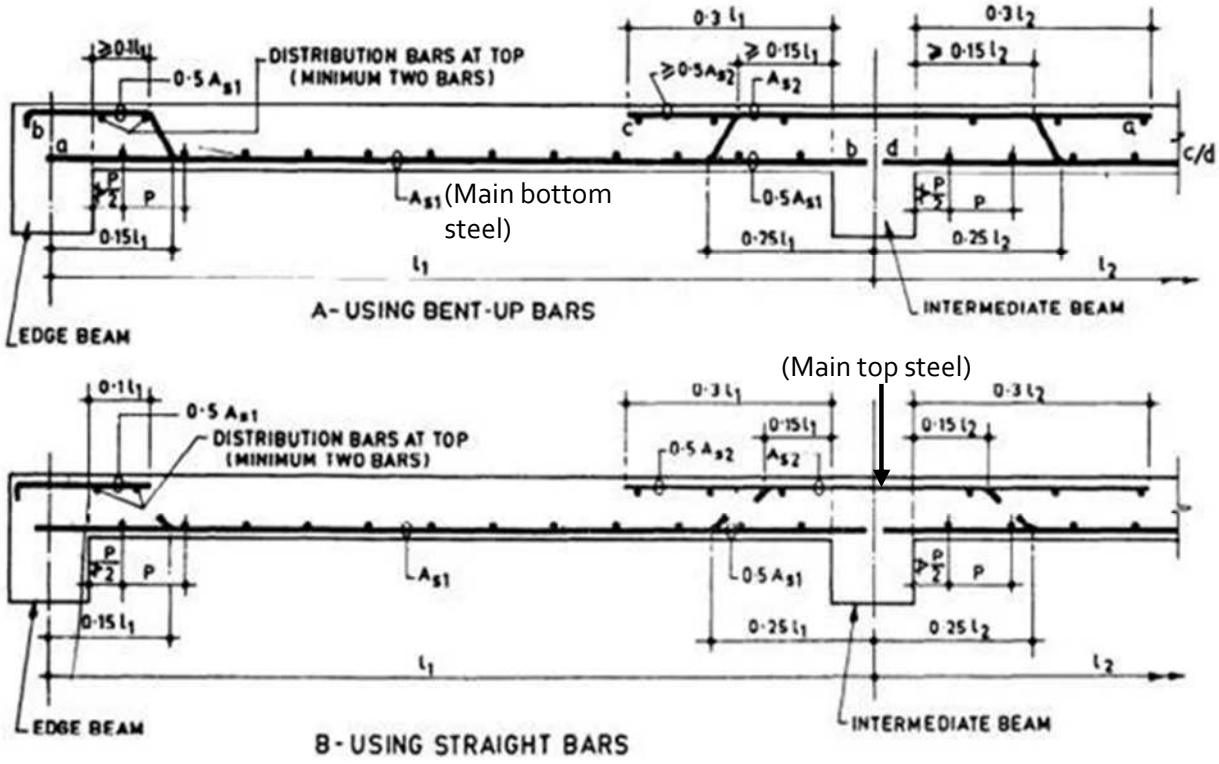
- Analysis. A strip - one meter wide - in the direction of the slab is analyzed as a continuous beam in hinge supports.



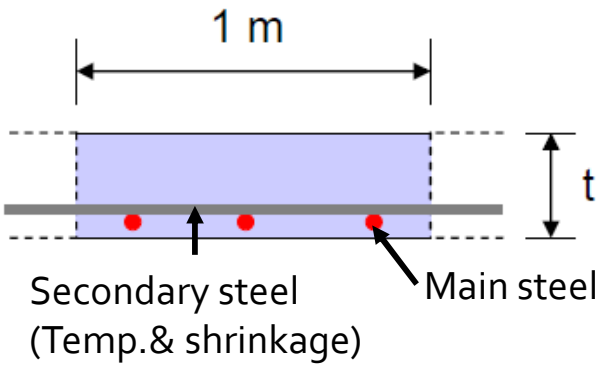
One-way solid slab

Typical Reinforcement





Section A-A



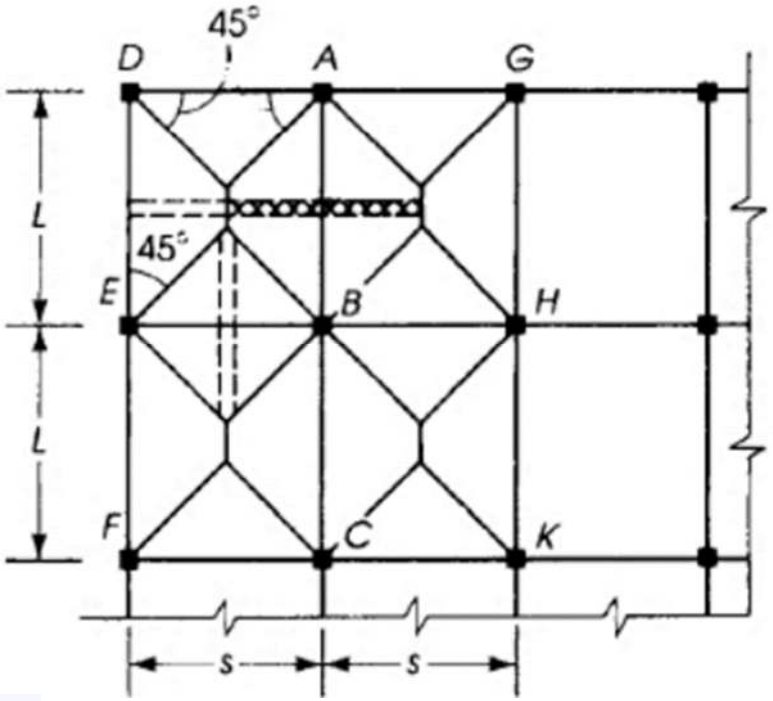
Section B-B

- A minimum area of flexural reinforcement, $A_{s,min}$, of $0.0018A_g$ shall be provided.

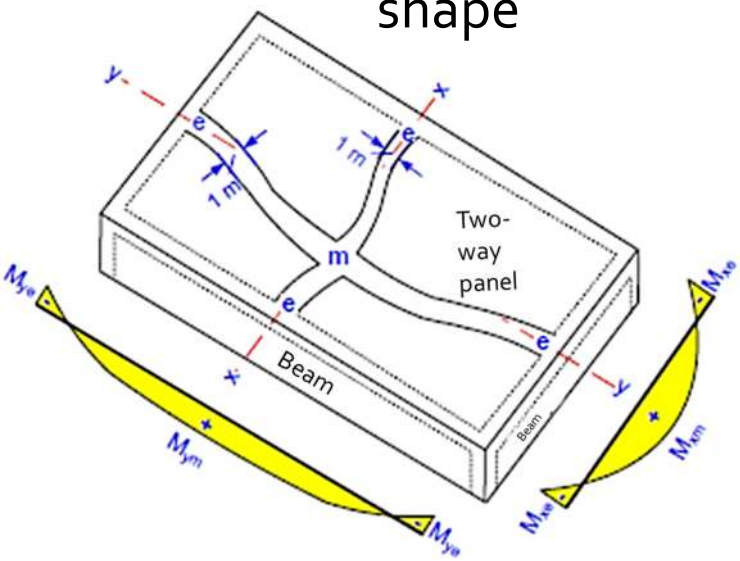
Two-way beam-supported slabs system

- A solid slab supported on beams on all four sides as shown in the photo. It was the original slab system in reinforced concrete.
- As a two-way system, the load is transferred in both orthogonal directions.

