CONFIDENTIAL

# UNIVERSITI TUN HUSSEIN ONN MALAYSIA

## FINAL EXAMINATION
## SEMESTER II
## SESSION 2014/2015

| | | |
|---|---|---|
| COURSE NAME | : | REINFORCED CONCRETE DESIGN I |
| COURSE CODE | : | BFC 32102 |
| PROGRAMME | : | BACHELOR OF CIVIL ENGINEERING WITH HONOURS |
| EXAMINATION DATE | : | JUNE2015/JULY 2015 |
| DURATION | : | 2 HOURS 30 MINUTES |
| INSTRUCTION | : | 1.ANSWER **ALL** QUESTIONS FROM SECTION A AND **TWO (2)** QUESTIONS FROM SECTION B<br><br>2.DESIGN SHOULD BE BASED ON:<br><br>BS EN 1990:2002+A1:2005<br>NA BS EN 1990:2002+A1:2005<br>BS EN 1991-1-1:2002<br>NA BS EN 1991-1-1:2002<br>BS EN 1992-1-1:2004<br>BS 8110:PART 1:1997 |

THIS QUESTION PAPER CONSISTS OF **THIRDTEEN (13)** PAGES

## SECTION A

**Q1** (a) Ideally, the owner and the architect, the architect and the engineer, the engineer and the contractor/fabricator will collaborate and interact to conceive, develop, design and build the structure in most efficient manner. Discuss your responsibilities as a structural engineer.

(5 marks)

(b) Depending on the amount of reinforcing steel provided, flexural failure may occur in 3 ways. Describe with help of the sketch the type of failure in reinforced concrete design.

(10 marks)

(c) **FIGUREQ1** shows a cross section for a simply supported beam. Given the following data:

Characteristic strength of concrete, $f_{ck} = 25$ N/mm$^2$
Characteristic strength of steel reinforcement, $f_{yk} = 500$ N/mm$^2$

(a) Illustrate and label simplified rectangular stress block

(7 marks)

(b) Determine the ultimate moment resistance.

(8 marks)

## SECTION B

**Q2** A simply supported beam of 6 m carries a distributed permanent action of 60 kN/m (including self-weight) and variable action of 18 kN/m . The beam cross section is 250 mm x 540 mm (bxh). Assume $f_{ck}$= 30 N/mm$^2$ and $f_{yk}$= 500 N/mm$^2$.The beam is inside building (XC1), subjected to 1 hour fire resistance and design life of 50 years. Assume diameter of bar used are 16 mm for compression (if required) and 20mm for tension. Diameter of the link is 8 mm.

(a) Calculate the nominal cover for the beam.

(6 marks)

(b) Design the flexural reinforcementfor the beam.

(12 marks)

(c) Verify the deflection of the beam.

(8 marks)

(d) Verify the cracking of the beam.

(7 marks)

(e) Sketch the detailing of the main and shear reinforcement.

(2 marks)

**Q3** **FIGUREQ3** shows part of a first floor office plan. All beams and slabs are cast simultaneously with specification of long-term water contact, 1-hour fire resistance and 50 years design life. Given:

| | | |
|---|---|---|
| Cross section of T beam (bxh) | = | 250 mm x 500 mm |
| Slab thickness | = | 100 mm |
| Concrete cover | = | 35 mm |
| Concrete strength | = | C25/30 |
| Characteristic strength of steel | = | 500 N/mm$^2$ |
| Characteristic strength of link | = | 500 N/mm$^2$ |

Assume $Ø_{bar1}$=12 mm (tension), $Ø_{bar2}$=10 mm (compression), $Ø_{link}$=8 mm. The total characteristic variable and permanent actions on T-beam 2/A-D are 8.75 kN/m and 11.76 kN/m respectively.

(a) Determine shear force and bending moment.
(7 marks)

(b) Determine $b_{eff}$ and illustrate (with label) the cross section the T-beam.
(7 marks)

(c) Design the longitudinal reinforcement for T-beam 2/B-C.
(11 marks)

(d) Check for crushing of the concrete strut at the maximum shear force.
(5marks)

(e) Calculate shear link required by the T beam.
(5 marks)

**Q4** **FIGUREQ4** shows the layout plan for the part of the first floor of residential building. The concrete for slabs and beams are poured together and the thickness of the slab is 150 mm. The permanent and variable actions for slab are as follows:

| | | |
|---|---|---|
| Ceiling and tile finishes | = | 1.75 kN/m$^2$ |
| Variable action | = | 3.0 kN/m$^2$ |
| Characteristic strength of concrete, $f_{ck}$ | = | 25 N/mm$^2$ |
| Characteristic strength of steel, $f_{yk}$ | = | 500 N/mm$^2$ |
| Concrete cover | = | 25 mm |

(a) Determine the positive and negative moments for slab B-C/2-3.
(5 marks)

(b) Determine the minimum and maximum reinforcement area.
(3marks)

(c) Design the flexural reinforcement required at mid span. Assume bar size is 10 mm.

