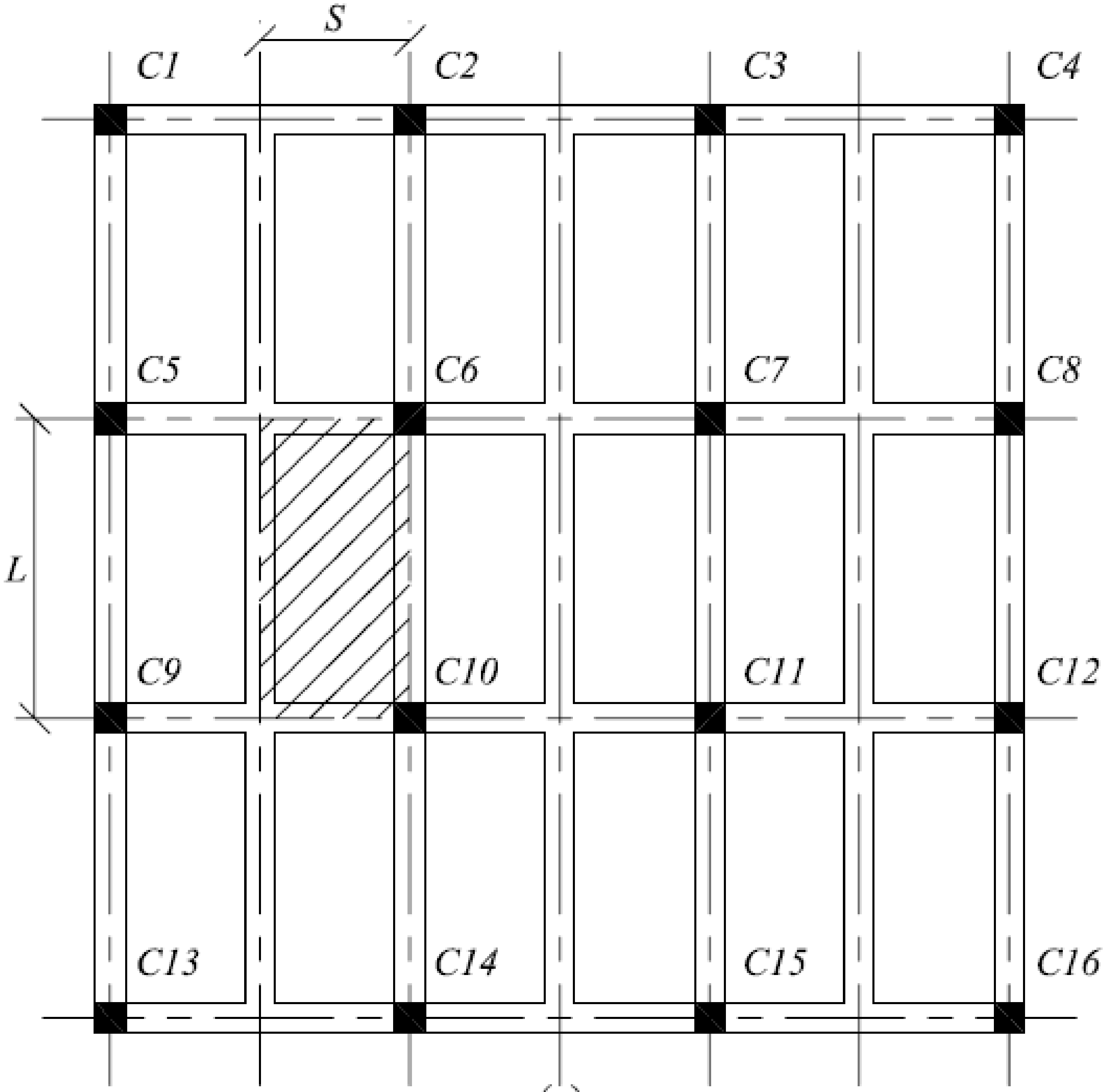
ONE-WAY SLAB

Introduction

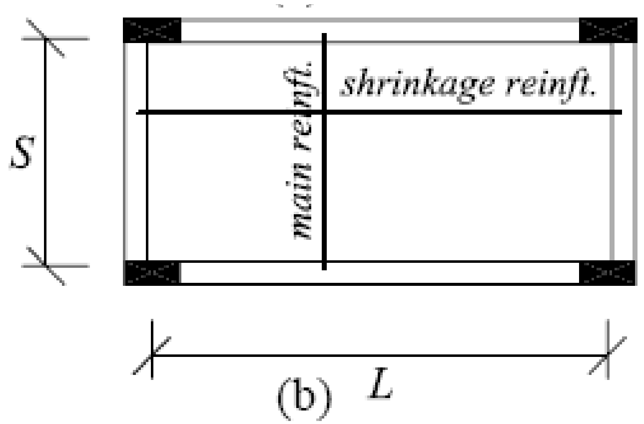
A slab is structural element whose thickness is small compared to its own length and width. Slabs are usually used in floor and roof construction.

One-way slabs:

When the ratio of the longer to the shorter side (L/S) of the slab is at least equal to 2.0, it is called one-way slab. Under the action of loads, it is deflected in the short direction only, in a cylindrical form. Therefore, main reinforcement is placed in the shorter direction, while the longer direction is provided with shrinkage reinforcement to limit cracking. When the slab is supported on two sides only, the load will be transferred to these sides regardless of its longer span to shorter span ratio, and it will be classified as one-way slab.



(a)