Distribution of slab load into supporting beams



Deflected shape

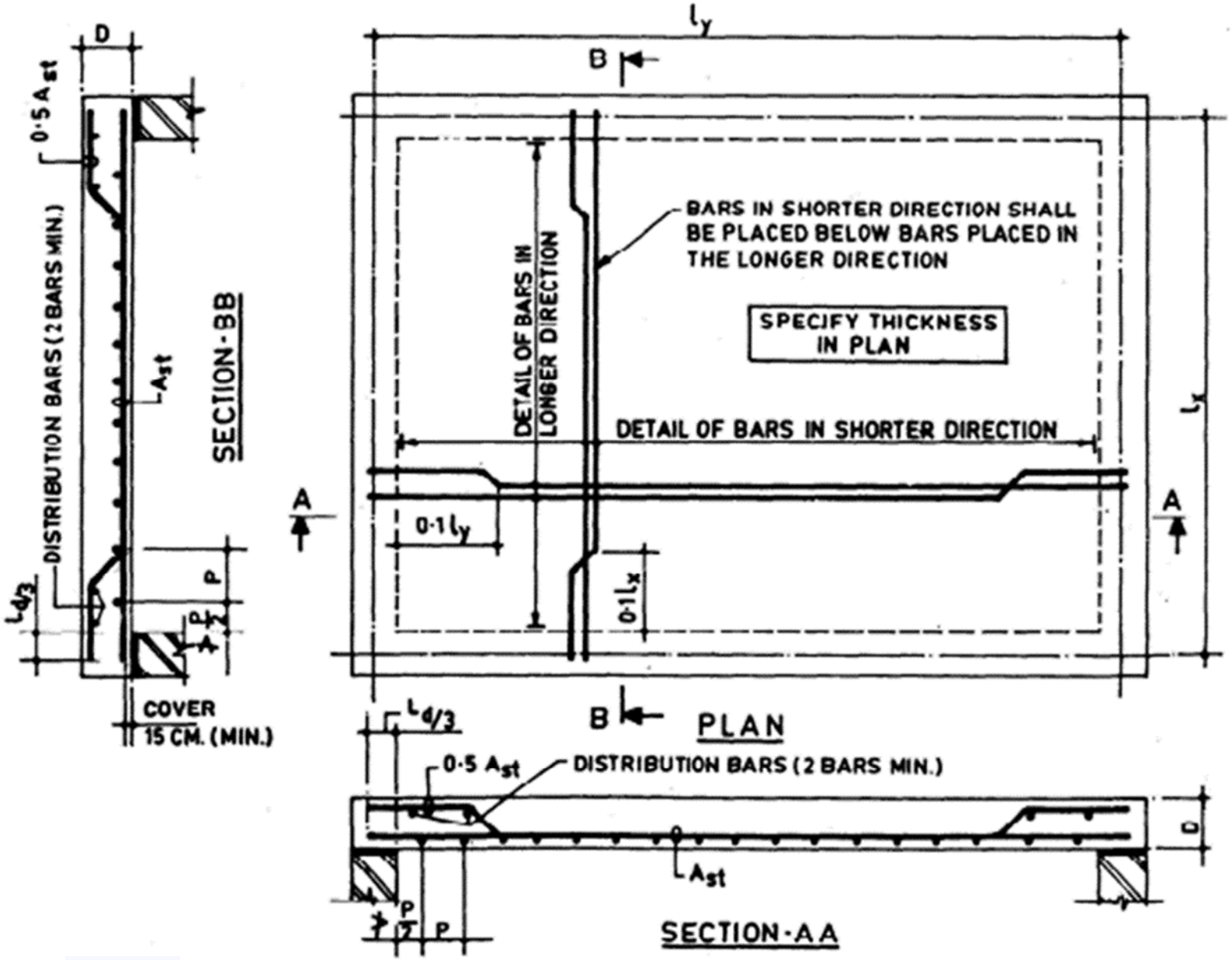


Two-way beam-supported slabs system

- The system can accommodate a wide range of span (4.5 to 9 m spans) and loading conditions. However, it is not as economical as other two-way systems with similar span and loading conditions, due to formwork costs and costs associated with deeper overall floor thickness.
- As such, the system is not used as often, except in cases where the demands for lateral force resistance are relatively large especially where the moment-resisting frames are used as the seismic force–resisting system.
- The minimum thickness of the slab h that satisfies serviceability requirements depends on the longer of the two spans and the average flexural stiffness of the beams on the perimeter of the panel. The distribution of bending moment and shear force between the slab and beams also depends on the relative stiffness of the beams.

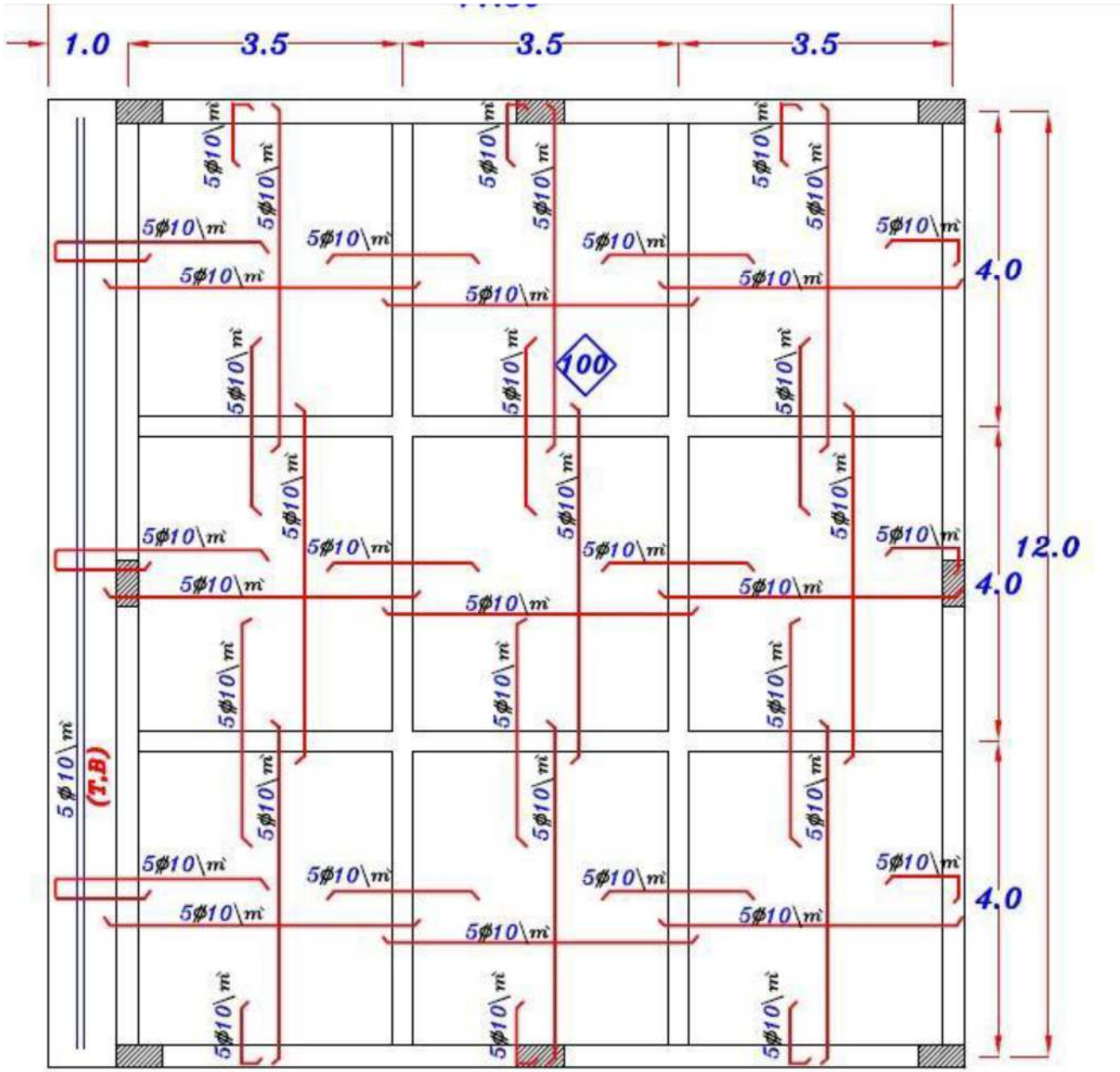
Two-way beam-supported slabs system

Typical Reinforcement - Panel



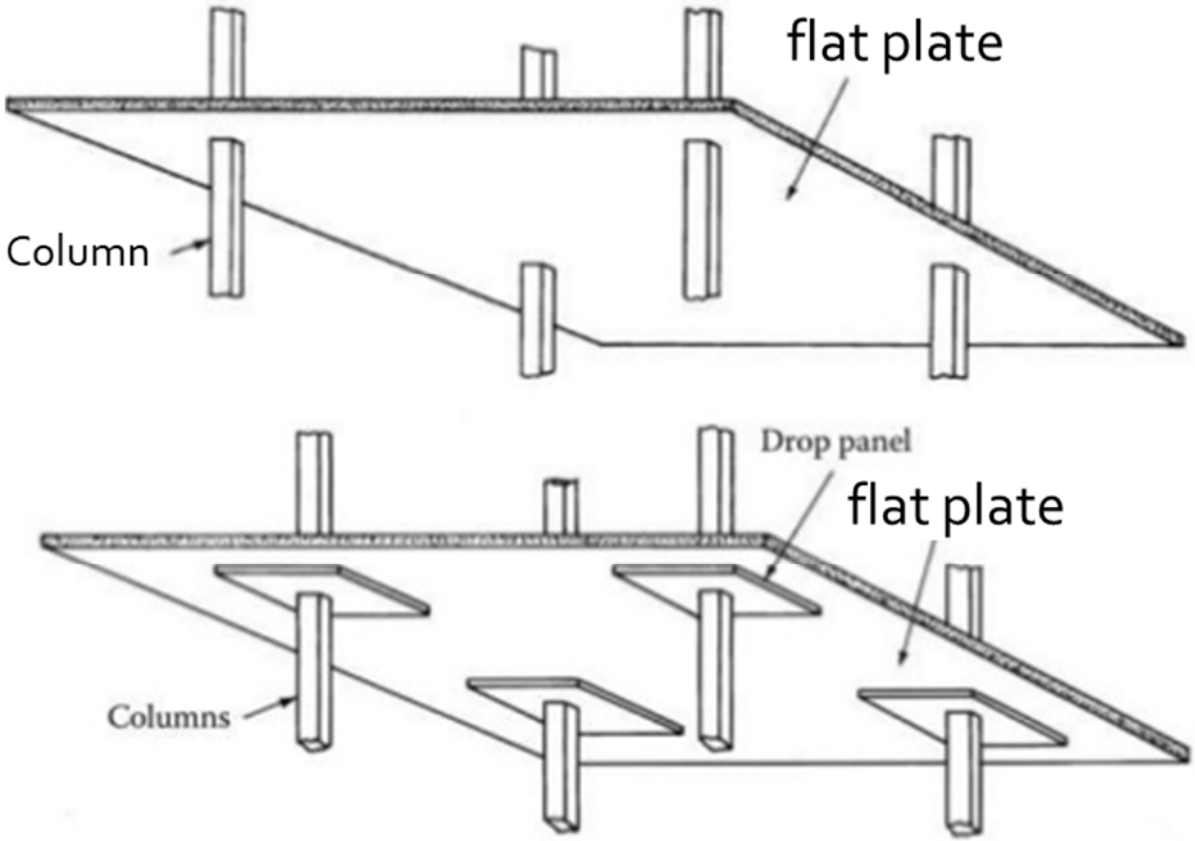
Two-way beam-supported slabs system

Typical Reinforcement - Plan



Flat Plate and Flat Slap System

- A flat-plate floor system is a two-way concrete slab supported directly on columns.
- A flat-slab floor system is similar to a flat-plate floor system, with the exception that the slab is thickened around the columns as shown in the figure.



