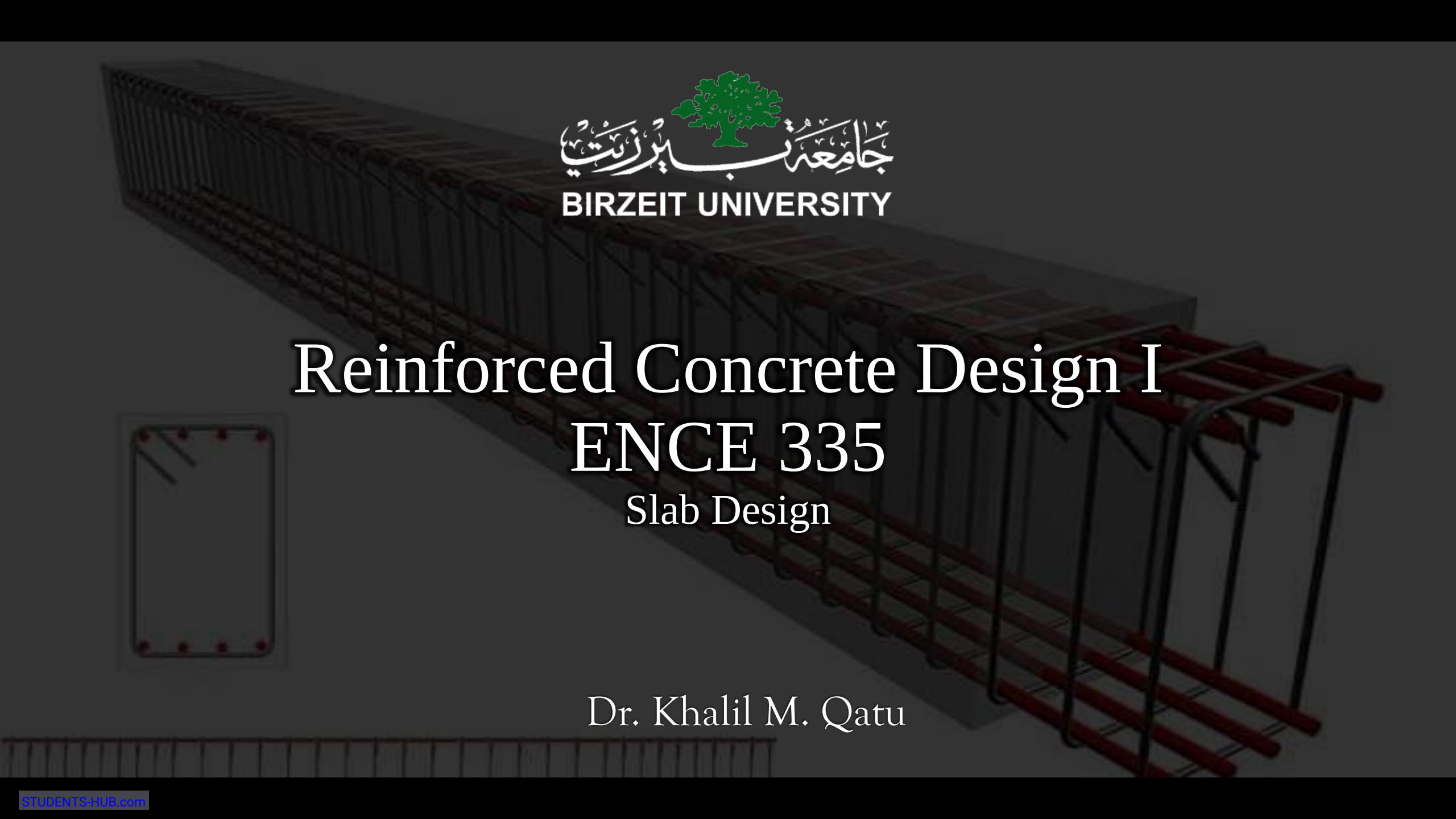


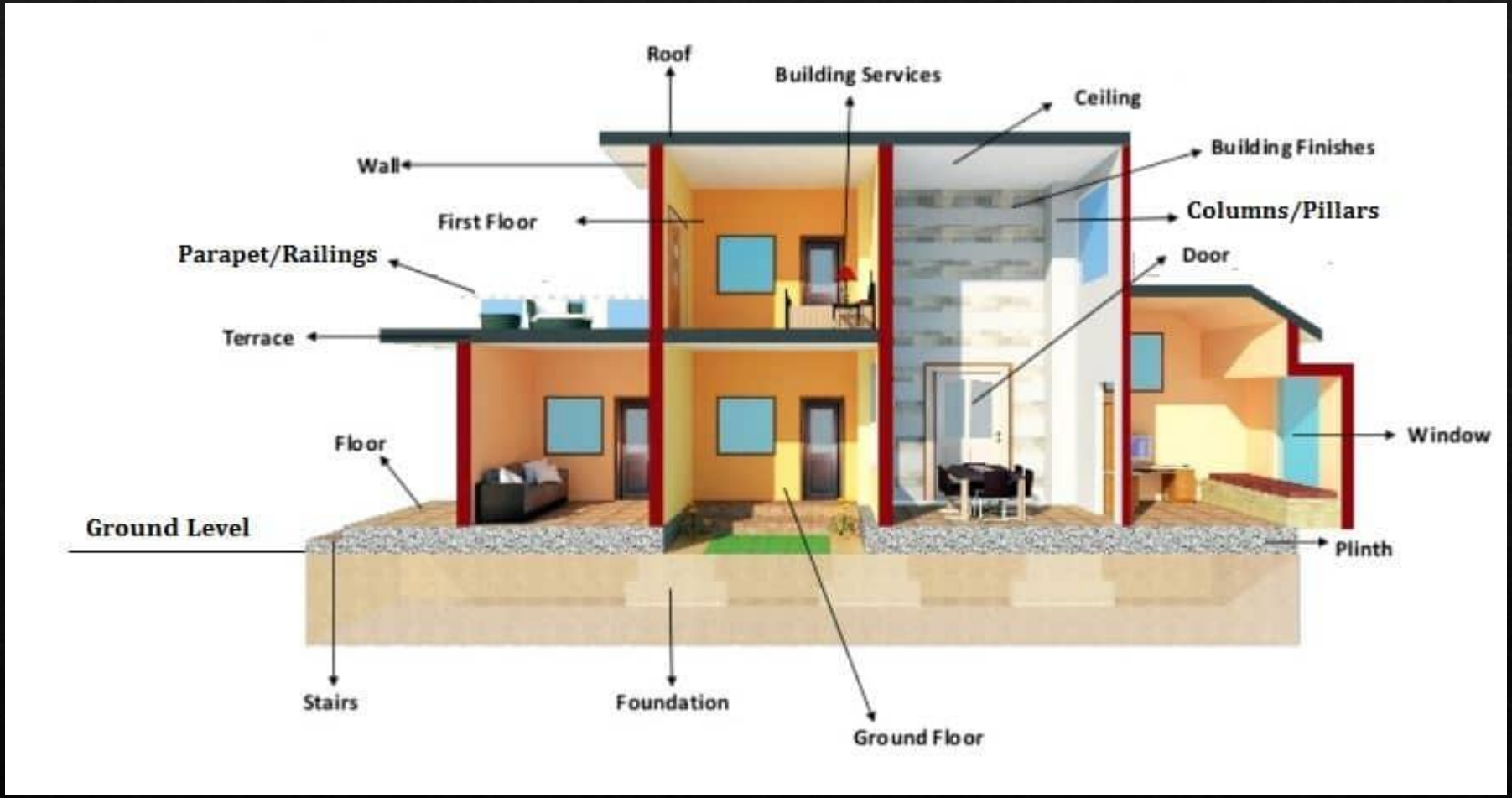
جامعة بيرزيت
BIRZEIT UNIVERSITY

Reinforced Concrete Design I
ENCE 335

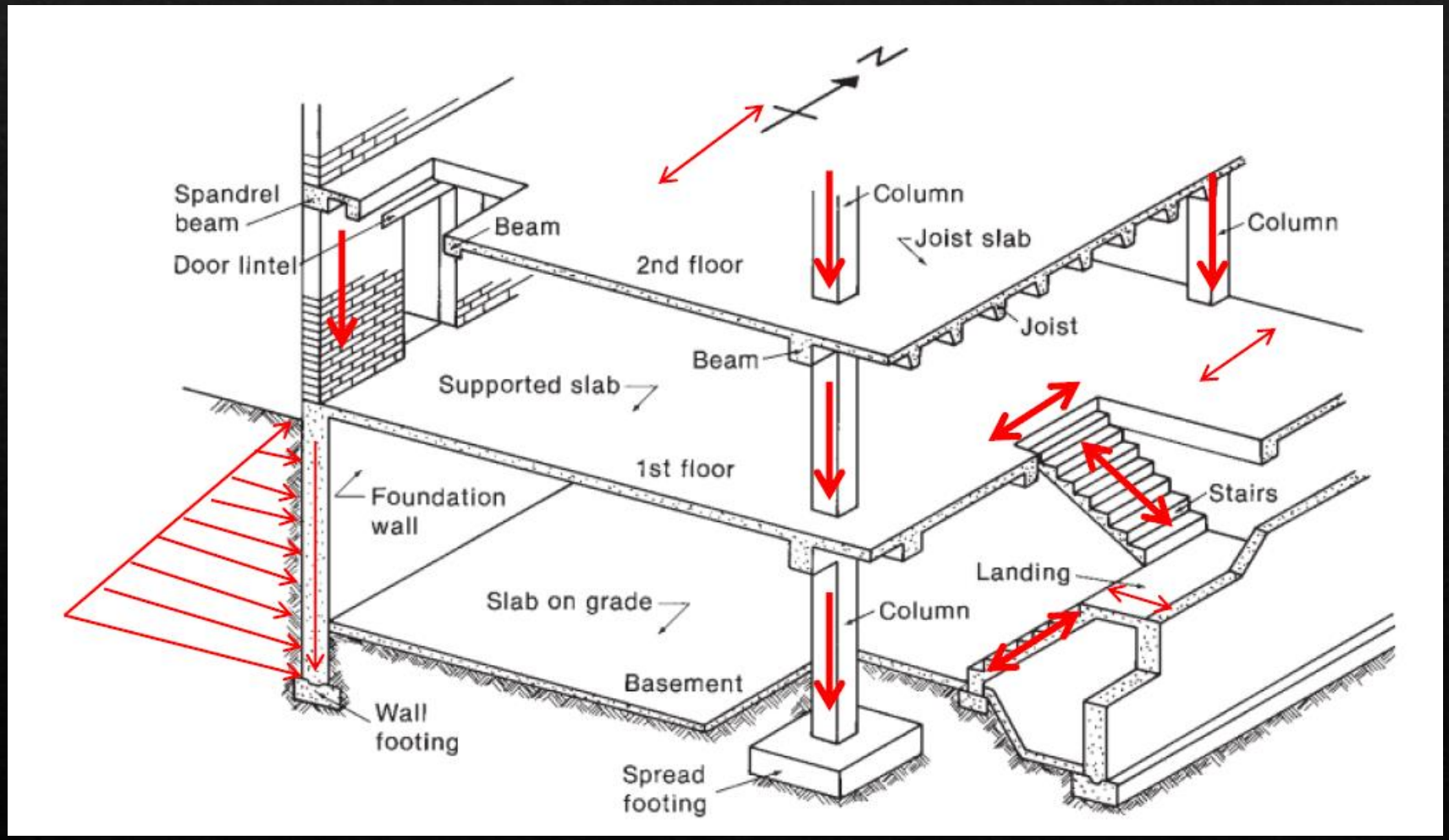
Slab Design

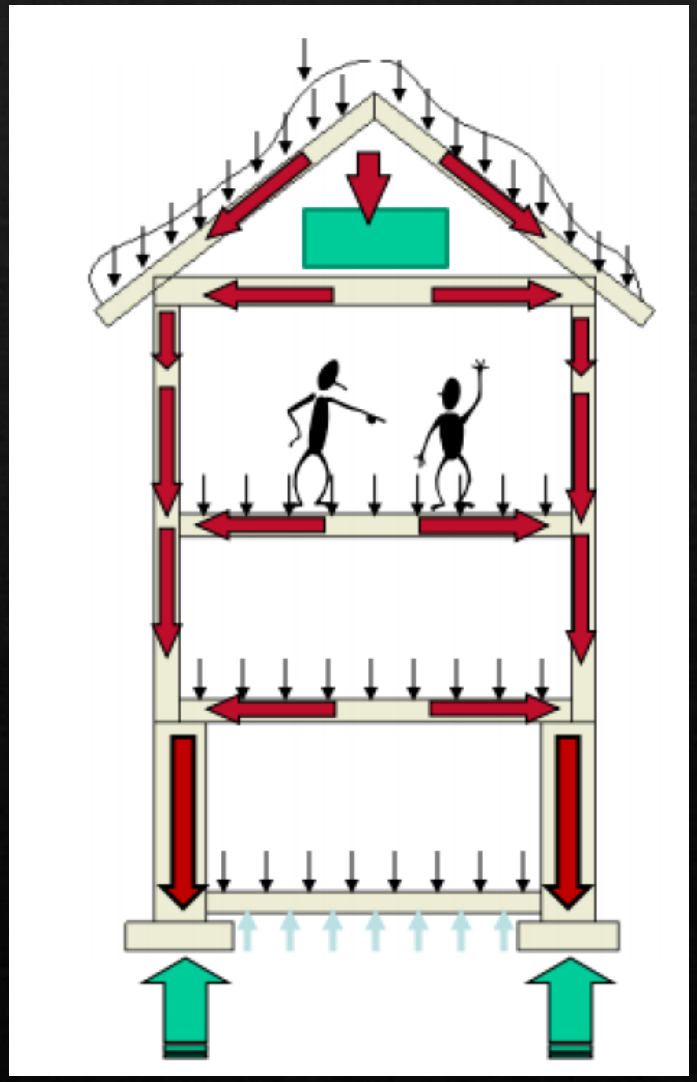
Dr. Khalil M. Qatu

Building components



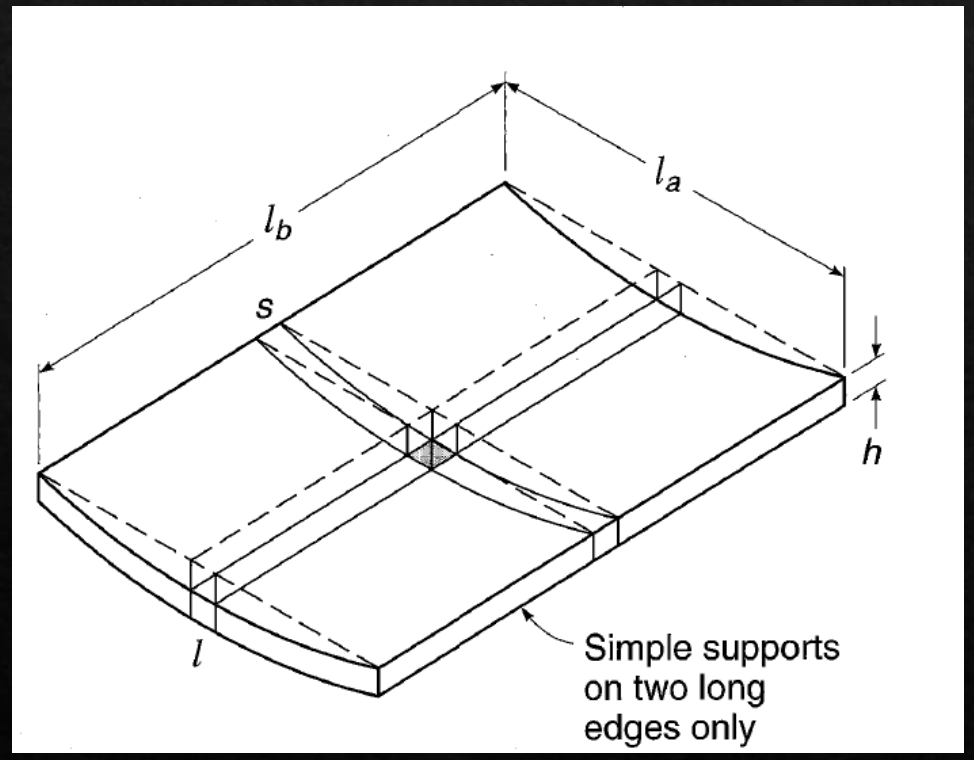
Structural components and load path

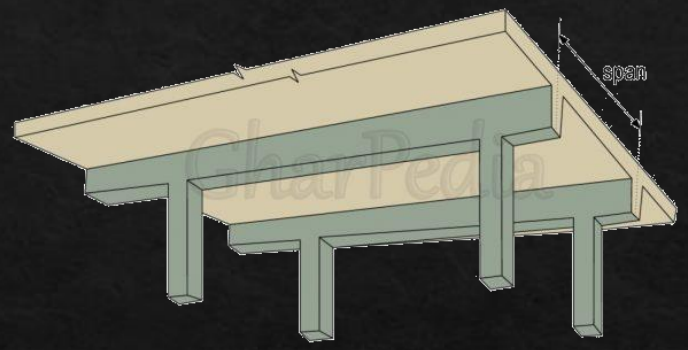


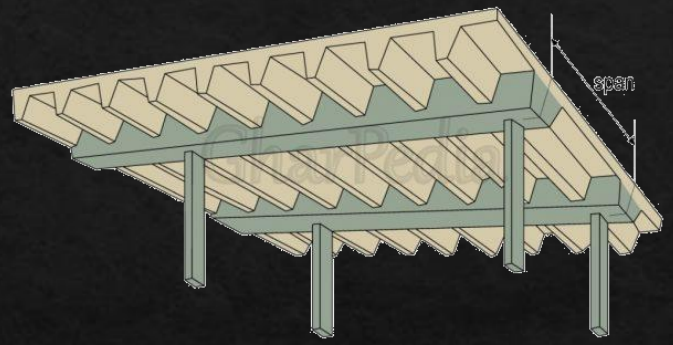


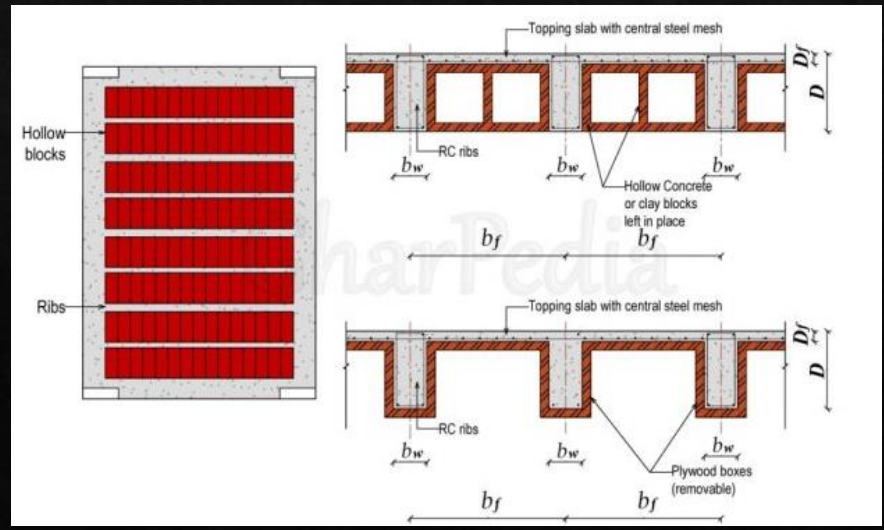
Types of slabs

- One-way slab



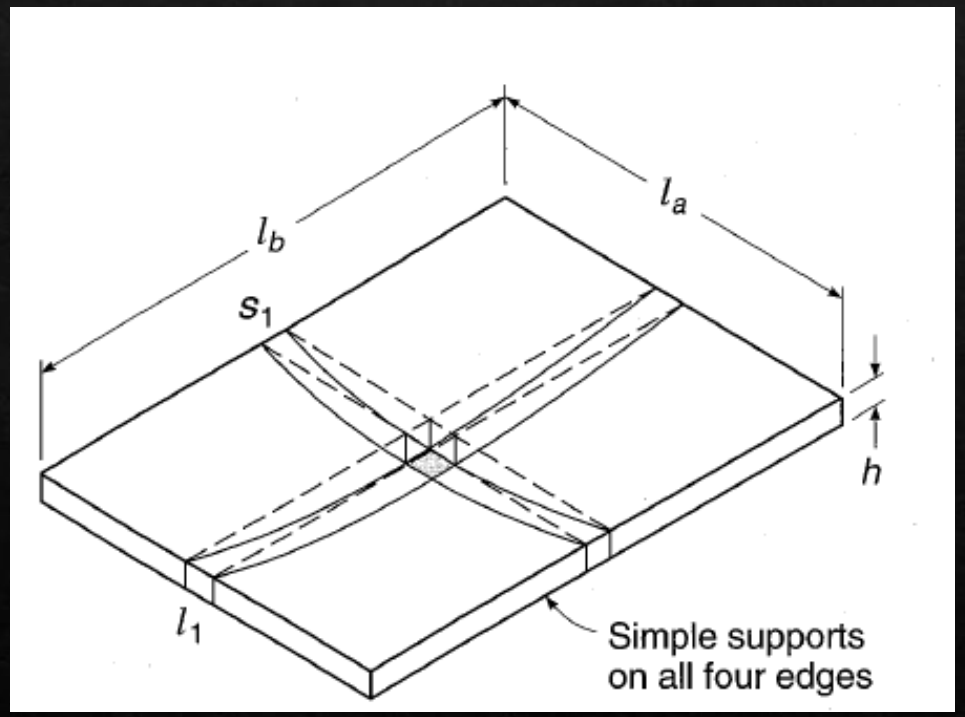