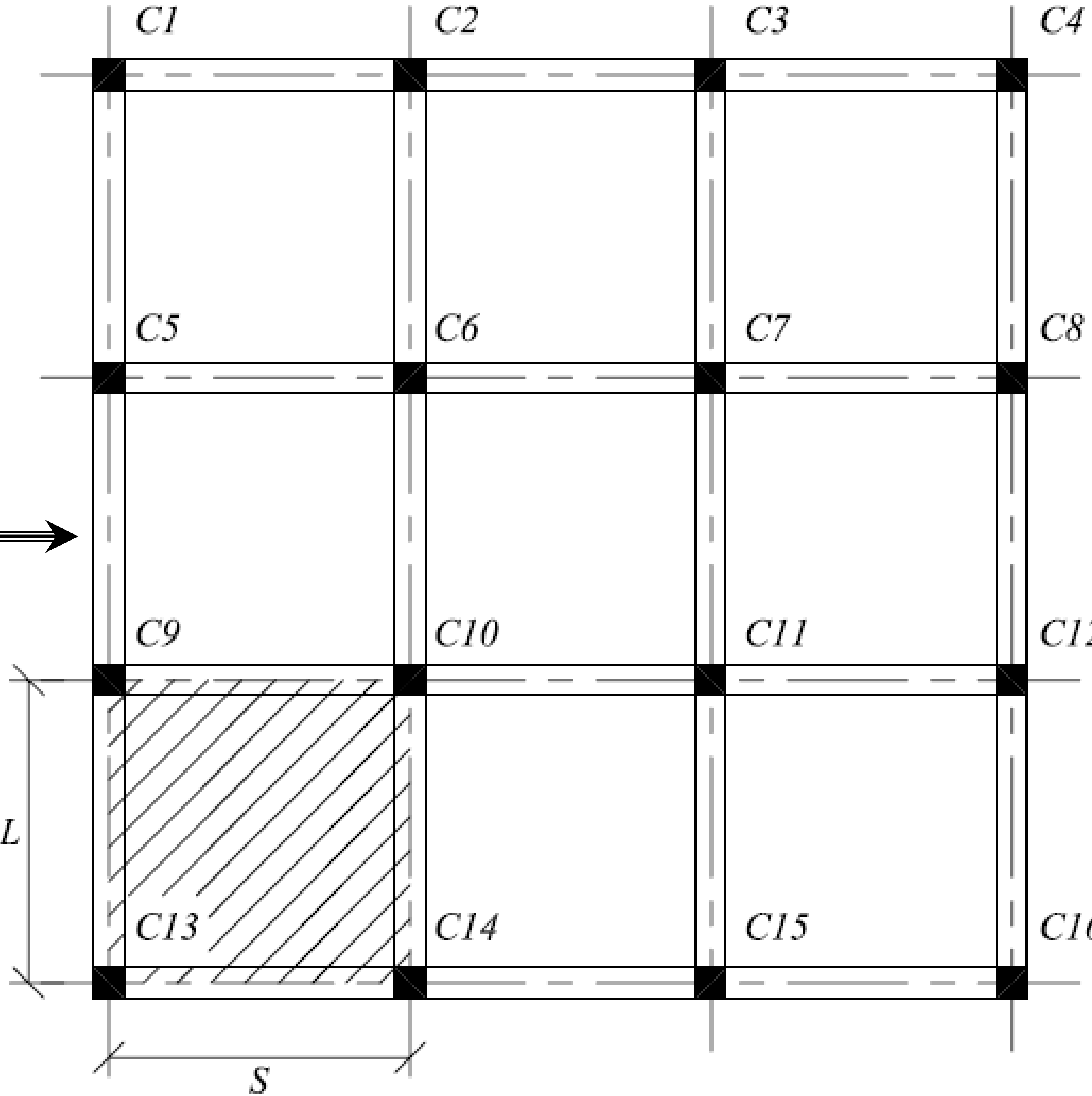


One way slab; (a) classification; (b) reinforcement

Two-way Slabs:

When the ratio (*L/ S*) is less than 2.0, it is called two-way slab. Bendig will take place rein the two directions in a dish-like form.
Accordingly, nmain inforcement is required in the two directions.

Two way slabs



One-way Slabs

In this section, two types will be discussed, one-way solid slabs and one-way ribbed slabs.

One-way Solid Slabs

Minimum Thickness

To control deflection, *ACI Code 9.5.2.1* specifies minimum thickness values for one-way solid slabs, shown in Table.

Minimum thickness of one-way solid slabs

Element	Simply supported	One end continuous	Both ends continuous	Cantilever
One-way solid slabs	$l/20$	$l/24$	$l/28$	$l/10$

where *l* is the span length in the direction of bending.

Minimum Concrete Cover

According to *ACI Code 7.7.1*, the following minimum concrete cover is to be provided:

a. Concrete not exposed to weather or in contact with ground:

- ϕ36 mm and larger bar -- 4 *cm*
- ϕ36 mm and smaller bars ------------------------------------ 2 *cm*

b. Concrete exposed to weather or in contact with ground:

- ϕ16 mm and larger bars -- 5 *cm*
- ϕ16 mm and smaller bars -------------------------------------- 4 *cm*

c. Concrete cast against and permanently exposed to earth----------- 7.5 *cm*

Design Concept

One-way solid slabs are designed as a number of independent 1 *m* wide strips which span in the short direction and supported on crossing beams.

Maximum Reinforcement Ratio

One-way solid slabs are designed as rectangular sections subjected to shear and moment. Thus, the maximum reinforcement ratio ρ_{max} is not to exceed

$$0.75\,\rho_b \text{ and } A_{s\,\max} = 0.75\,A_{sb}$$

Shrinkage Reinforcement Ratio

According to *ACI Code 7.12.2.1* and for steels yielding at $f_y = 4200 kg/cm^2$, the shrinkage reinforcement is taken not less than 0.0018 of the gross concrete area, or $A_{s\,shrinkage} = 0.0018\,b\,h$ where, *b* = width of strip, and *h* = slab thickness.

Minimum Reinforcement Ratio

According to *ACI Code 10.5.4*, the minimum flexural reinforcement is not to be less than the shrinkage reinforcement, or

$$A_{s\,min} = 0.0018\, b\, h$$

Spacing Of Flexural Reinforcement Bars

Flexural reinforcement is to be spaced not farther than three times the slab thickness, nor farther apart than 45 *cm*, center-to-center.

Spacing Of Shrinkage Reinforcement Bars

Shrinkage reinforcement is to be spaced not farther than five times the slab thickness, nor farther apart than 45 *cm*, center-to-center.

Loads Assigned to Slabs

(1) Own weight of slab:

(2) Weight of slab covering materials:

- Sand fill with a thickness of about 5 *cm*,

$$0.05 \times 1.80\ t/m^2$$

-Cement mortar, 2.5 *cm* thick.

$$0.025 \times 2.10\ t/m^2$$

- Tiling

$$0.025 \times 2.30\ t/m^2$$

-A layer of plaster about 2 *cm* in thickness.

$$0.02 \times 2.10\ t/m^2$$

(3) Live Load:

Table shows typical values used by the *Uniform Building Code* (*UBC*).

Minimum live Load values on slabs ⟹

Type of Use	Uniform Live Load kg/m^2
Residential	200
Residential balconies	300
Computer use	500
Offices	250
Warehouses	
▪ Light storage	600
▪ Heavy Storage	1200
Schools	
▪ Classrooms	200
Libraries	
▪ Reading rooms	300
▪ Stack rooms	600
Hospitals	200
Assembly Halls	
▪ Fixed seating	250
▪ Movable seating	500
Garages (cars)	250
Stores	
▪ Retail	400
▪ wholesale	500
Exit facilities	500
Manufacturing	
▪ Light	400
▪ Heavy	600

(4) Equivalent Partition Weight:

This load is usually taken as the weight of all walls carried by the slab divided by the floor area and treated as a dead load rather than a live load.

Loads Assigned to Beams

The beams are usually designed to carry the following loads:

- Their own weights.
- Weights of partitions applied directly on them.
- Floor loads.