Flat Plate

- A flat plate floor system is a two-way concrete slab. The system has the advantages of simple construction and formwork and a flat ceiling. Typically economical for span lengths between 4.5m and 8m when subjected to moderate live loads.
- **System Characteristics**
- For relatively short spans and live loads of 2.5 KN/m^2 or less, the thickness of a flat plate will usually be controlled by the deflection requirements. In this case flexural reinforcement will be the minimum specified by the code.
- Because the minimum slab thickness requirements are independent of the concrete compressive strength, a 30 Mpa concrete mixture is usually the most economical.

Flat Plate

System Characteristics

- Where the spans are relatively long and/or the live load is 5 KN/m² or greater. Two-way or punching shear may determine the slab thickness. Shear stresses at edge columns and corner columns are particularly critical.
- In this case

  I. Increase slab thickness

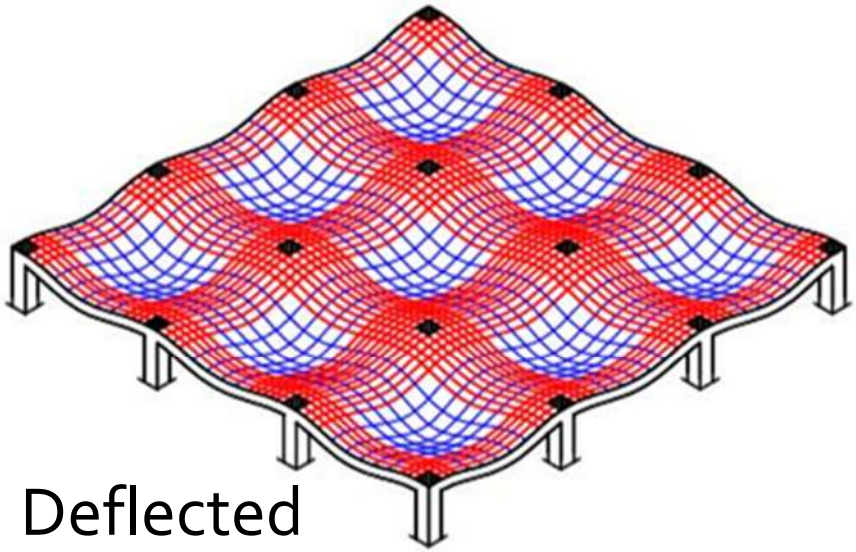
  II. Increase column sizes.