(12 marks)

(d) Check the deflection for the slab panel.

(15 marks)

**-END OF QUESTION-**

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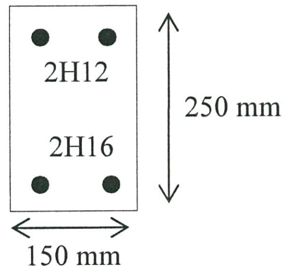


**FIGURE Q1**

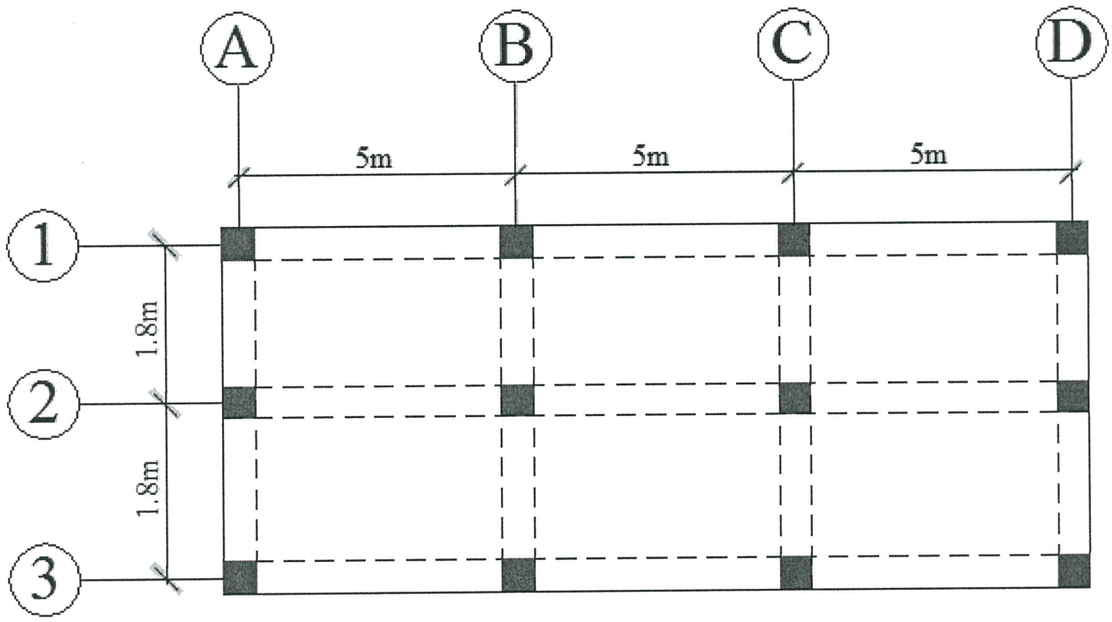


**FIGURE Q3**

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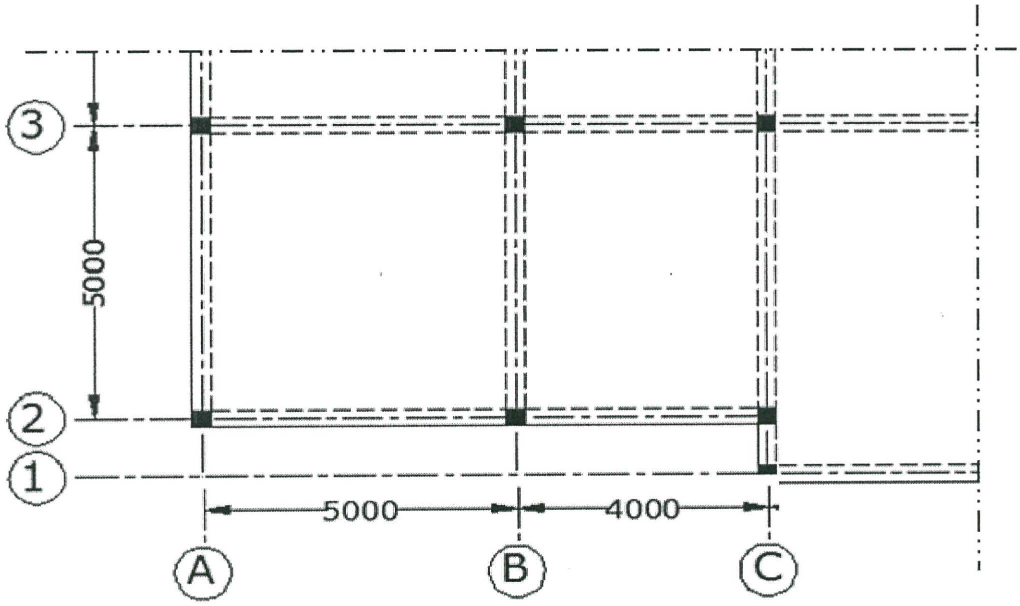