The floor loads on beams supporting the slab in the shorter direction may be assumed uniformly distributed throughout their spans.

Approximate Structural Analysis

ACI Code 8.3.3 permits the use of the following approximate moments and shears for design of continuous beams and one-way slabs, provided:

1. Positive Moment:

a. End Spans:

- When discontinuous end unrestrained, $M_u = w_u l_n^2 / 11$
- When discontinuous end is integral with support, $M_u = w_u l_n^2 / 14$

where l_n is the corresponding clear span length

b. Interior Spans:

- $M_u = w_u l_n^2 / 16$

2. Negative Moment:

a. Negative moment at exterior face of first interior support:

- Two spans, $M_u = w_u l_n^2 / 9$

- More than two spans, $M_u = w_u l_n^2/10$

where l_n is the average of adjacent clear span lengths.

b. Negative moment at other faces of interior supports:

- $M_u = w_u l_n^2/11$

c. Negative moment at interior face of exterior support:

- Support is edge beam, $M_u = w_u l_n^2/24$
- Support is a column, $M_u = w_u l_n^2/16$

3. Shear:

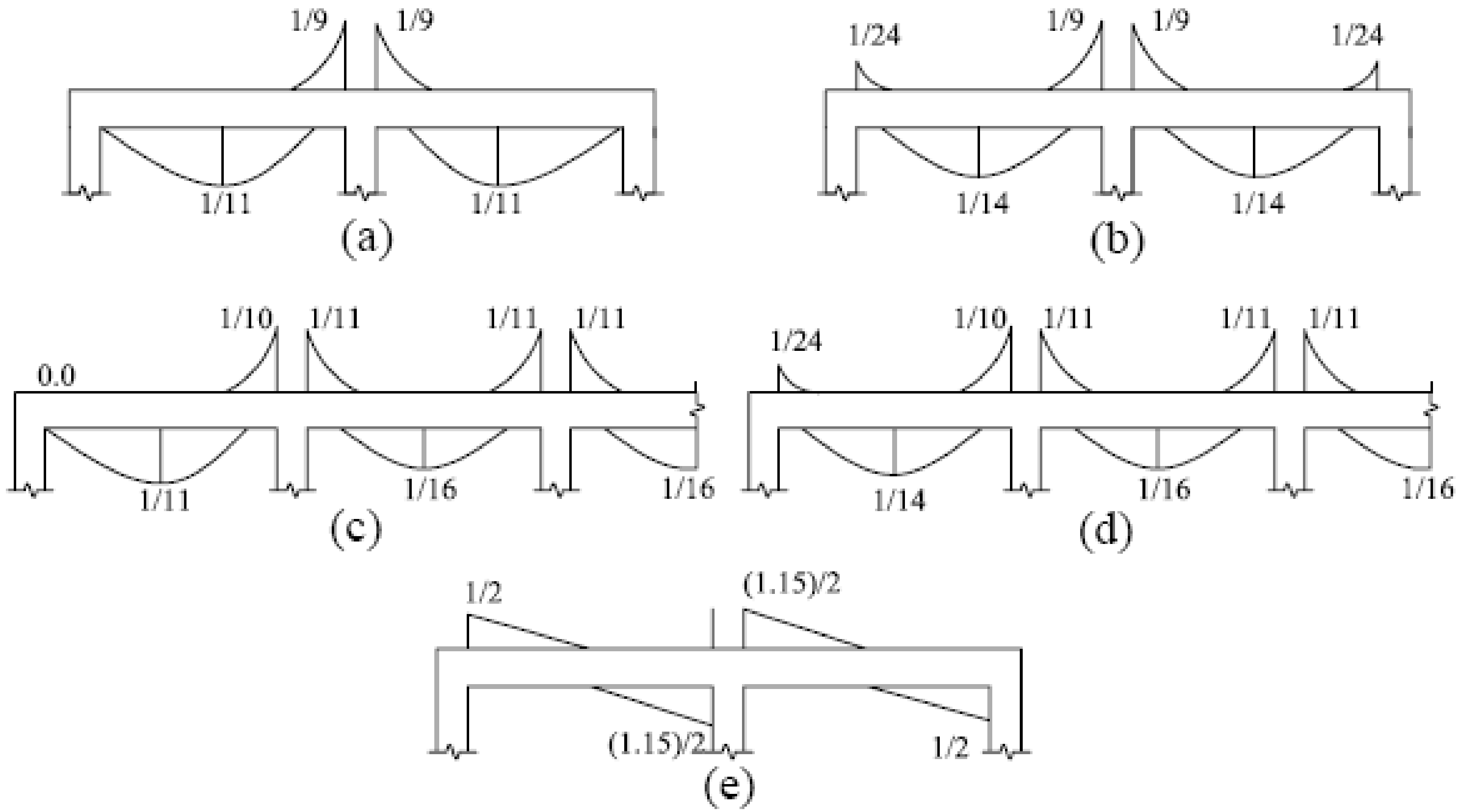
a. Shear in end members at face of first interior support:

- $V_u = 1{,}15 w_u l_n / 2$

b. Shear at face of all other supports:

- $V_u = w_u l_n / 2$

where l_n is the corresponding clear span length.