  III. Use drop panels/ column capital

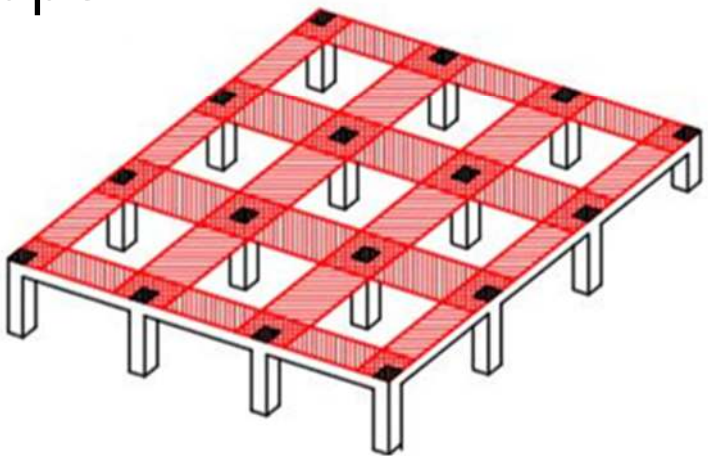
  IV. Provide shear reinforcement

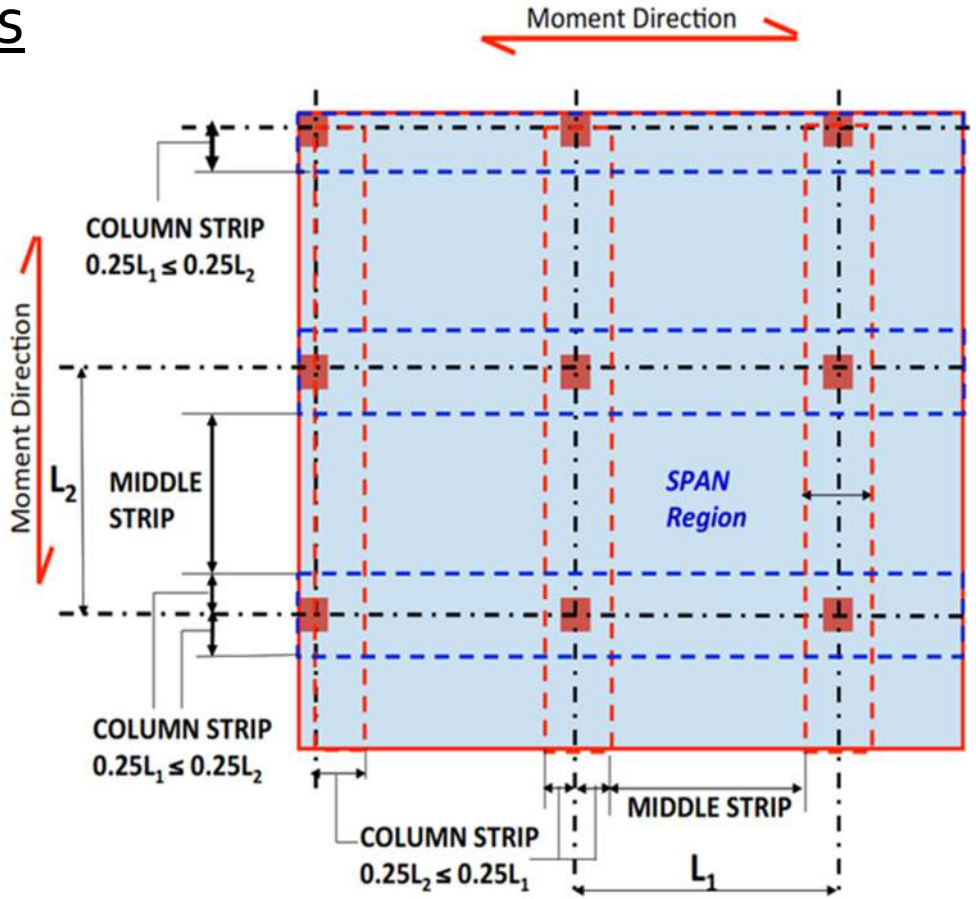
Flat Plate

- Structural behavior under loads



Deflected shape

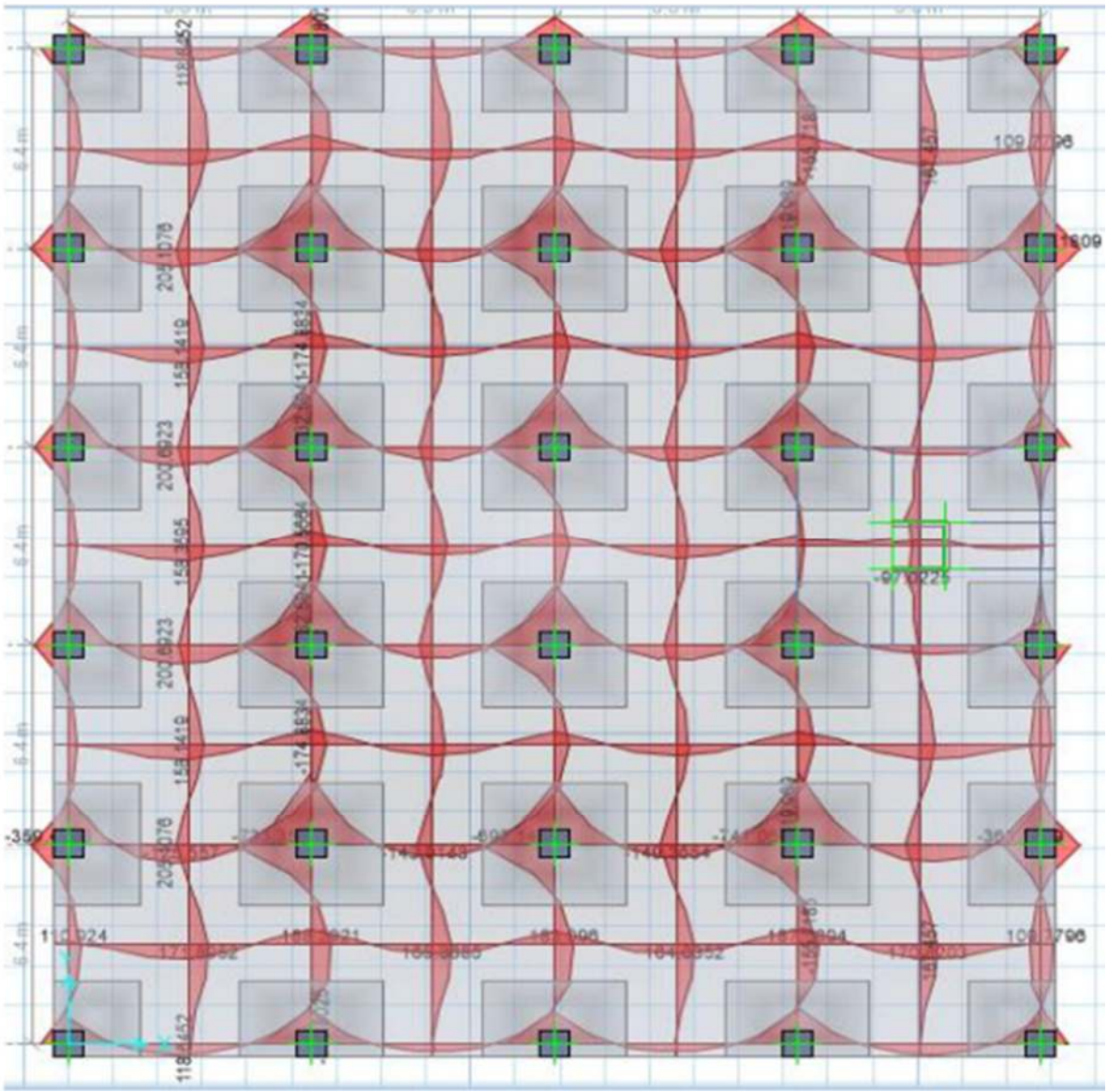




- The panels are divided into 'column strips' and middle strips 'in both directions as shown in the figure

Flat Plate

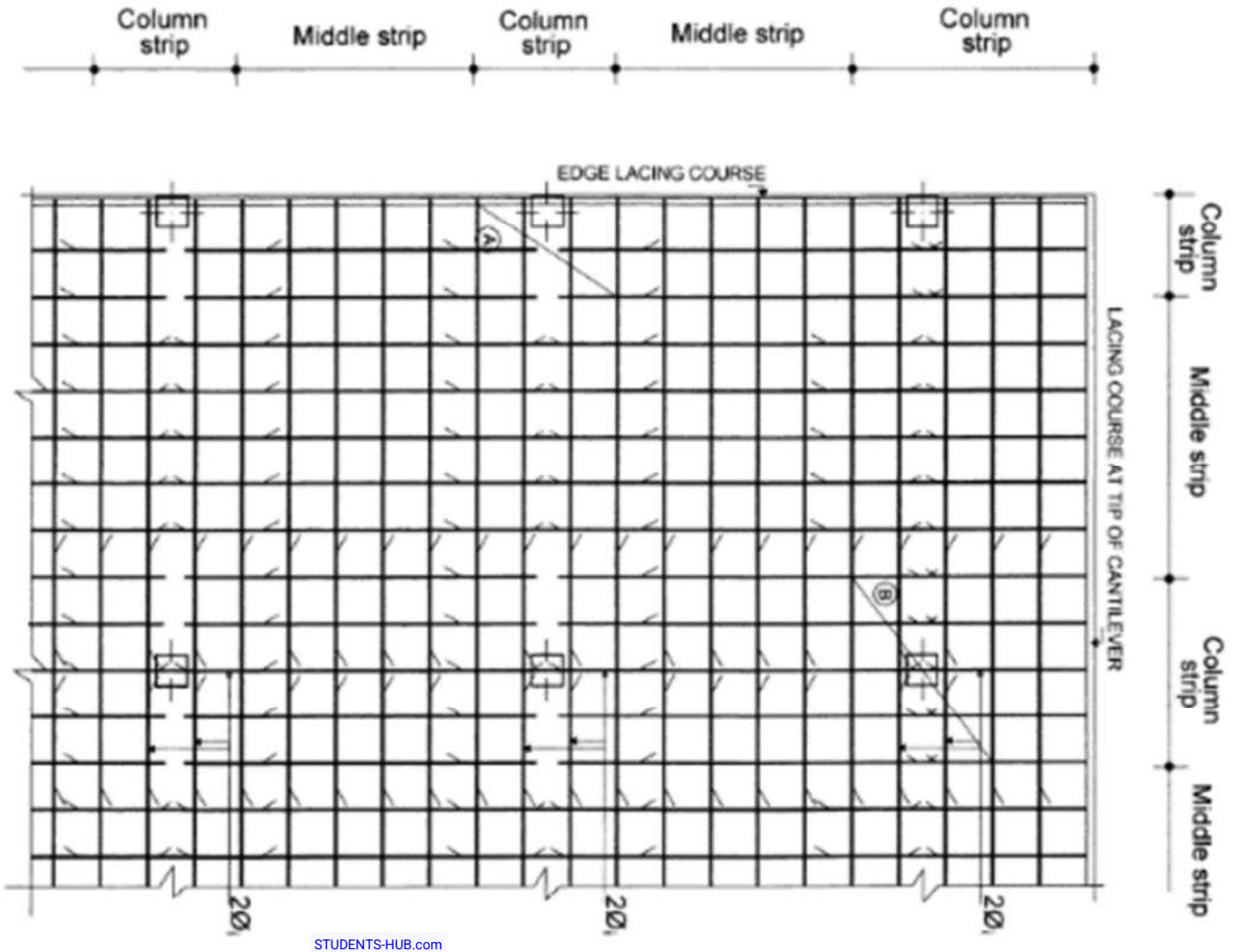
- Structural behavior under loads



- Strip Moments

Flat Plate Reinforcement

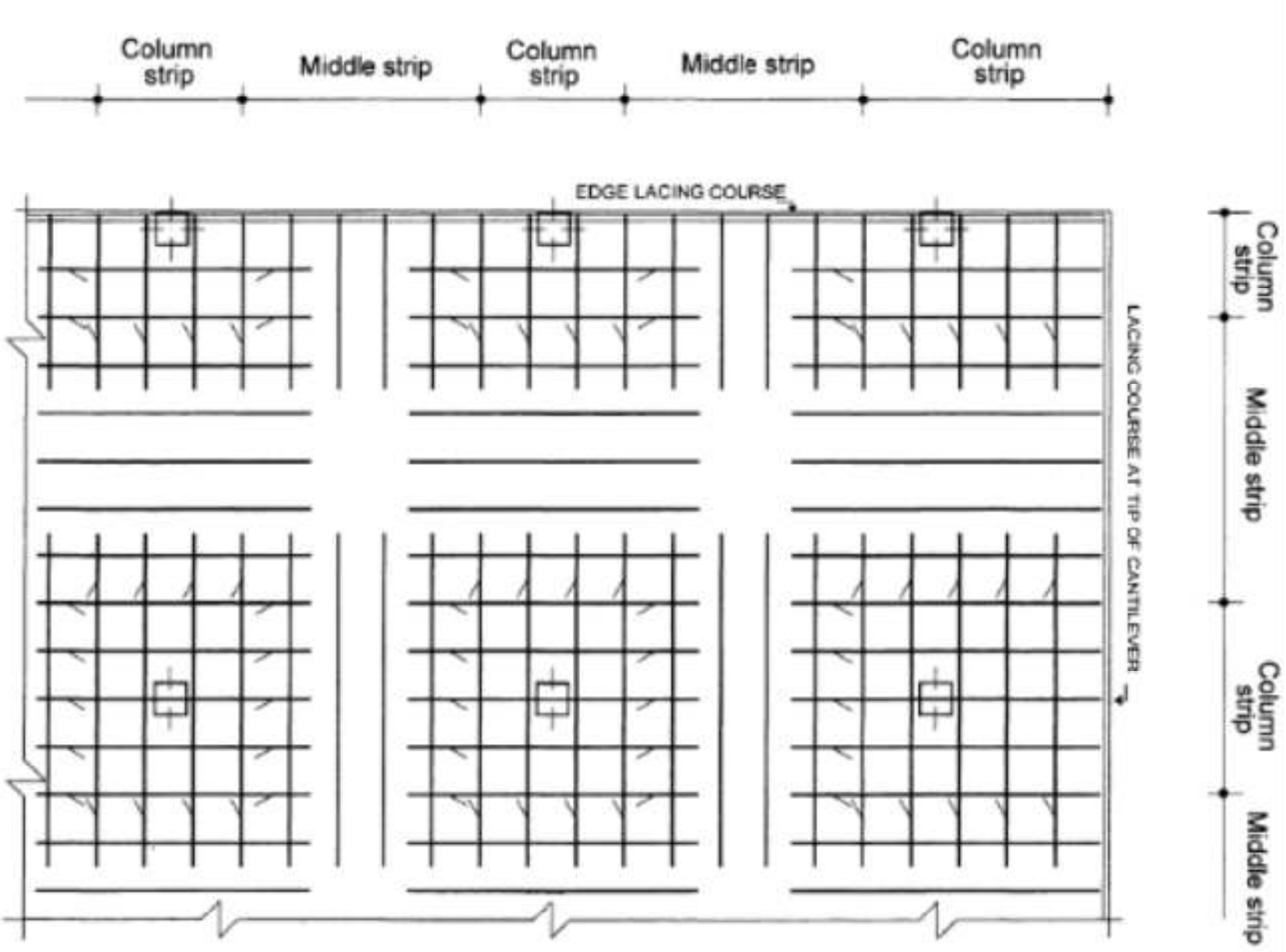
Flexural reinforcement. The required reinforcement is laid off for each strip typically as shown. (Usually, two-way mats, top and bottom are used in small projects)