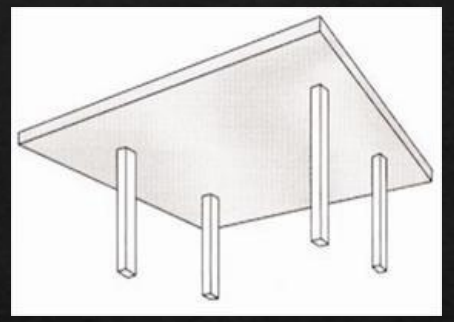


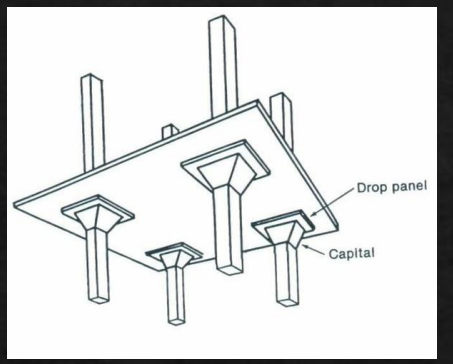


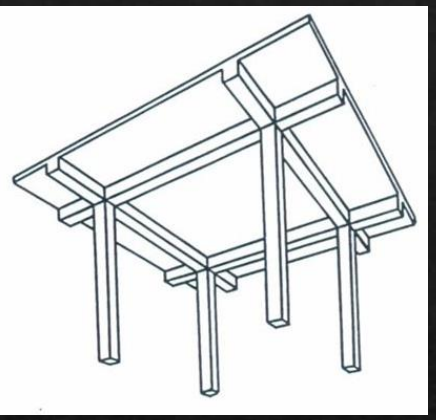
Types of slabs

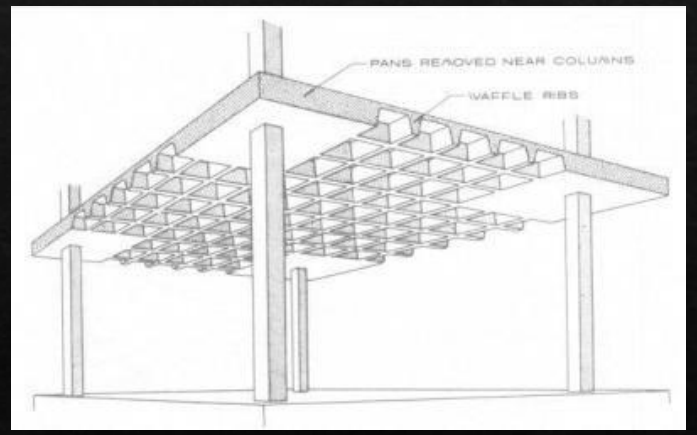
- Two-way slab

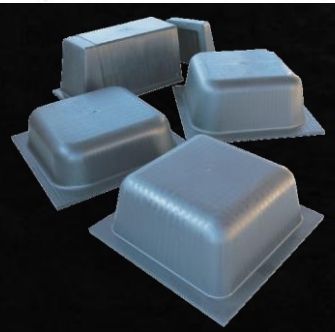


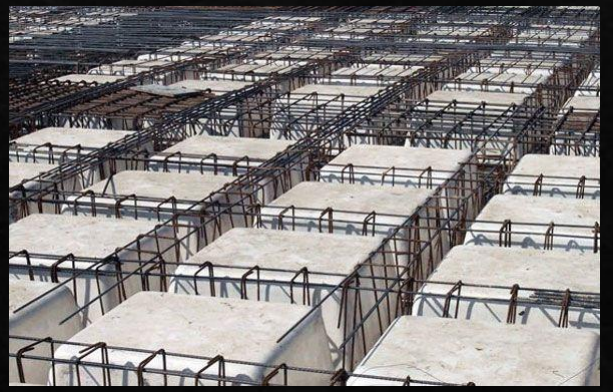




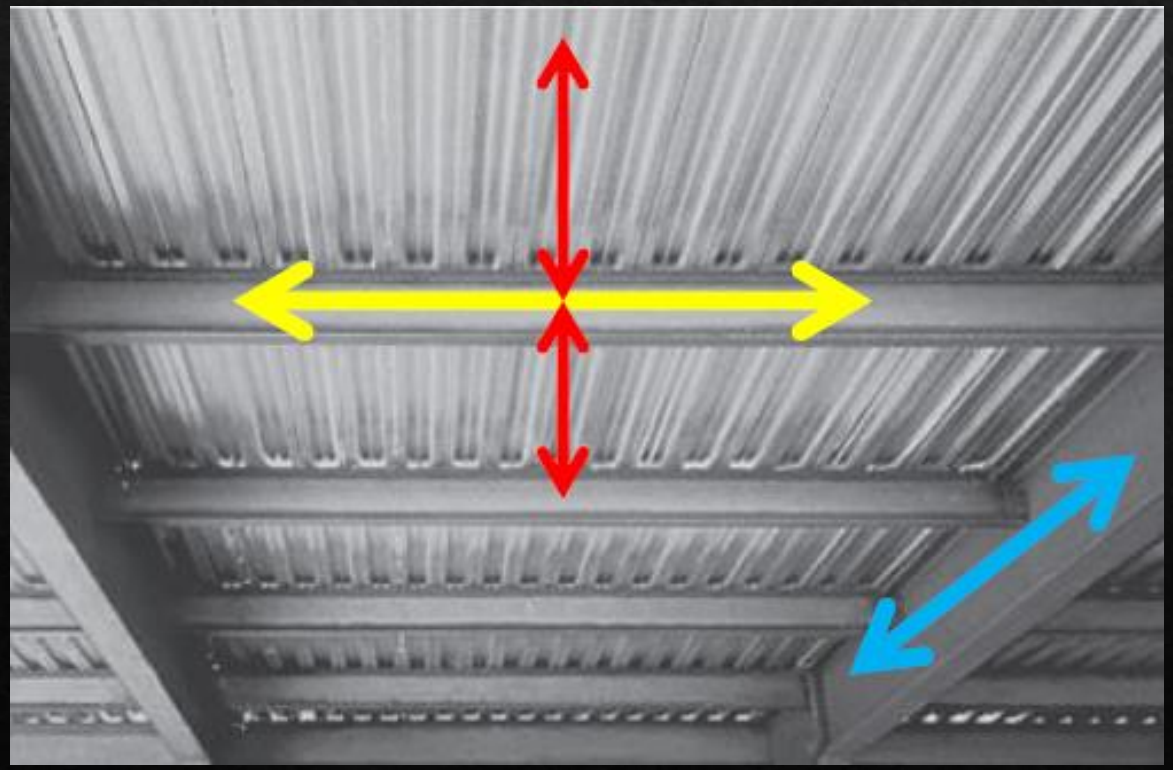


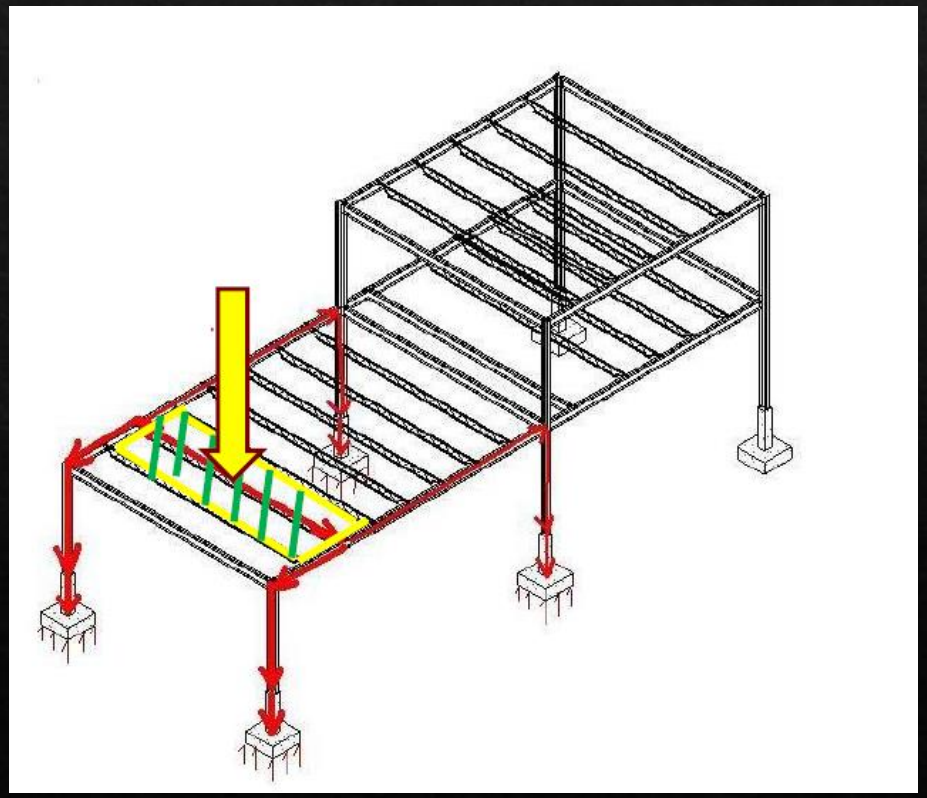




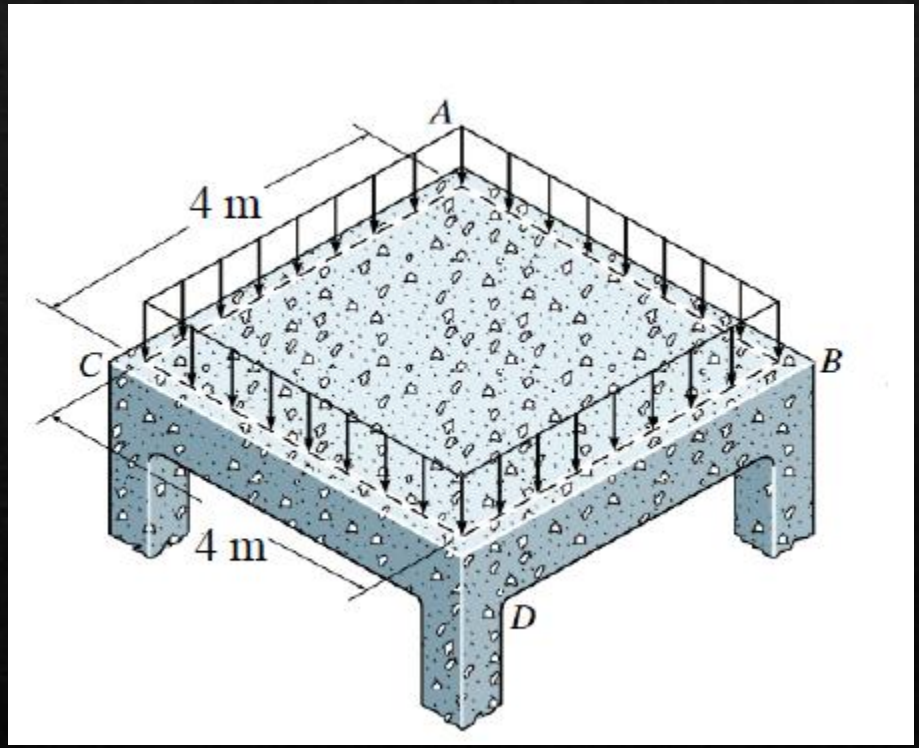


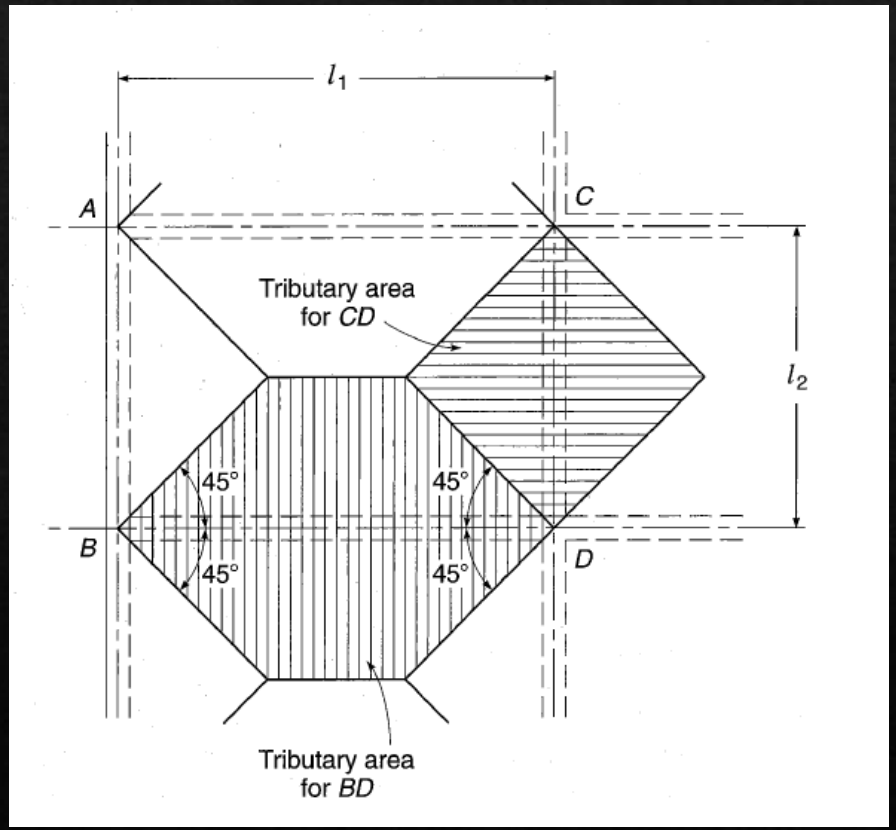
Tributary area and load transfer





Tributary area and load transfer





Design of one-way slabs