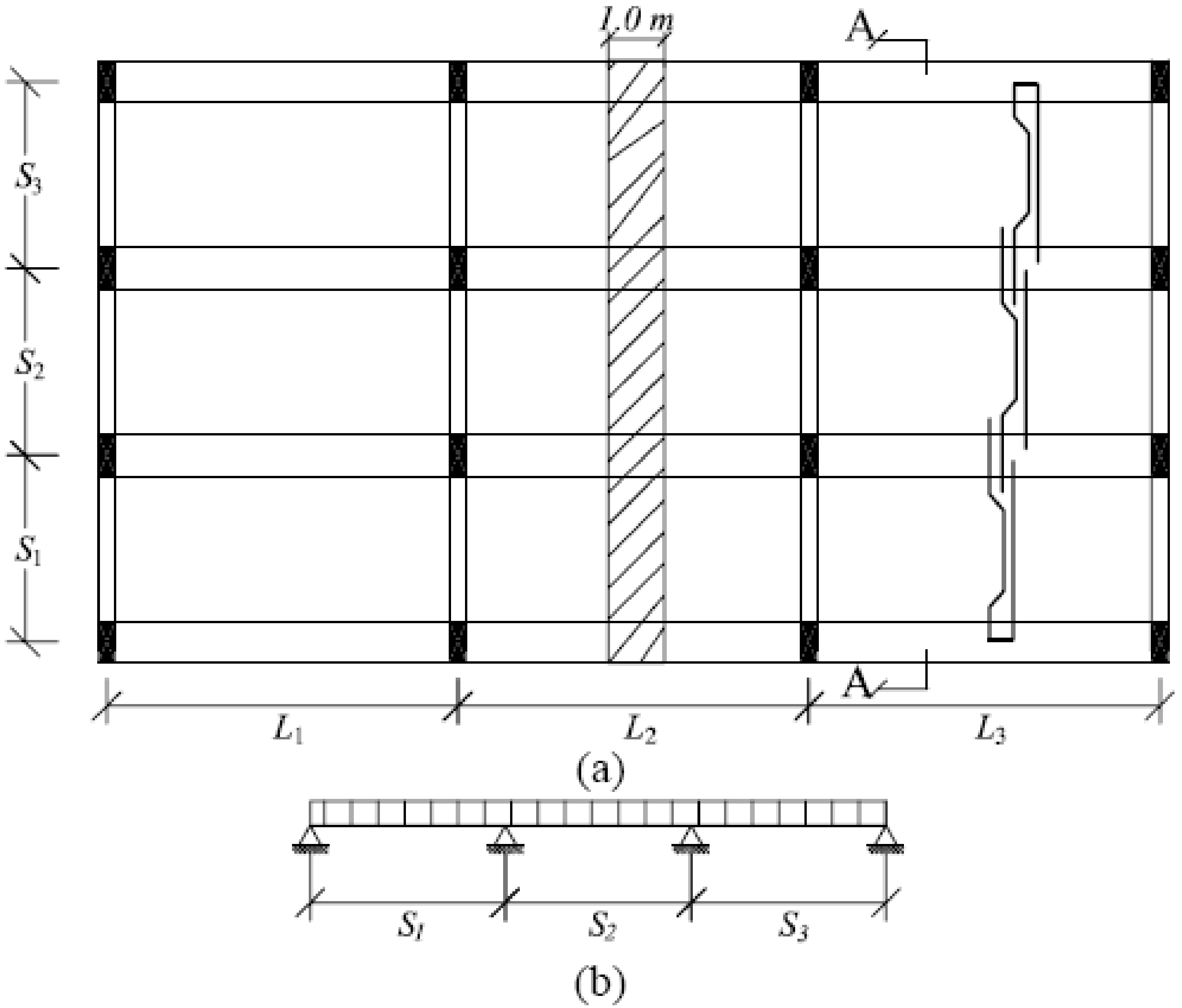


(a) Two spans, exterior edge unrestrained; (b) two spans, support is spandrel beam; (c) more than two spans, exterior edge unrestrained; (d) more than two spans, support is spandrel beam; (e) two spans, shearing force diagram

Summary of One-way Solid Slab Design Procedure

Once design compressive strength of concrete and yield stress of reinforcement are specified, the next steps are followed:

1. Select representative 1 *m* wide design strip/strips to span in the short direction.
2. Choose a slab thickness to satisfy deflection control requirements. When several numbers of slab panels exist, select the largest calculated thickness.
3. Calculate the factored load W_u by magnifying service dead and live loads according to this equation $w_u = 1.40 w_d + 1.70 w_l$.



(a) Representative strip and reinforcement; (b) strip and loads

4. Draw the shear force and bending moment diagrams for each of the strips.

5. Check adequacy of slab thickness in terms of resisting shear by satisfying the following equation:

$$V_u \leq 0.53\Phi\sqrt{f_c^{'}}bd$$

where

V_u = factored shear force

V_c = shear force resisted by concrete alone

Φ = strength reduction factor for shear is equal to 0.85.

b = width of strip = 100 cm

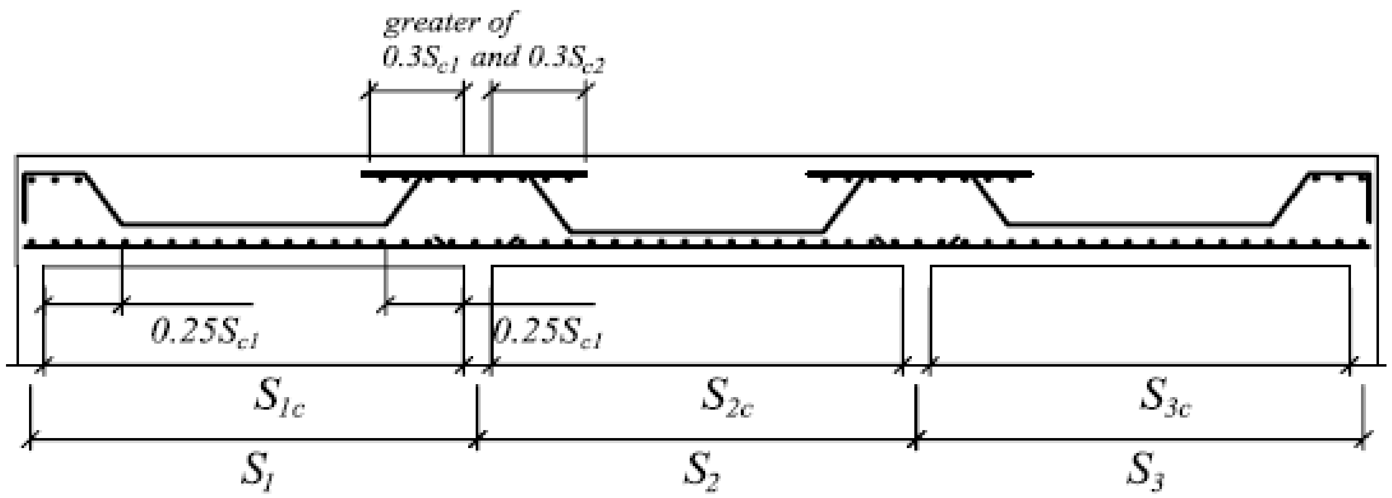
d = effective depth of slab

If the previous equation is not satisfied, go ahead and enlarge the thickness to do so.

6. Design flexural and shrinkage reinforcement:
Flexural reinforcement ratio is calculated from the following equation:

$$\rho = \frac{0.85 f_c'}{f_y}\left[1 - \sqrt{1 - \frac{2.61\times 10^5 M_u}{b d^2 f_c'}}\right]$$

Make sure that the reinforcement ratio is not larger than ¾ ρ_b
Compute the area of shrinkage reinforcement, where $A_{s\,min} = 0.0018\, b\, h$
Select appropriate bar numbers and diameters for both, main and secondary reinforcement.
Check reinforcement spacing, modify your bar selection if needed.
7. Draw a plan of the slab and representative cross sections showing the dimensions and the selected reinforcement.