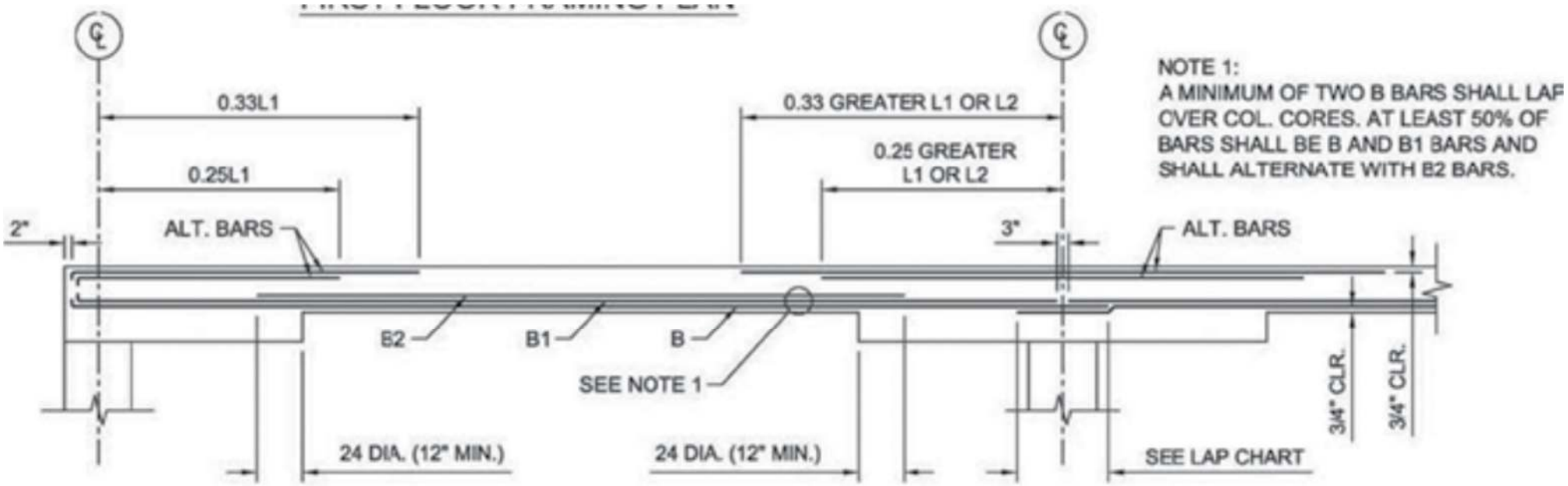
Typical BOTTOM flexural reinforcement - Plan

Flat Plate Reinforcement

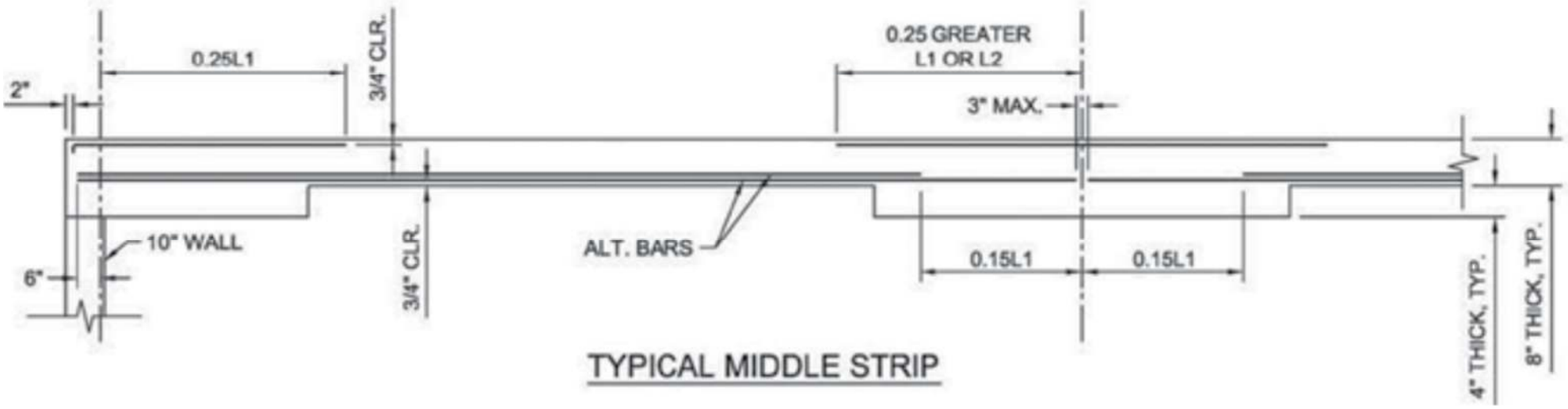
Typical TOP flexural reinforcement - Plan