- Design of Solid slab
  - One unit strip is taken in the direction of load transfer
  - The strip is designed as a beam with one unit width
  - Same ACI code requirements applies with some exceptions
    - Min thickness
    - Min reinforcement
    - Maximum spacing between bars
    - Clear cover
  - Shear is only carried by concrete ($V_u \leq \phi V_c$)

TABLE 13.1
Minimum thickness *h* of nonprestressed one-way slabs

Simply supported	$l/20$
One end continuous	$l/24$
Both ends continuous	$l/28$
Cantilever	$l/10$

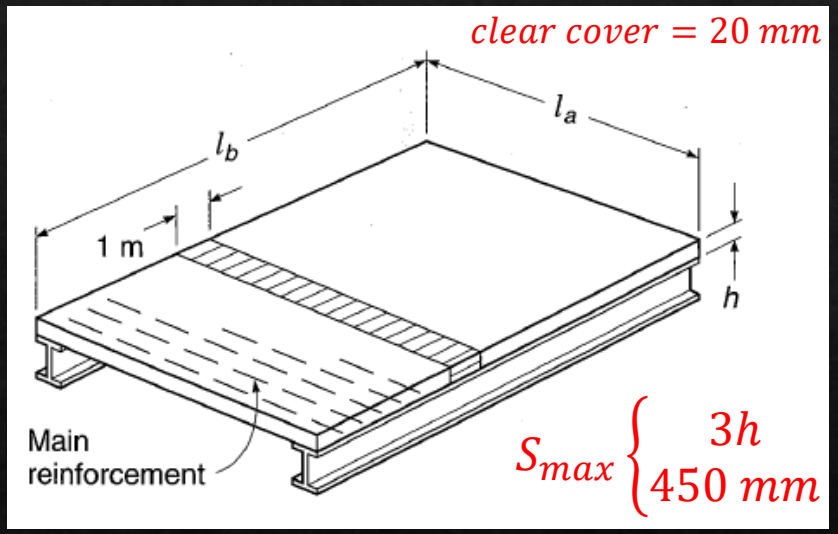