Section A-A

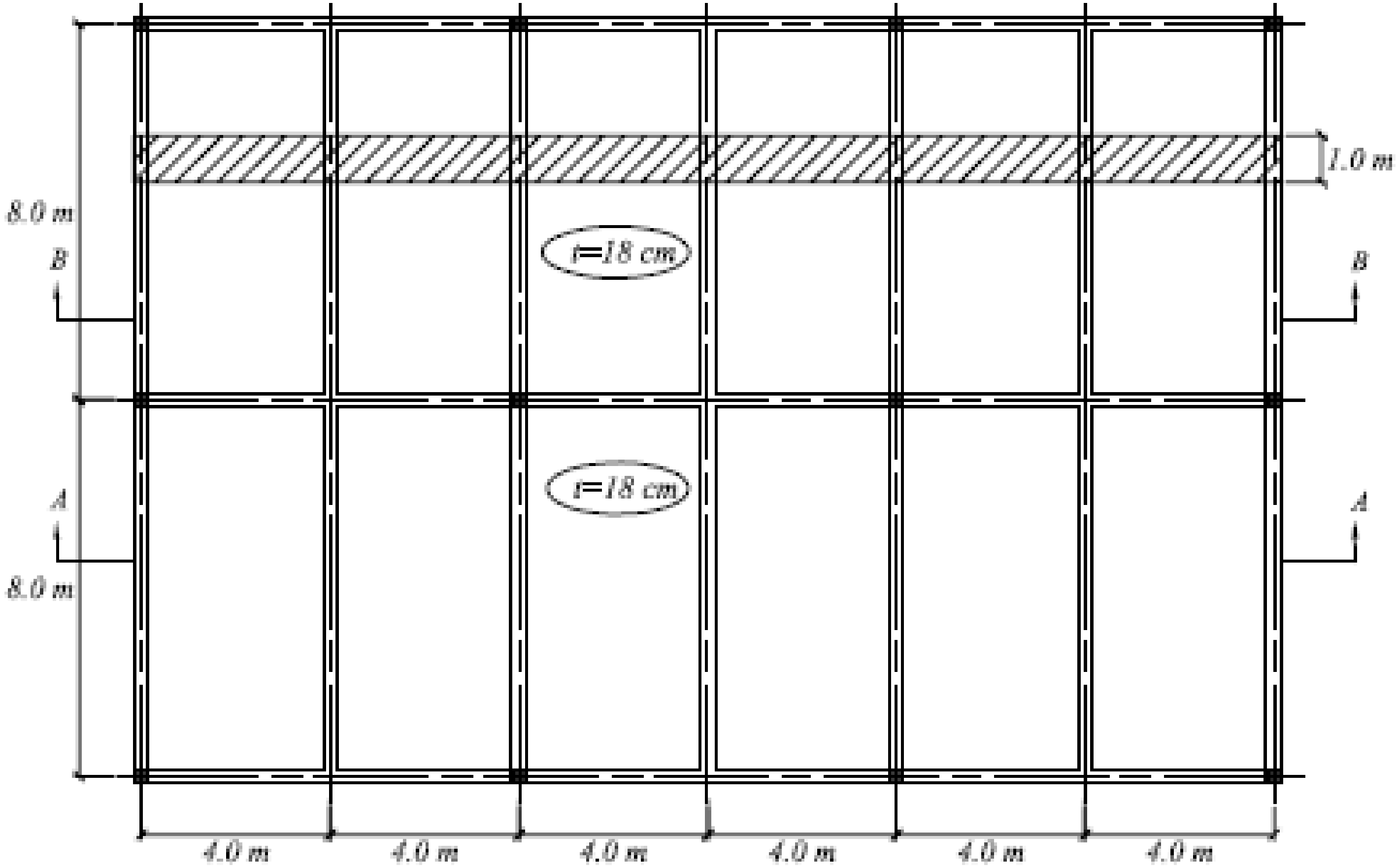
Example (8.1):

Using the ACI Code approximate structural analysis, design for a warehouse, a continuous one-way solid slab supported on beams 4.0 m apart as shown. Assume that the beam webs are 30 cm wide.
The dead load is 300 kg/m² in addition to own weight of the slab, and the live load is 300 kg/m²

Use $f_c' = 250\ kg/cm^2$ and $f_y = 4200\ kg/cm^2$.

Solution :

1- Select a representative 1 *m* wide slab strip:



Representative strip

2- Select slab thickness:

The clear span length $l_n = 4.0 - 0.30 = 3.70\ m$

For one-end continuous spans, $h_{\min} = l/24 = 400/24 = 16.67\,cm$

Slab thickness is taken as 18 *cm*.

3- Calculate the factored load W_u per unit length of the selected strip:

$$\text{Own weight of slab} = 0.18 \times 2.50 = 0.45\ ton/m^2$$

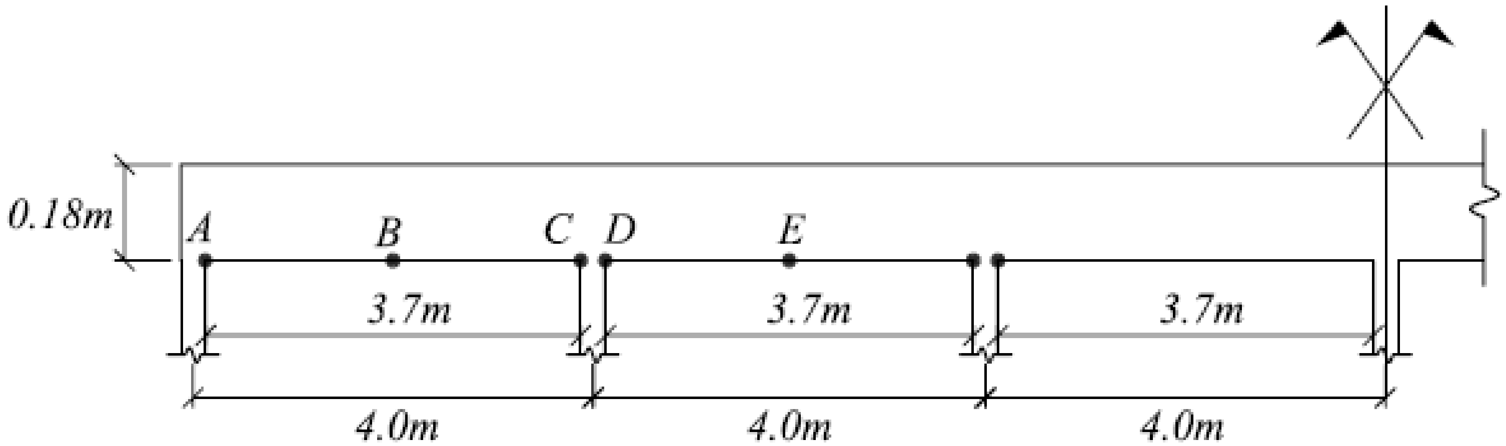
$$w_u = 1.40(0.30 + 0.45) + 1.70(0.30) = 1.56\ ton/m^2$$

For a strip 1 *m* wide, $w_u = 1.56\ ton/m$

4- Evaluate the maximum factored shear forces and bending moments in the strip:

The results are shown in the following table. Points at which moments and shear are calculated.