Flat Plate Reinforcement

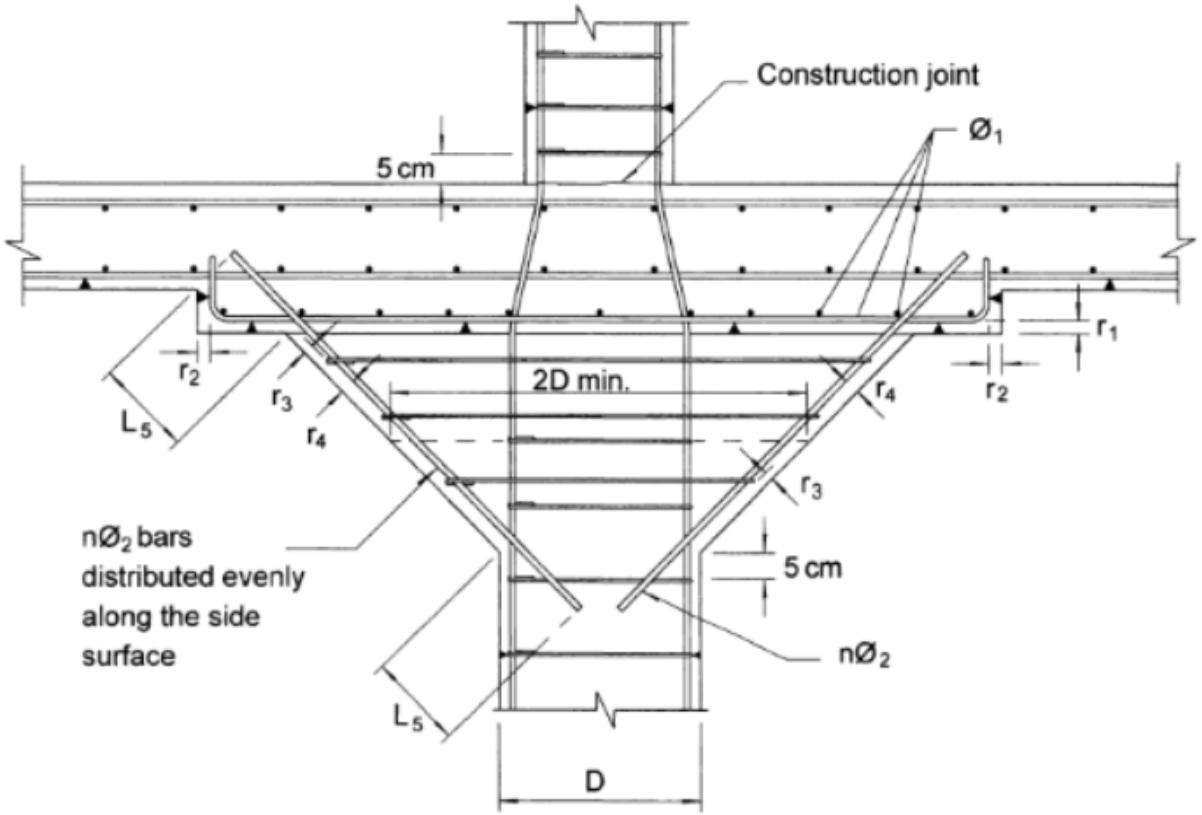


TYPICAL COLUMN STRIP

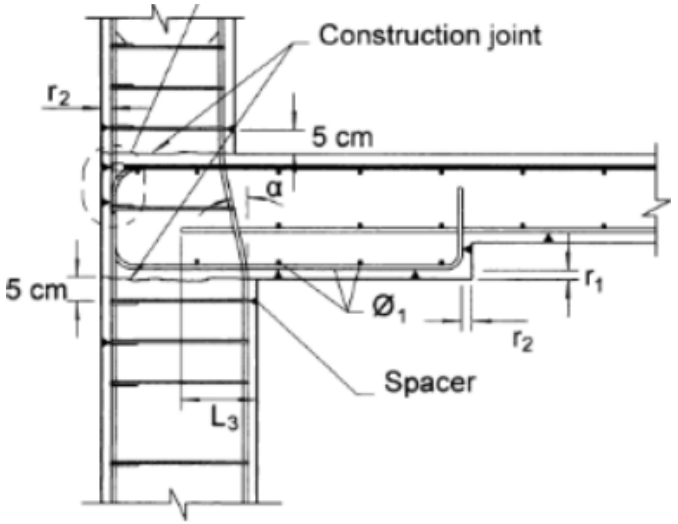


TYPICAL MIDDLE STRIP

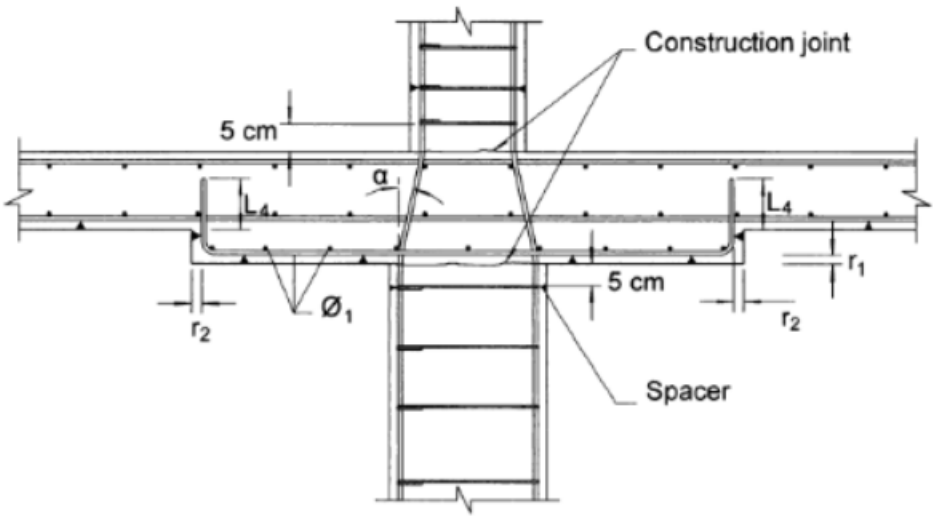
Drop Panels & Capital Details



Drop Panels *with column capital*



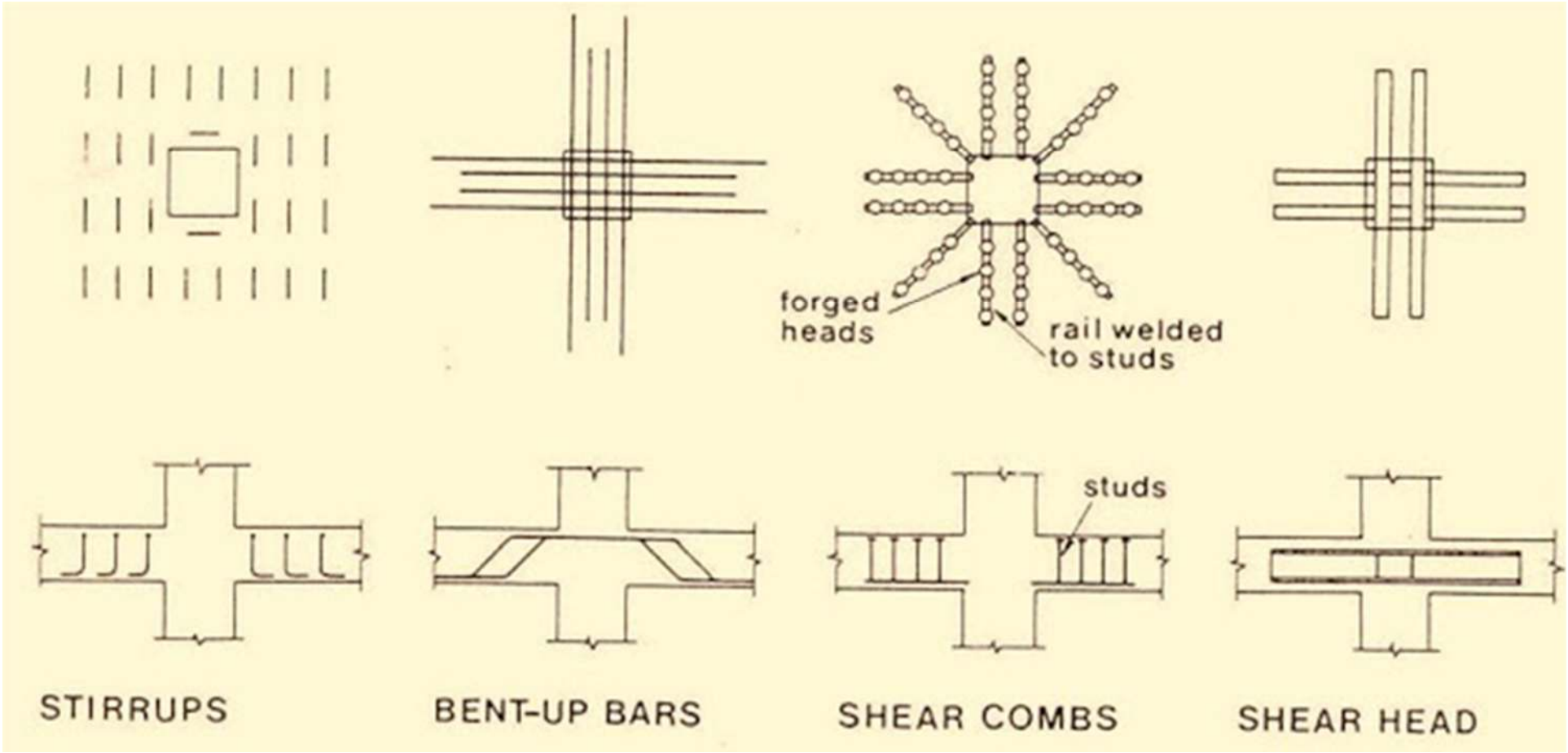
EDGE OR CORNER COLUMN



INTERNAL COLUMN

Punching Shear Reinforcement

Typical shear reinforcement methods

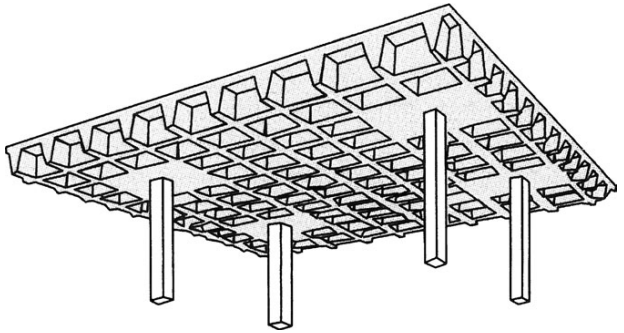


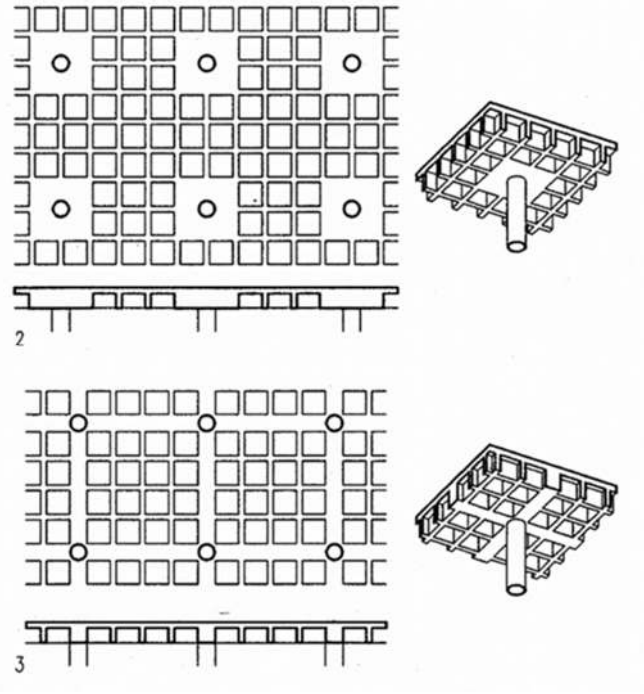
Punching Shear Reinforcement

Examples of shear reinforcement for flat plate

Waffle slab System

- Waffle slab system (also called Two-way joist) consists of rows of concrete joists at right angles to each other.
- The joists are formed by using standard square "dome" forms that are 30, 41, and 52 in. wide. For the 30" form, the standard joist width is 6" (15 cm) and the depth of the form is 8" to 20" in 2" increments. The thickness of the mat is controlled by either structural or fire resistance requirements; typically 4.5" (11-12 cm) is usually specified.
- A solid heads at the columns or beams are usually provided for two-way shear resistance.





Waffle slab System

- Waffle slab construction allows a considerable reduction in dead load compared with conventional flat-slab construction. Thus, this system is particularly advantageous where long spans and/or heavy loads are desired without the use of deepened drop panels or support beams.
- Waffle slabs are economically viable for long spans (12-16m) with heavy loads and are used in office buildings, warehouses, libraries, museums, and industrial buildings.
- The geometric shape formed by the joist ribs is generally considered to be architecturally desirable and is often left exposed.
- Like beam-supported slabs, waffle slabs are not specified as often as they once were. This is primarily due to the cost attributed to the formwork.