TABLE 13.2
Minimum ratios of temperature and shrinkage reinforcement in slabs based on gross concrete area

Slabs where Grade 40 or 50 deformed bars are used	0.0020
Slabs where Grade 60 deformed bars or welded wire fabric (smooth or deformed) is used	0.0018
Slabs where reinforcement with yield strength exceeding 420 MPa measured at yield strain of 0.35 percent is used	$\frac{0.0018 \times 420}{f_y}$

Design of one-way slabs

- Solid slab – load calculation
  - Dead load

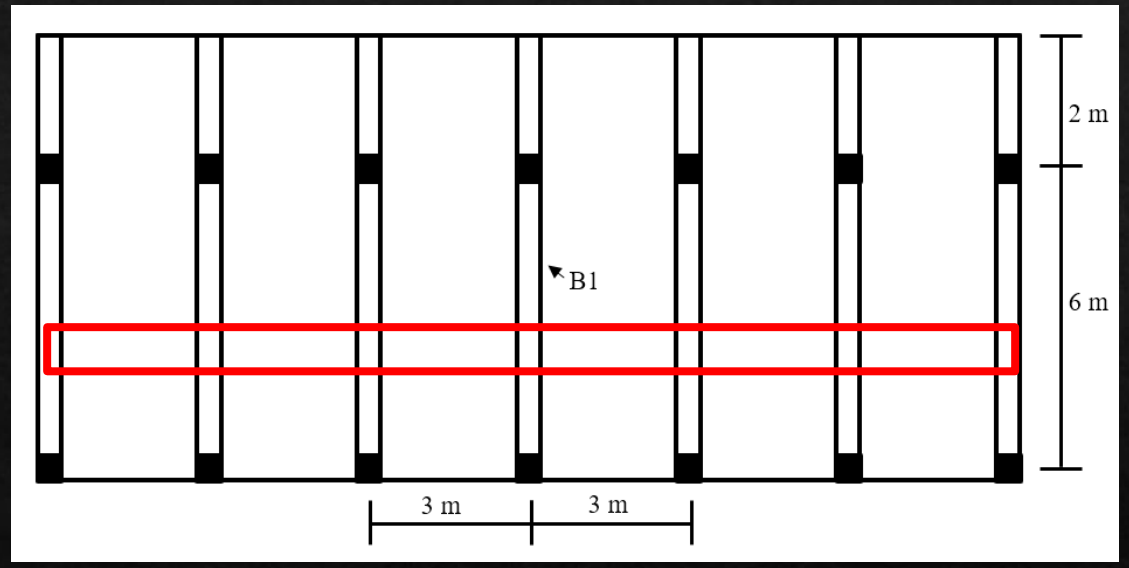
Hmin = 130 mm
Self weight
SW = 0.13*1*1*24 = 3.12 kN/m2