	A	B	C	D	E
Moment coefficient	- 1/24	1/14	- 1/10	-1 /11	1/16
Factored moment in *t.m*	- 0.890	1.525	- 2.135	- 1.941	1.335
Reinforcement ratio	0.0010	0.0017	0.0024	0.0022	0.0015
Steel reinforcement cm^2	1.54	2.62	3.70	3.39	2.31
Minimum reinforcement cm^2	3.24	3.24	3.24	3.24	3.24
Bar size *mm*	ϕ 10	ϕ 10	ϕ 10	ϕ 10	ϕ 10
Bar spacing *cm*	20	20	20	20	20



Points at which moments and shear are evaluated

5- Check slab thickness for beam shear:

Effective depth $d = 18 - 2 - 0.60 = 15.40\ cm$, assuming $\phi\, 12\ mm$ bars.

$$V_{u\,\max} = \frac{1.15}{2} w_u\, l_n = \frac{1.15}{2}(1.56)(3.70) = 3.32\ ton$$

$$\Phi\ V_c = 0.85(0.53)\sqrt{250}\ (100)(15.40)/1000 = 10.97\ ton$$

i.e. , slab thickness is adequate in terms of resisting beam shear.

6- Design flexural and shrinkage reinforcement:

Steel reinforcement ratios are then calculated, and be checked against minimum and maximum code specified limits, where

$$\rho = \frac{0.85\, f_c'}{f_y}\left[1-\sqrt{1-\frac{2.61\times10^5\, M_u}{b\, d^2\, f_c'}}\right]$$

Minimum reinforcement = 0.0018 (100) (18) = 3.24 cm^2/m

Maximum reinforcement ratio =¾ ρ_b. = 0.75 (0.0255)= 0.0191

Calculate the area of shrinkage reinforcement:

Area of shrinkage reinforcement = 0.0018 (100) (18) = 3.24 cm^2/m

Select reinforcement bars:

Main and secondary reinforcement bars are also shown in the table

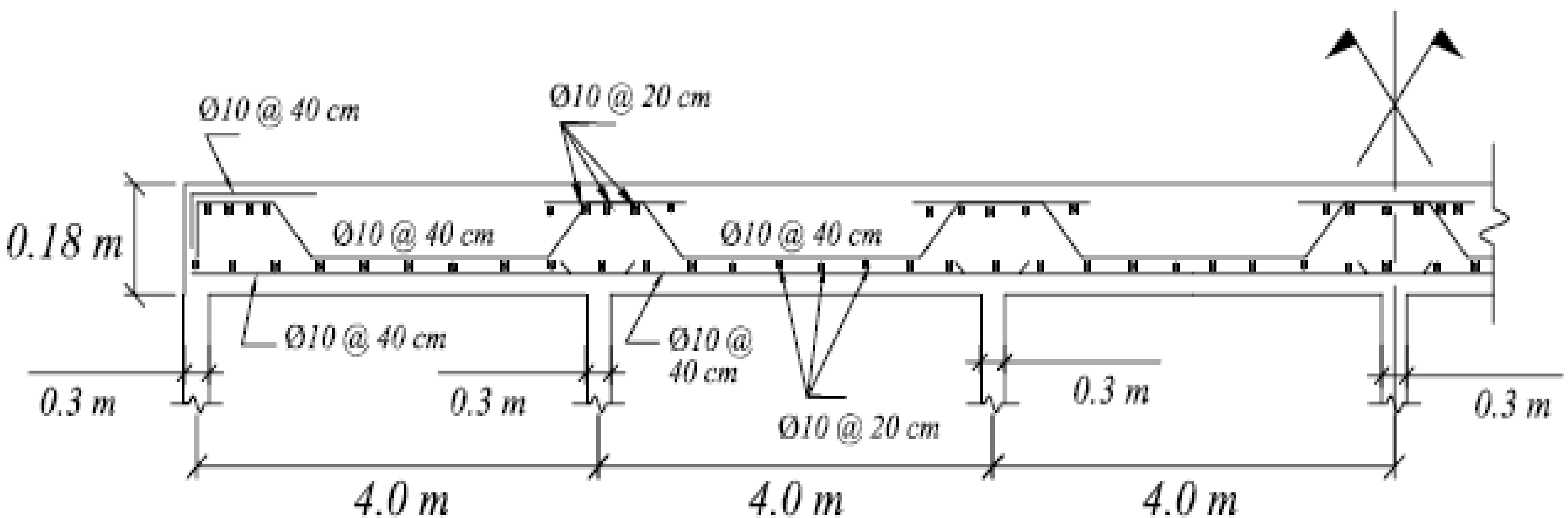
For shrinkage reinforcement use ϕ 10 *mm* @ 20 *cm*, or 5 ϕ 10 *mm* @ 1 *m*.