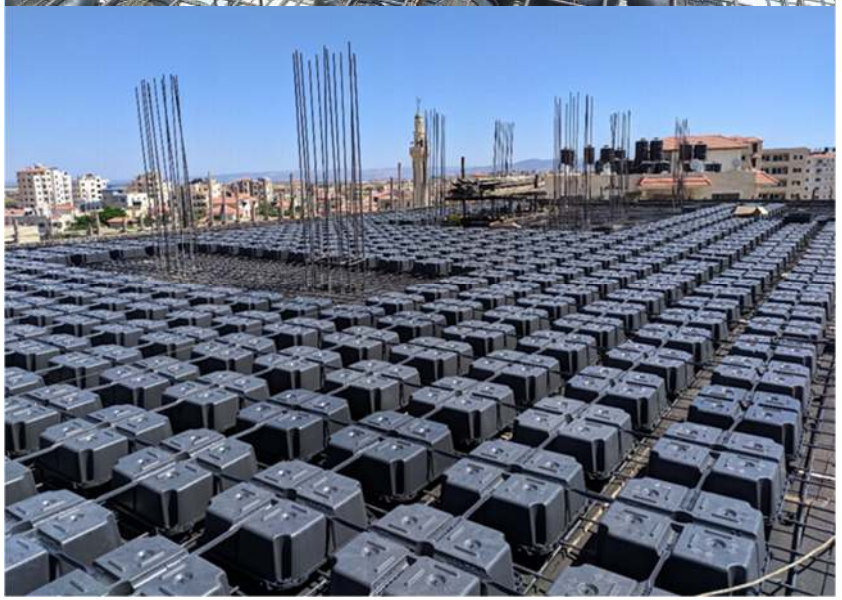
Waffle slab System

Waffle slab under construction with dome forms.

Interior face of a waffle slab

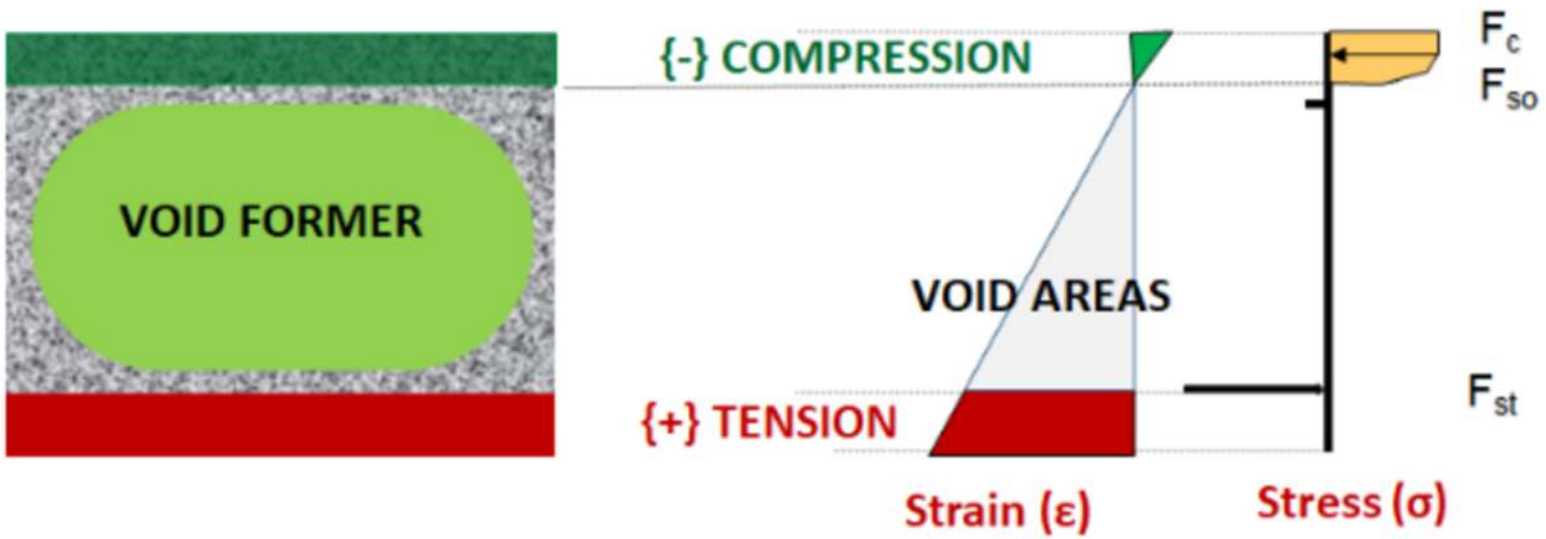
Voided slabs System

- The voided slab is a two-way reinforced concrete system of uniform thickness that incorporates regularly spaced, hollow, plastic void formers made of high-density recycled polyethylene (HDPE) inside the concrete.
- The void formers are positioned within wire support cages locked between the upper and lower reinforcement layers in zones where concrete is not needed and where the flexural strength and load transfer to the supports are not compromised.
- Commonly, void formers are omitted at column locations so that concrete section is available to resist punching shear.



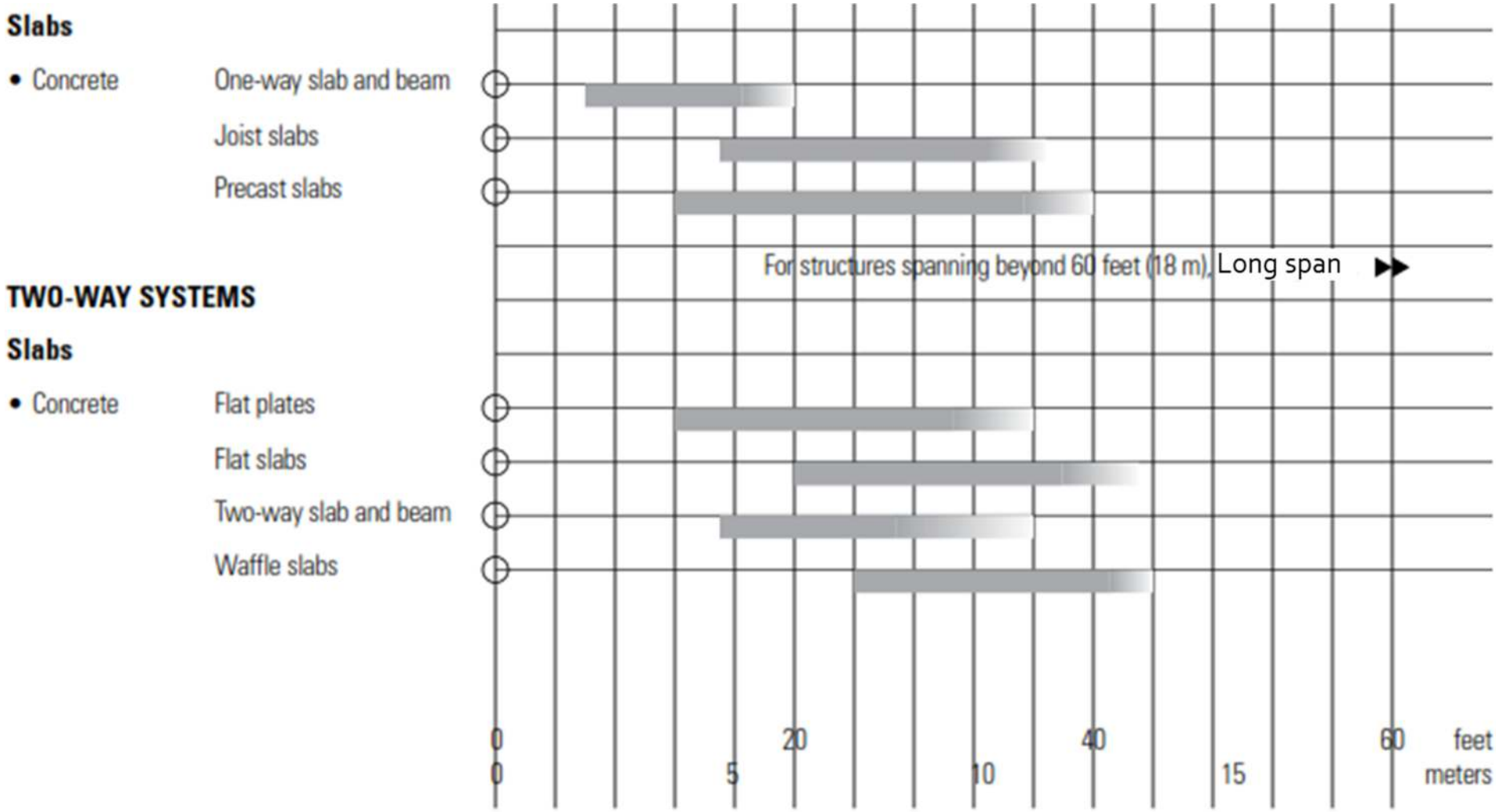
Voided Slabs System

- Depending on the size and distribution of the void formers, the weight of the voided concrete slab can be up to 35% lighter than a solid slab of the same thickness.
- The system is economically viable for medium to long spans and for moderate live loads (7-12 m).



Cross-section of voided slab

Typical Spans



Typical span ranges for basic types of slabs.