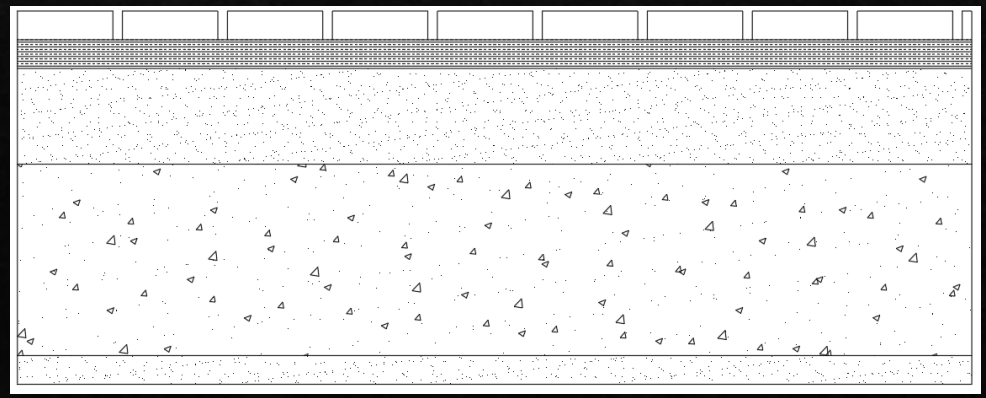
Super imposed dead loads
Plastering = 0.02*1*1*22= 0.44
Fill = 0.1*1*1*18= 1.8
Mortar = 0.03*1*1*22 = 0.66
Tiles = 20 kg/m2 = 0.2 kN/m2

Total SI= 3.1 kN/m2
Partitions = 1.5 kN/m2
Total dead load = 7.72 kN/m2

TABLE 13.1
Minimum thickness *h* of nonprestressed one-way slabs

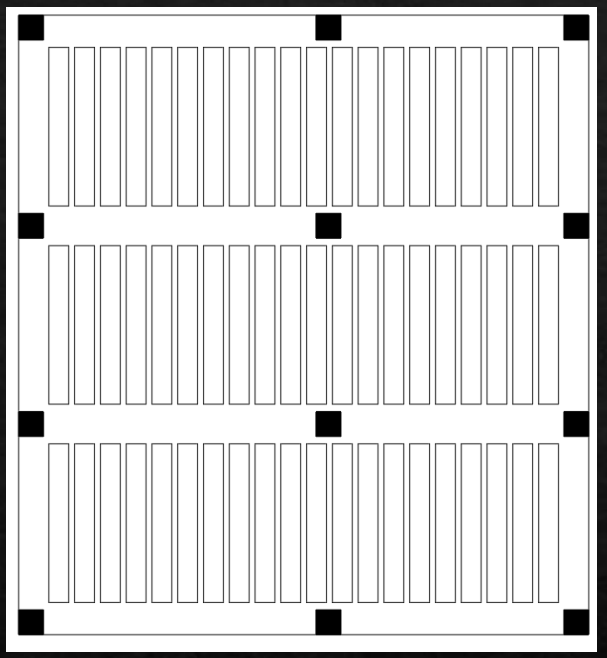
Simply supported	*l*/20
One end continuous	*l*/24
Both ends continuous	*l*/28
Cantilever	*l*/10





Design of one-way slabs

- Design of Ribbed slab
  - Hollow blocks other types of filler are used to reduce self-weight of the slab
  - Typically used when the required thickness of a solid slab is more than 20 cm
  - The direction of load transfer is controlled by the direction of ribs
  - Same ACI code requirements applies with some exceptions
    - Monolithic combination of regularly spaced ribs and a top slab
    - For structural integrity, at least one bottom bar in each joist shall be continuous and shall be anchored to develop fy at the face of supports.
    - Reinforcement area shall be at least the shrinkage and temperature reinforcement area
    - Shear is only carried by concrete ($V_u \leq \phi V_c$)
      - Vc shall be permitted to be taken as 1.1 times the values calculated in 22.5.



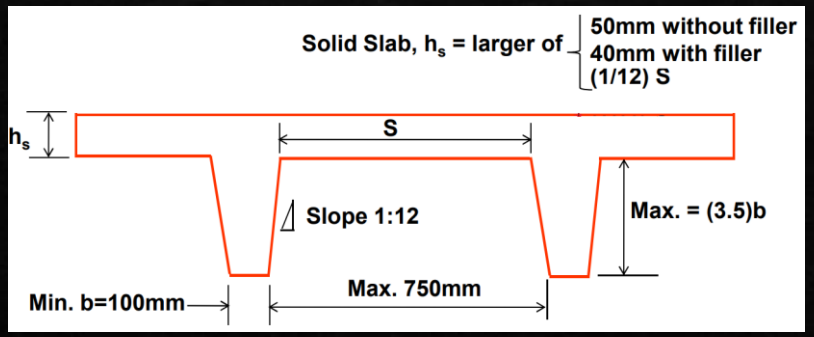
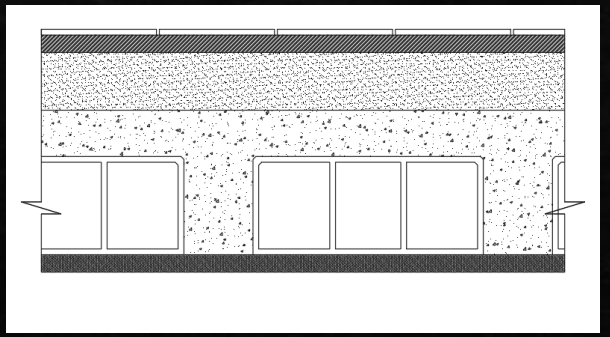


Table 9.3.1.1—Minimum depth of nonprestressed beams

Support condition	Minimum h[1]
Simply supported	ℓ/16
One end continuous	ℓ/18.5
Both ends continuous	ℓ/21
Cantilever	ℓ/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.



Design of one-way slabs

- Ribbed slab – load calculation
  - Dead load

Total SI= 3.1 kN/m^2

Min thickness →

$$H_{min} \rightarrow one\ end\ cont. = \frac{4}{18.5} = 22\ cm$$

$$H_{min} \rightarrow one\ end\ cont. = \frac{6}{18.5} = 32\ cm$$

Self weight → study area =1*0.52 = 0.52 m^2

HB = (14cm,17cm, 20 cm, 24cm) = (15 kg, 17 kg, 20kg) = 5*20/100= 1 kN

Topping mat – (7~8 cm) = 0.08*0.4*1*24= 0.768 kN

Rib = 0.32*0.12*1*24= 0.9 kN

Total / study area = 2.67 kN/study area

Total /m2 = 2.67/0.52 = 5.1 kN/m2

+ 1.5 kN/m^2 Partitions

Total dead load = 3.1 +5.1 +1.5 = 9.7 kN/m^2

Table 9.3.1.1—Minimum depth of nonprestressed beams

Support condition	Minimum h[1]
Simply supported	ℓ/16
One end continuous	ℓ/18.5
Both ends continuous	ℓ/21
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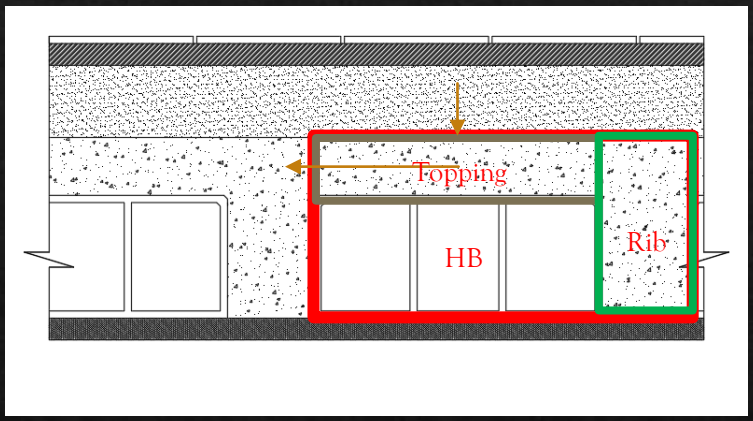
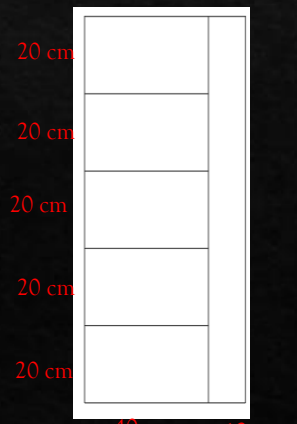
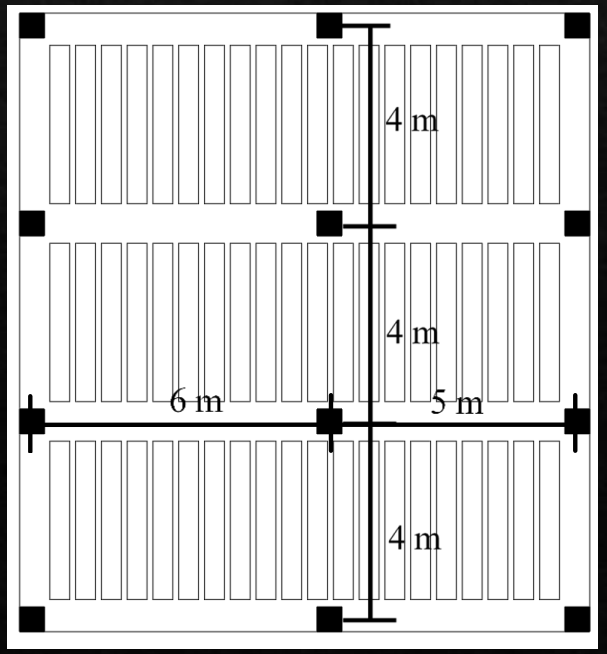