Check bar spacing against code specified values

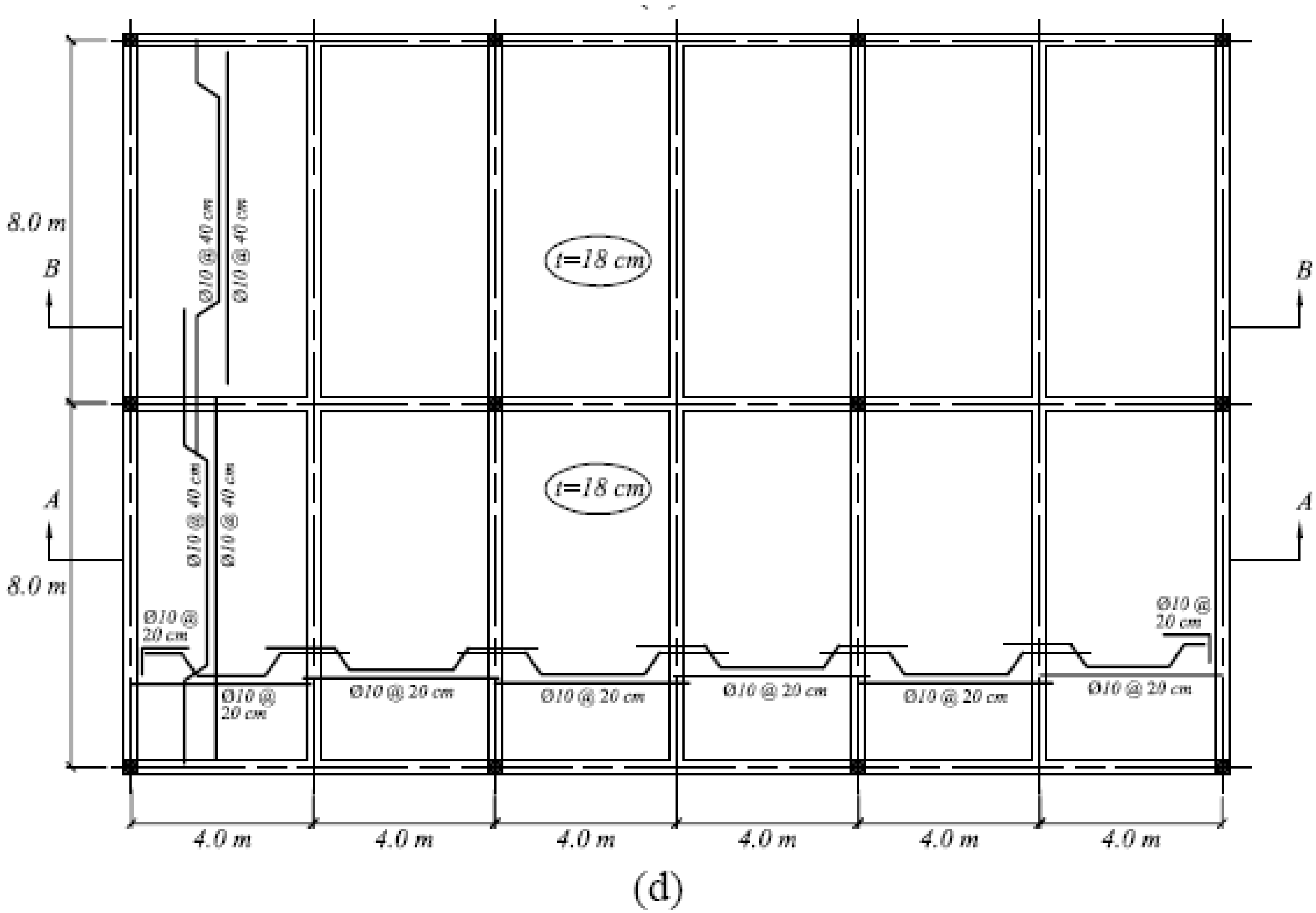
For main reinforcement, spacing between bars is not to exceed the larger of 3 (18) = 54 *cm* and 45 *cm*, which is already satisfied as shown in the table.

For shrinkage reinforcement, spacing between bars is not to exceed the larger of 5 (18) = 90 *cm* and 45 *cm*, which is also satisfied.

7- Prepare neat sketches showing the reinforcement and slab thickness:



(c)



(continued); (c) Section A-A; (d) reinforcement details

Example (8.2):

Design the slab shown in Example (8.1) using any available structural analysis software.

Solution :

1- Select a representative 1 *m* wide slab strip:

The selected representative strip is shown.

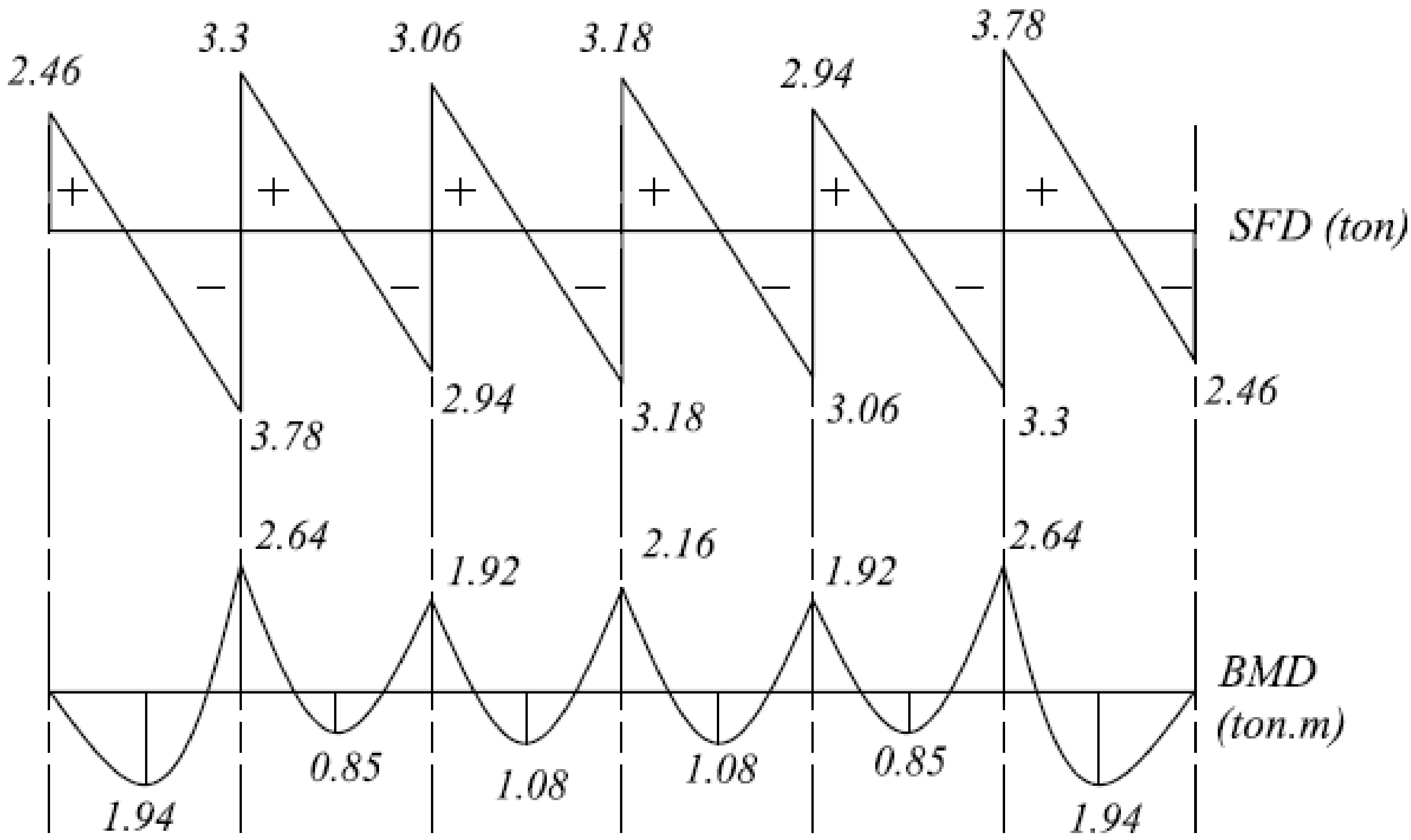
2- Select slab thickness:

Same as in Example (8.1), the thickness is taken as 18 *cm*.

3- Calculate the factored load W_u per unit length of the selected strip:

For a strip 1 *m* wide, $w_u = 1.56\, ton/m$

4- Evaluate the maximum factored shear forces and bending moments in the strip:



Shearing force and bending moment diagrams

5- Check slab thickness for beam shear:

Effective depth $d = 18 - 2 - 0.60 = 15.40\ cm$, assuming $\phi\, 12\ mm$ bars.

$$V_{u\,max} = 3.78\ ton$$

$$\Phi\ V_c = 0.85(0.53)\sqrt{250}\ (100)(15.40)/1000 = 10.97\ ton$$

i.e. , slab thickness is adequate in terms of resisting beam shear.