Selecting Economic System

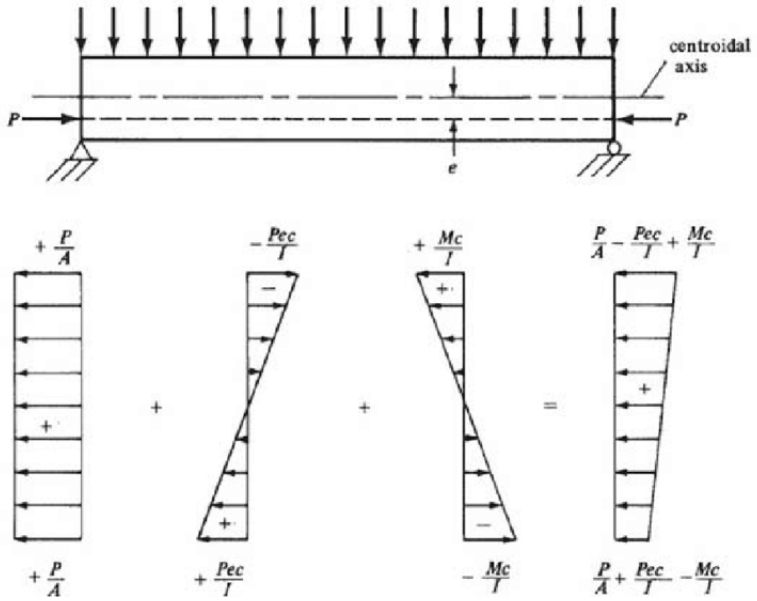
- The slab of the structure is determined by the need to provide effective resistance to both gravitational and lateral load and to achieve a reasonable economy in the use of material.

Cost-effective two-way reinforced concrete floor system based on span and live load

Span	Live Load (KN/m²)	Floor System				
		Flat Plate	Flat Slab	Wide-module Joist	Two-way Joist	Flat Plate Voided Slab
6m	2-5	X				
6 – 8 m	2	X				
	3	X	X			
	5		X	X		
8 - 9 m	2-5		X	X		
9 – 12 m	2-5			X	X	X
12 – 15 m	2-5				X	X

Post-tensioned Slab System

- Post tension slab is a combination of conventional slab reinforcement and additional protruding high-strength steel tendons, which are consequently subjected to tension after the concrete has been set. This hybridization helps achieve the formation of a much thinner slab with a longer span devoid of any column-free spaces.
- Require experience, special equipment, strict supervision, and skilled labor and can not be modified after casting. Additionally, the prestressing tendons are costly compared with normal reinforcement steel.

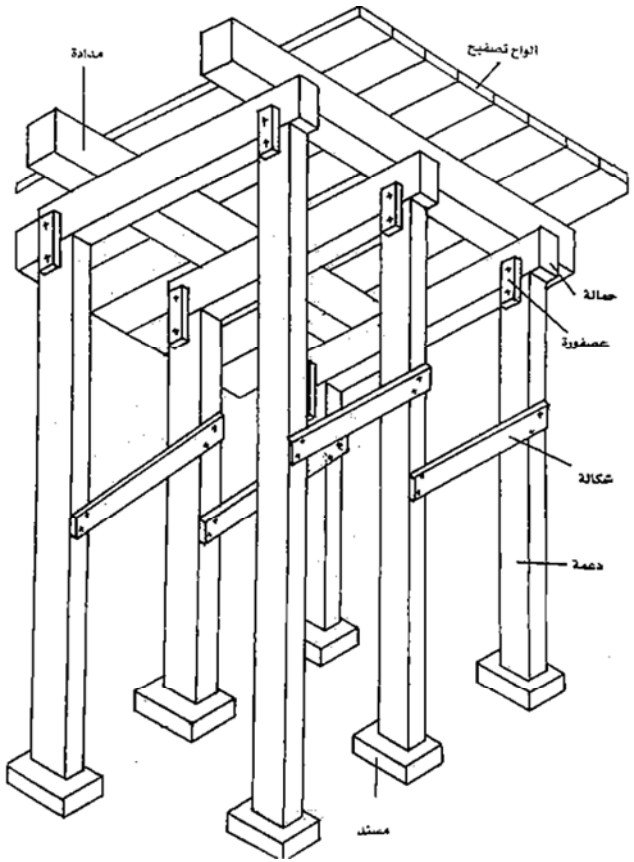


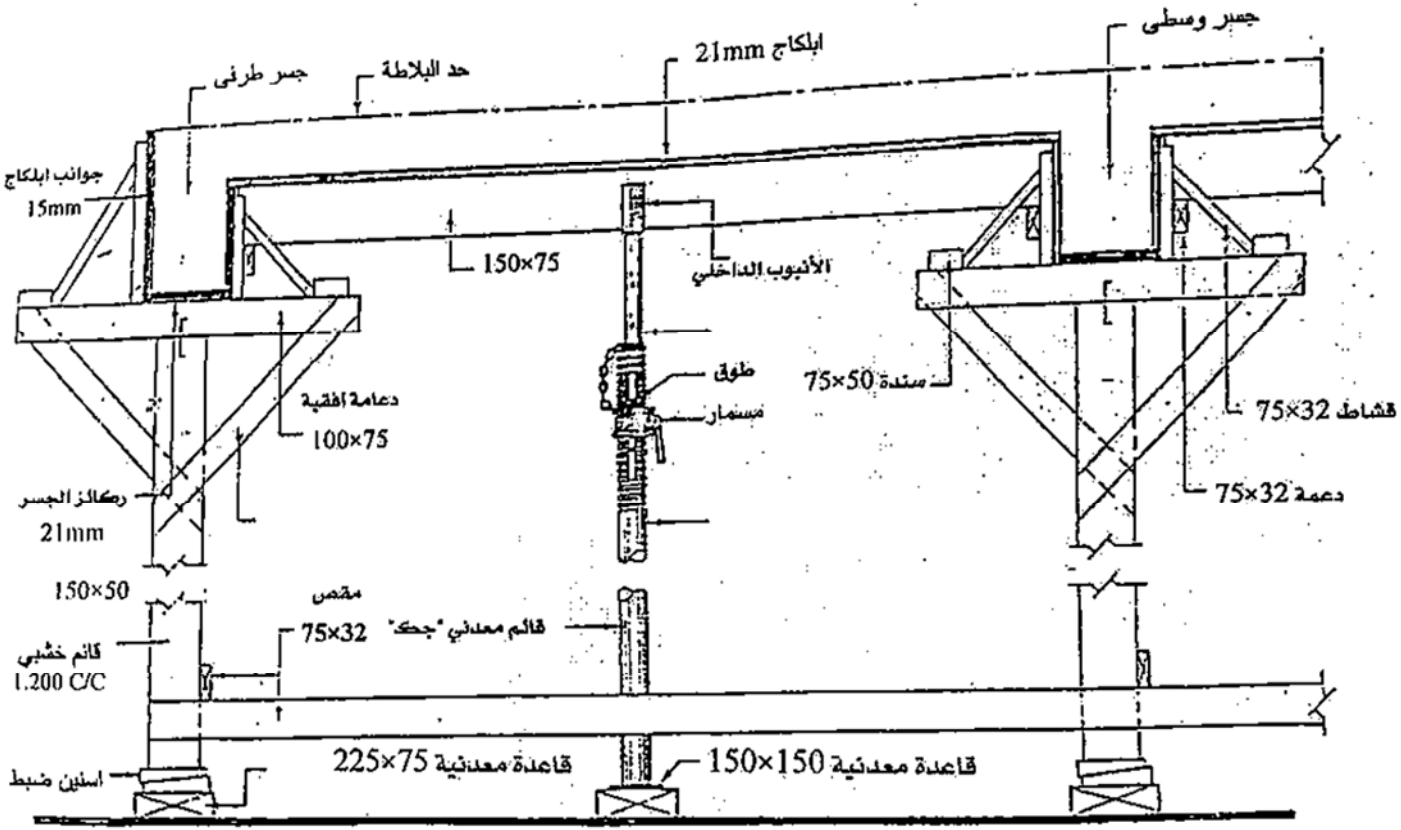
Post-tensioned Slab System

تنفيذ الأسقف

الطوبار

- يجب أن يكون السقف مدعما بشكل كامل وأن تكون المسافات بين الدعامات متناسبة مع الأحمال، وان تكون الركائز عمودية، مستنده على أرضية صلبة ومثبته جانبيا.





تنفيذ الأسقف

- يجب أن تكون جوانب الطوبار بأبعاد وزوايا صحيحة تطابق المخططات وان تكون مدعومة جانبيا بشكل كافي.
- يجب التأكد من كون سطح الطوبار العلوي مستوياً، متراصاً، وخالياً من الفراغات.
- دهن الواح الطوبار الملاصقة للخرسانة بمواد تسهل فصلها عنها وتقلل من إمكانية امتصاصها للماء.

الحديد

- التأكد من خلو الحديد من الصدأ و تنظيفه إن لزم.
- مطابقة الحديد المستخدم مع المخططات من حيث عدد أسياخ التسليح وأقطارها وأطوالها ومواقعها وتشريكها وغطائها الخرساني.

الأعمال الصحية والتمديدات الكهربائية

- التأكد من صحة التمديدات الكهربية ومطابقتها للمخططات قبل البدء بعملية صب السقف.
- فحص التمديدات الصحية والتأكد من صلاحيتها وأماكنها وتثبيتها.