Design of one-way slabs

- Live load

TABLE 1.1
Minimum uniformly distributed live loads

Occupancy or Use	Live Load, kN/m²	Occupancy or Use	Live Load, kN/m²
Apartments (see residential)		Dining rooms and restaurants	4.8
Access floor systems		Dwellings (see residential)	
Office use	2.4	Fire escapes	4.8
Computer use	4.8	On single-family dwellings only	1.9
Armories and drill rooms	7.2	Garages (passenger cars only)	1.9
Assembly areas and theaters		Trucks and buses[a]	
Fixed seats (fastened to floor)	2.9	Grandstands (see stadium and arena bleachers)	
Lobbies	4.8	Gymnasiums, main floors and balconies[b]	4.8
Movable seats	4.8	Hospitals	
Platforms (assembly)	4.8	Operating rooms, laboratories	2.9
Stage floors	7.2	Patient rooms	1.9
Balconies (exterior)	4.8	Corridors above first floor	3.8
On one and two-family residences only, and not exceeding 9.3 m²	2.9	Hotels (see residential)	
Bowling alleys, poolrooms, and similar recreational areas	3.6	Libraries	
		Reading rooms	2.9
		Stack rooms[c]	7.2
Catwalks for maintenance access	1.9	Corridors above first floor	3.8
Corridors		Manufacturing	
First floor	4.8	Light	6.0
Other floors, same as occupancy served except as indicated		Heavy	12.0
		Marquees and canopies	3.6
Dance halls and ballrooms	4.8	Office buildings	
Decks (patio and roof)		File and computer rooms shall be designed for heavier loads based on anticipated occupancy	
Same as area served, or for the type of occupancy accommodated		Lobbies and first-floor corridors	4.8

(continued)

TABLE 1.1
(Continued)

Occupancy or Use	Live Load, kN/m²	Occupancy or Use	Live Load, kN/m²
Offices	2.4	Schools	
Corridors above first floor	3.8	Classrooms	1.9
Penal institutions		Corridors above first floor	3.8
Cell blocks	1.9	First-floor corridors	4.8
Corridors	4.8	Sidewalks, vehicular driveways, and yards subject to trucking[d]	12.0
Residential		Stadiums and arenas	
Dwellings (one and two-family)		Bleachers[b]	4.8
Uninhabitable attics without storage	0.5	Fixed seats (fastened to floor)[b]	2.9
Uninhabitable attics with storage	1.0	Stairs and exit ways	4.8
Habitable attics and sleeping areas	1.4	One and two-family residences only	1.9
All other areas except stairs and balconies	1.9	Storage areas above ceilings	1.0
Hotels and multifamily houses		Storage warehouses (shall be designed for heavier loads if required for anticipated storage)	
Private rooms and corridors serving them	1.9		
Public rooms and corridors serving them	4.8	Light	6.0
Reviewing stands, grandstands, and bleachers[b]		Heavy	12.0
Roofs		Stores	
Ordinary flat, pitched, and curved roofs	1.0	Retail	
Roofs used for promenade purposes	2.9	First floor	4.8
Roofs used for roof gardens or assembly purpose	4.8	Upper floors	3.6
Roofs used for other special purposes[e]		Wholesale, all floors	6.0
Awnings and canopies		Walkways and elevated platforms (other than exitways)	2.9
Fabric construction supported by a lightweight rigid skeleton structure[f]	0.25	Yards and terraces, pedestrians	4.8
All other construction	1.0		

[a] Garages accommodating trucks and buses shall be designed in accordance with an approved method that contains provisions for truck and bus loadings.
[b] In addition to the vertical live loads, the design shall include horizontal swaying forces applied to each row of seats as follows: 350 N per linear m of seat applied in the direction parallel to each row of seats and 146 N per linear m of seat applied in the direction perpendicular to each row of seats. The parallel and perpendicular horizontal swaying forces need not be applied simultaneously.
[c] The loading applies to stack room floors that support nonmobile, double-faced library bookstacks subject to the following limitations: (a) The nominal bookstack unit height shall not exceed 2.3 m; (b) the nominal shelf depth shall not exceed 0.3 m for each face; and (c) parallel rows of double-faced bookstacks shall be separated by aisles not less than 0.9 m wide.
[d] Other uniform loads in accordance with an approved method that contains provisions for truck loadings shall also be considered where appropriate.
[e] Roofs used for other special purposes shall be designed for appropriate loads as approved by the authority having jurisdiction.
[f] Nonreducible.

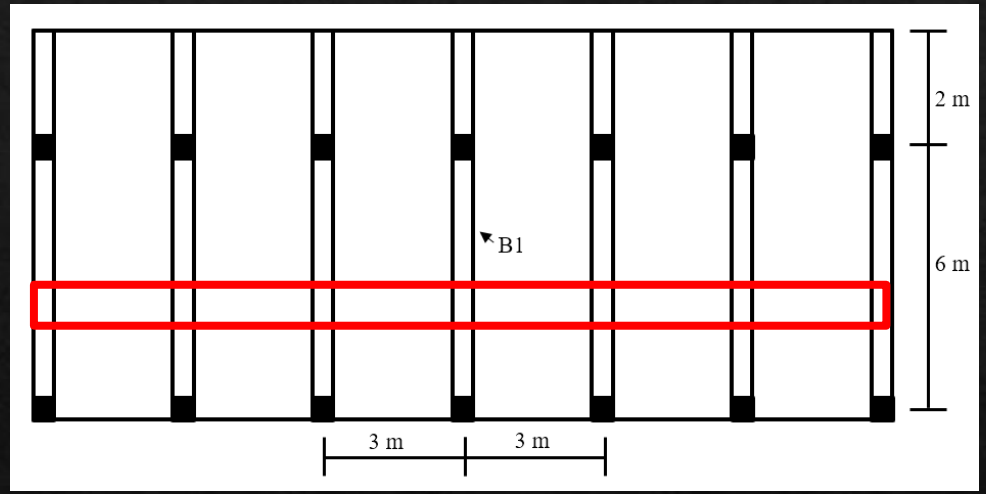
Source: From Ref. 1.1. Used by permission of the American Society of Civil Engineers.

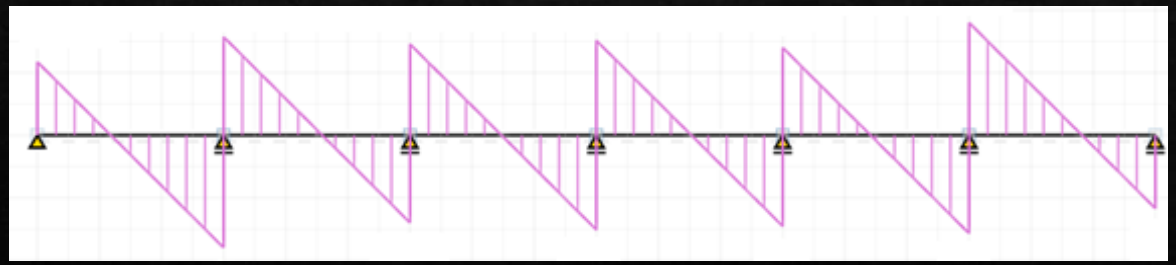
Design of one-way slabs

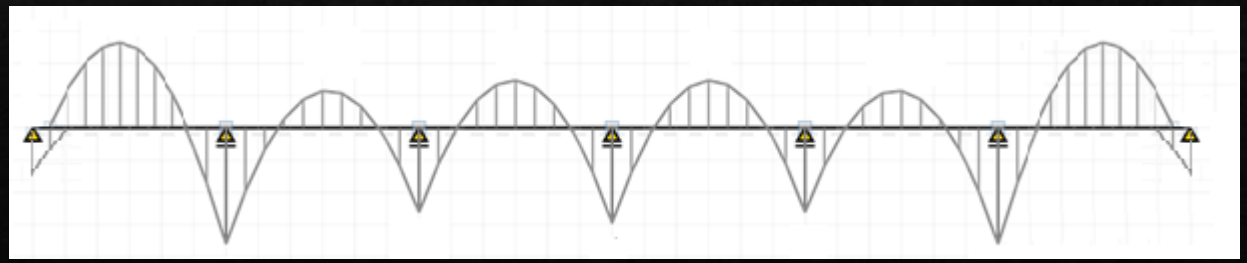
- Solid slab
  - Example: Design a solid slab for the given Floor layout

    $f_c' = 28\ MPa\ , f_y = 420\ MPa$

    - Analysis
      - $w_u = 1.2 * w_D + 1.6\ w_L = 1.2 * 7.94 + 1.6 * 4.8 = 17.21\ kN/m$