6- Design flexural and shrinkage reinforcement:

Steel reinforcement ratios are calculated and checked against minimum and maximum code specified limits.

For $M_u = -2.64\ t.m$

$$\rho = \frac{0.85(250)}{4200}\left[1-\sqrt{1-\frac{2.61\times10^5(2.64)}{(100)(15.4)^2(250)}}\right] = 0.00303$$

$A_s = 0.00303(100)(15.4) = 4.67\ cm^2/m$, use $\phi\,10\ mm$ @ $15\ cm$.

For $M_u = -2.16\ t.m$

$$\rho = \frac{0.85(250)}{4200}\left[1-\sqrt{1-\frac{2.61\times10^5(2.16)}{(100)(15.4)^2(250)}}\right] = 0.00246$$

$A_s = 0.00246(100)(15.4) = 3.79\ cm^2/m$, use $\phi\,10\ mm$ @ $20\ cm$.

For $M_u = -1.92\ t.m$

$$\rho = \frac{0.85(250)}{4200}\left[1-\sqrt{1-\frac{2.61\times10^5(1.92)}{(100)(15.4)^2(250)}}\right] = 0.00218$$

$$A_s = 0.00218(100)(15.4) = 3.36\ cm^2/m, \text{ use } \phi\, 10\ mm\ @\ 20\ cm.$$

For $M_u = 1.94\ t.m$

$$\rho = \frac{0.85(250)}{4200}\left[1 - \sqrt{1 - \frac{2.61\times 10^5\,(1.94)}{(100)(15.4)^2(250)}}\right] = 0.0022$$

$$A_s = 0.0022(100)(15.4) = 3.39\ cm^2/m, \text{ use } \phi\, 10\ mm\ @\ 20\ cm.$$

For $M_u = 1.08\ t.m$

$$\rho = \frac{0.85(250)}{4200}\left[1 - \sqrt{1 - \frac{2.61\times 10^5\,(1.08)}{(100)(15.4)^2(250)}}\right] = 0.0012$$

$$A_s = 0.0018(100)(18.0) = 3.24\ cm^2/m, \text{ use } \phi\, 10\ mm\ @\ 20\ cm.$$

For $M_u = 0.85\ t.m$

$A_s = 0.0018(100)(18.0) = 3.24\ cm^2/m$, use $\phi\,10\ mm\ @\ 20\ cm$.

Calculate the area of shrinkage reinforcement:

Area of shrinkage reinforcement = 0.0018 (100) (18) = 3.24 cm^2/m, use $\phi\,10\ mm\ @\ 20\ cm$.

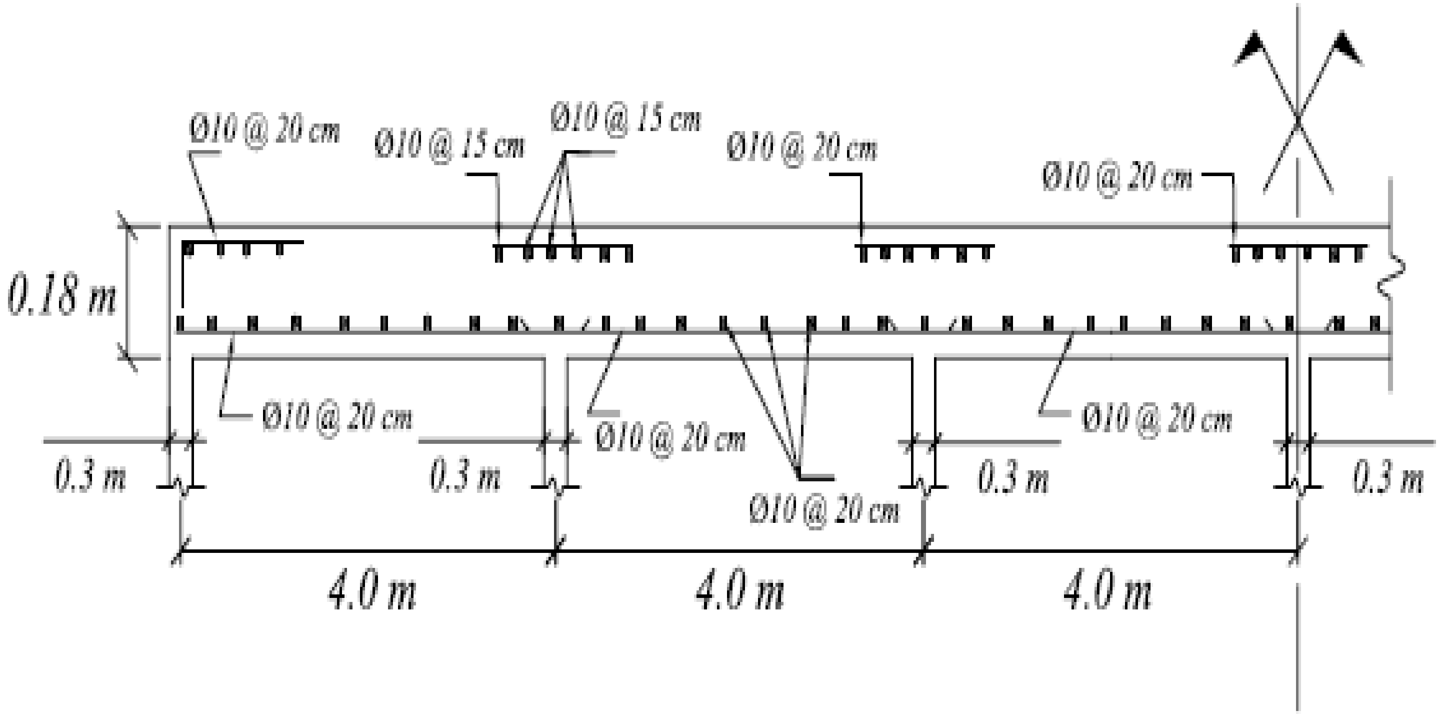
Select reinforcement bars:

It is already done in step 6.

Check bar spacing:

Same as in Example (8.1).

7- Prepare neat sketches showing the reinforcement and slab thickness:



Ø10 @ 20 cm
Ø10 @ 15 cm
Ø10 @ 15 cm
Ø10 @ 20 cm
Ø10 @ 20 cm
0.18 m
Ø10 @ 20 cm
Ø10 @ 20 cm
Ø10 @ 20 cm
Ø10 @ 20 cm
0.3 m
0.3 m
0.3 m
0.3 m
4.0 m
4.0 m
4.0 m

Section A-A