Design of one-way slabs

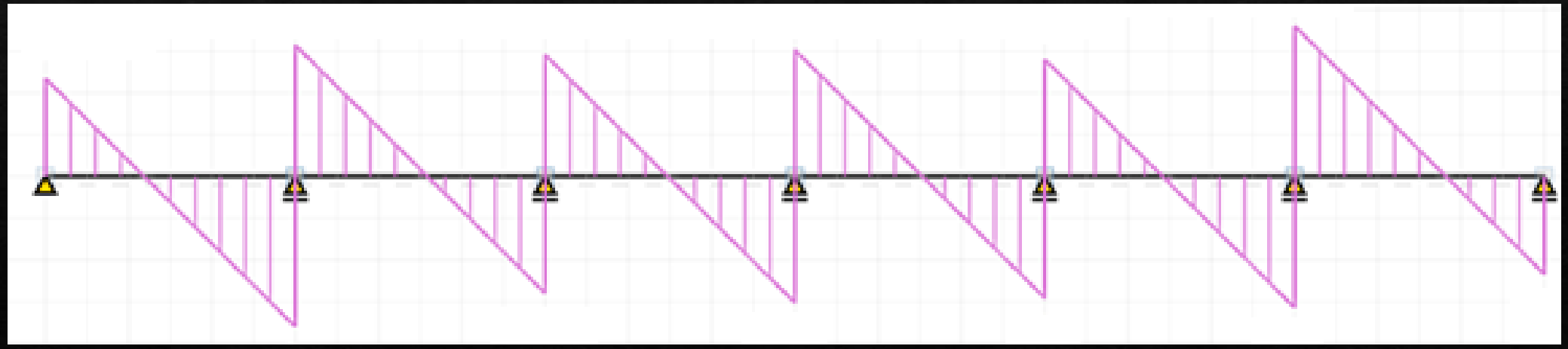
- Solid slab – Design Shear

$$\phi V_c = \phi 0.17 \sqrt{f_c'}\, b\, d$$

$$d = h - clear\ cover\ - 0.5 d_b = 130 - 20 - 7 = 103 \sim 100\ mm$$

$$\phi V_c = \phi 0.17 \sqrt{f_c'} b\, d = 0.75\ * .17 * \sqrt{28} * 1000 * 100 = 67.5\ kN$$

$$V_u = 31.27\ kN \rightarrow \frac{\phi V_c}{2} = 33.75\ kN\ \rightarrow V_u < \frac{\phi V_c}{2} \rightarrow No\ shear\ reinforcement\ needed$$



Design of one-way slabs

- Solid slab – Design Flexure

$design\ section \rightarrow rectangular\ B = 1000\ mm\ d = 100\ mm$

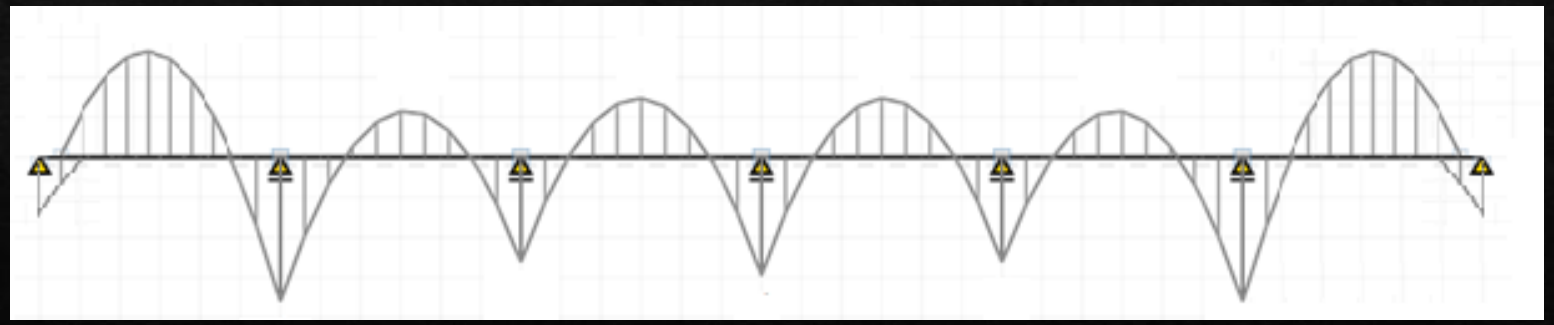
$Mu{=}16.4\ kN.m$

$$R = \frac{M_u}{\phi bd^2} = \frac{16.4 * 10^6}{0.9 * 1000 * 100} = 2.18\ MPa \rightarrow Table\ A5 \rightarrow \frac{0.005 - 0.0055}{2.01 - 2.2} = \frac{0.005 - \rho}{2.01 - 2.18} \rightarrow \rho = 0.0054$$

$$A_s = \rho bd = 0.0054 * 1000 * 100 = 540\ mm^2 \rightarrow table\ A3 \rightarrow \phi 10@130\ mm \rightarrow A_s = 546\ mm^2$$

$$S_{max} \begin{cases} 3h = 3 * 130 = 390\ mm \\ 450\ mm \end{cases}$$

$\rho > \rho_{min}, check\ \ S < S_{max}$



$M_u = 13.4\ kN.m$

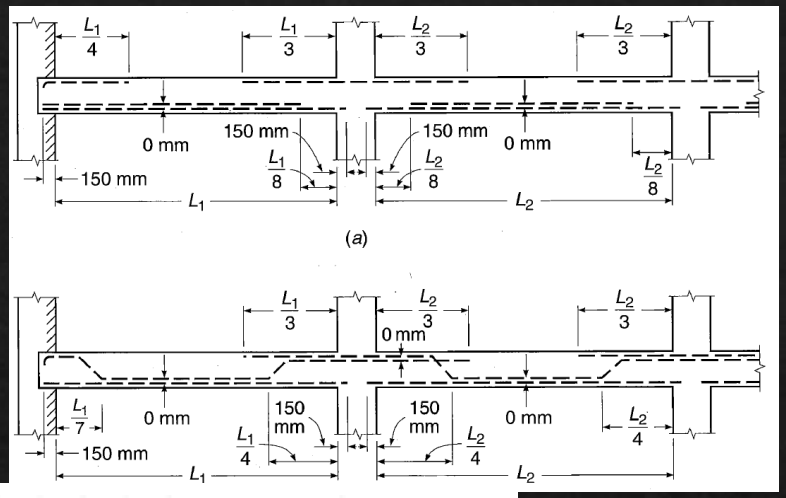
$R = 1.5\ MPa \rightarrow \rho = 0.0037 \rightarrow A_s = 370\ mm^2$

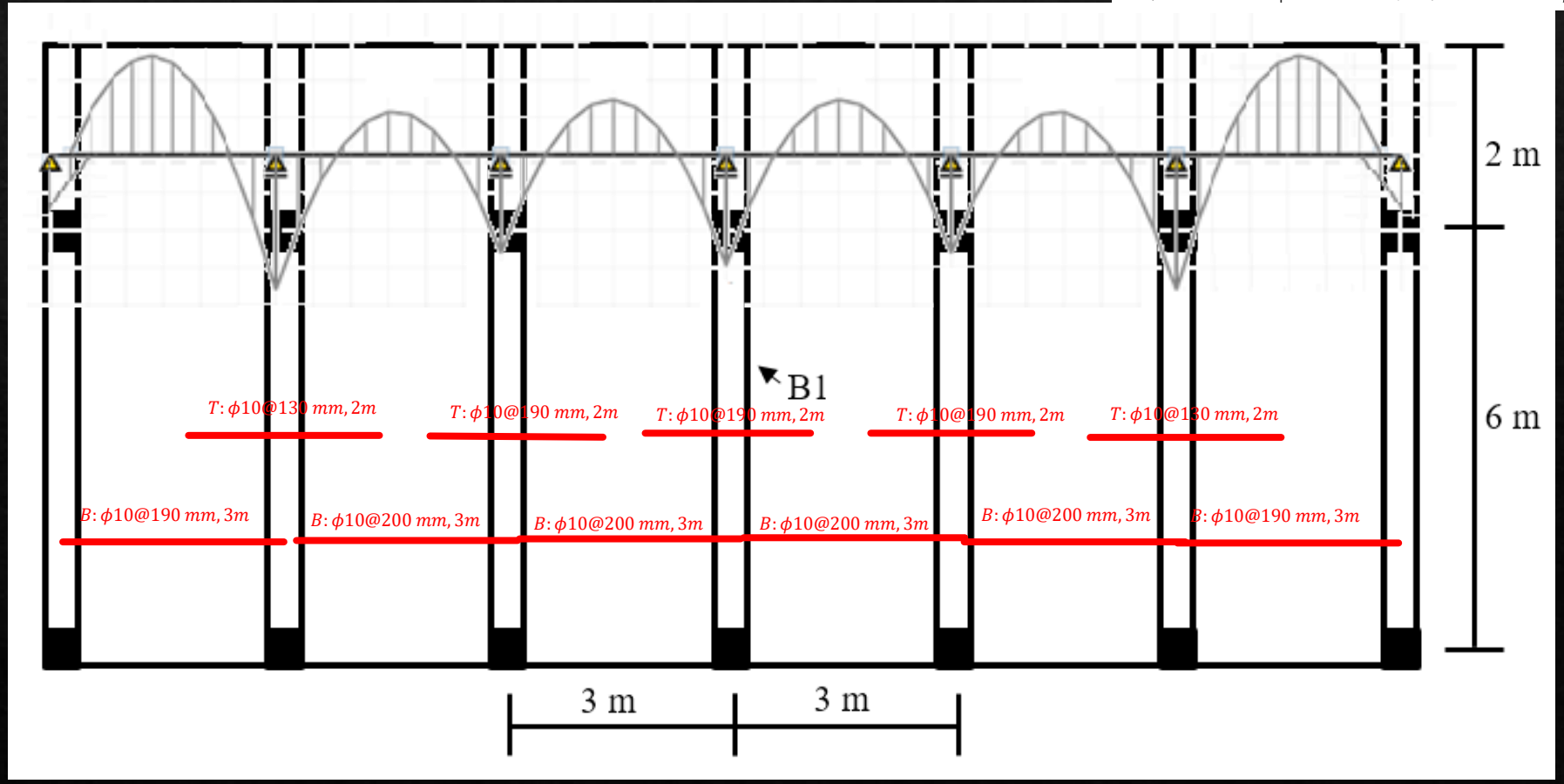
$\rightarrow\ \phi 10@190\ mm$

$M_u = 6.7\ kN.m \rightarrow R = 0.74\ MPa \rightarrow \rho_{min} = 0.0033 \rightarrow A_s = 330\ mm^2 \rightarrow \phi 10\ @200\ mm$

Design of one-way slabs

- Solid slab – Detailing





Design of one-way slabs

- Ribbed slab

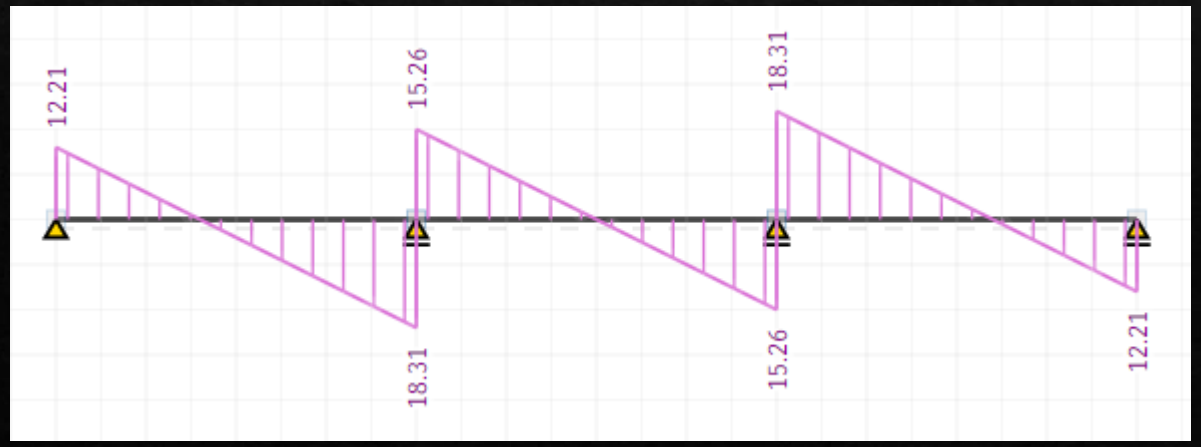
  Example: Design a ribbed slab for the given floor layout

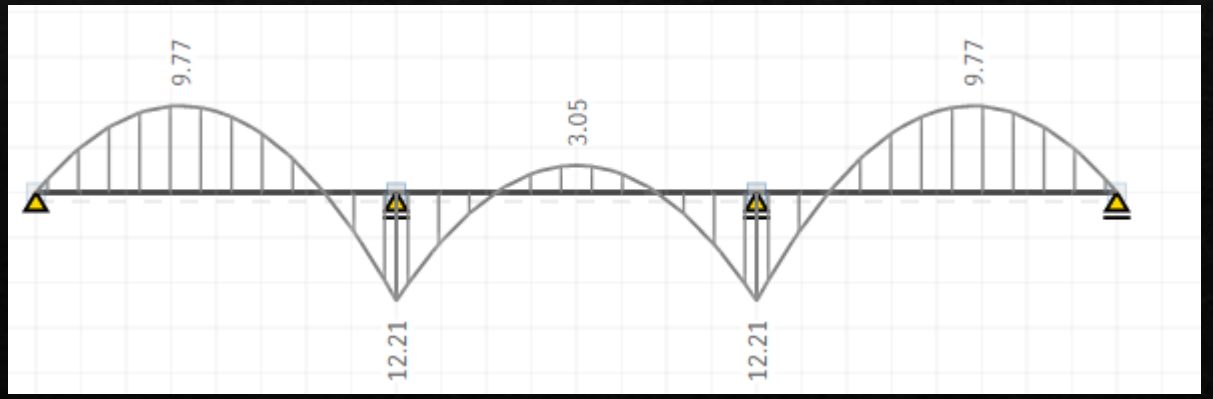
  $f_c' = 28\ MPa\ , f_y = 420\ MPa$

  - Analysis

    $w_u = 1.2 * 9.7 + 1.6 * 1.9 = 14.68\ kN/m^2$

    Tributary width = 0.52 m → load per rib = $14.68 * 0.52 = 7.63$ kN/m





Design of one-way slabs

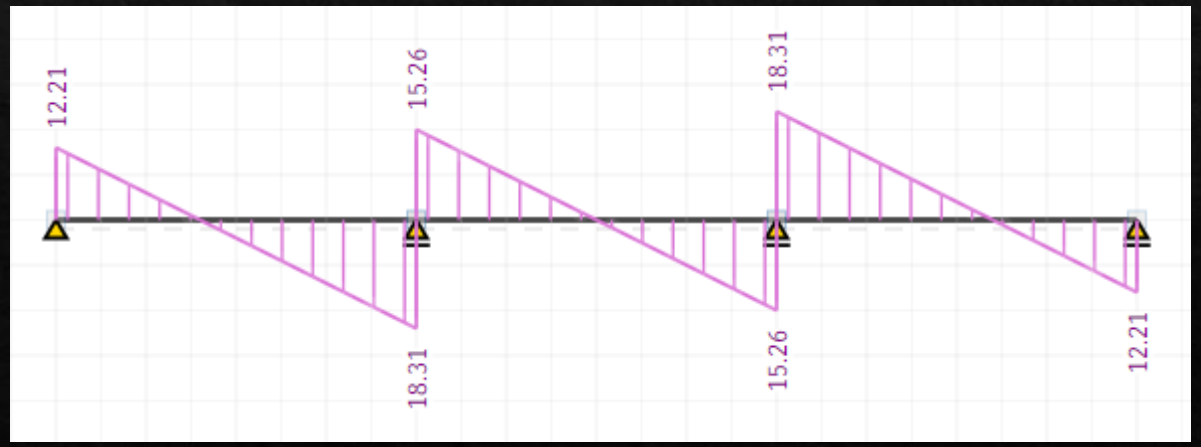
- Ribbed slab – Design Shear

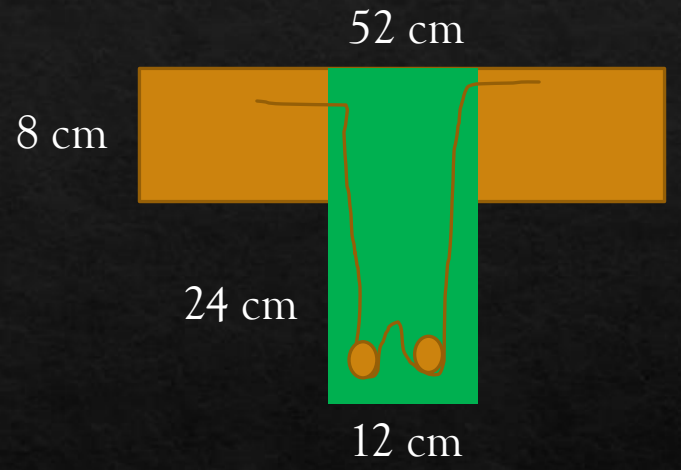
$\phi V_c = \phi 0.17 \sqrt{f'_c}\, b\, d$

$d = h - clear\ cover\ - 0.5 d_b = 320 - 20 - 10\ -\ 7 = 283\ mm$

$\phi V_c = 1.1\ * \phi 0.17 \sqrt{f'_c} b\, d = 0.75\ * .17 * \sqrt{28} * 120 * 283 = 25.2\ kN$

$V_u = 18.31\ kN \rightarrow \phi V_c > V_u$



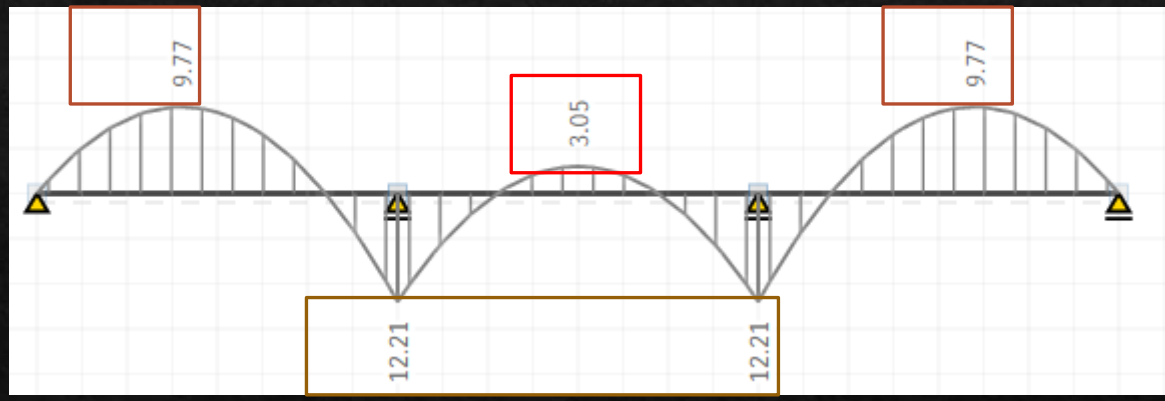


Design of one-way slabs

- Ribbed slab – Design Flexure
  - -ve moment = 12.21 kN.m
    - rectangular – b= 120 mm d=283 mm

    R= 1.41 MPa $\rightarrow \rho = 0.0035 \rightarrow A_s = 118.8\, mm^2$

    $2\phi 10 \rightarrow A_s = 142\, mm^2$



  - +ve moment = 9.77 kN.m
    - T-section or rect. – b= 520 mm d=283 mm

    R= 0.26 MPa $\rightarrow \rho < \rho_{min} \rightarrow \rho_{min} = 0.0033\ A_s = 485.6\, mm^2$

    $2\phi 19 \rightarrow A_s = 568\, mm^2$

Design of one-way slabs

- Ribbed slab – Detailing