**FIGURE Q4**

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**FORMULA**

$$A_S' = \frac{(K - K_{bal}) f_{ck} b d^2}{0.87 f_{yk}(d - d')}$$

$$A_S' = \frac{(K - K_{bal}) f_{ck} b d^2}{f_{sc}(d - d')}$$

$$V_{Rd,max} = \frac{0.36 b d f_{ck}(1 - f_{ck}/250)}{cot\theta + tan\theta}$$

$$f_{sc} = 700\left(1 - \frac{d'}{x}\right)$$

$$A_S = \frac{K_{bal} f_{ck} b d^2}{0.87 f_{yk}(d - d')} + A_S'\left(\frac{f_{sc}}{0.87 f_{yk}}\right)$$

$$A_s = \frac{K_{bal} f_{ck} b d^2}{0.87 f_{yk} z} + A_s'$$

$$\frac{A_{sw}}{s} = \frac{V_{Ed}}{0.78 f_{yk} d \cot\theta}$$

$$f_s = \frac{f_{yk}}{1.15}\left[\frac{G_k + 0.3Q_k}{1.35G_k + 1.5Q_k}\right]\frac{1}{\delta}$$

$$M = (0.454 f_{ck} b x)(d - 0.4x)$$

$$z = d\left[0.5 + \sqrt{(0.25 - K/1.134)}\right]$$

$$\frac{A_{sw}}{s} = \frac{0.08 f_{ck}^{1/2} b_w}{f_{yk}}$$

$$x = (d - z)/0.4$$

$$M_f = (0.567 f_{ck} b_{eff} h_f)(d - h_f/2)$$

$$\theta = 0.5 \sin^{-1}\left(\frac{V_{Ed}}{0.18 b d f_{ck}(1 - f_{ck}/250)}\right)$$

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**Table 1: Shear force coefficient for uniformly loaded rectangular panels supported on four sides with provision for torsion at corners**

**Table 3.15 — Shear force coefficient for uniformly loaded rectangular panels supported on four sides with provision for torsion at corners**

| Type of panel and location | $\beta_{vx}$ for values of $l_y/l_x$ | | | | | | | | $\beta_{vy}$ |
|---|---|---|---|---|---|---|---|---|---|
| | 1.0 | 1.1 | 1.2 | 1.3 | 1.4 | 1.5 | 1.75 | 2.0 | |
| **Four edges continuous** | | | | | | | | | |
| Continuous edge | 0.33 | 0.36 | 0.39 | 0.41 | 0.43 | 0.45 | 0.48 | 0.50 | 0.33 |
| **One short edge discontinuous** | | | | | | | | | |
| Continuous edge | 0.36 | 0.39 | 0.42 | 0.44 | 0.45 | 0.47 | 0.50 | 0.52 | 0.36 |
| Discontinuous edge | — | — | — | — | — | — | — | — | 0.24 |
| **One long edge discontinuous** | | | | | | | | | |
| Continuous edge | 0.36 | 0.40 | 0.44 | 0.47 | 0.49 | 0.51 | 0.55 | 0.59 | 0.36 |
| Discontinuous edge | 0.24 | 0.27 | 0.29 | 0.31 | 0.32 | 0.34 | 0.36 | 0.38 | — |
| **Two adjacent edges discontinuous** | | | | | | | | | |
| Continuous edge | 0.40 | 0.44 | 0.47 | 0.50 | 0.52 | 0.54 | 0.57 | 0.60 | 0.40 |
| Discontinuous edge | 0.26 | 0.29 | 0.31 | 0.33 | 0.34 | 0.35 | 0.38 | 0.40 | 0.26 |
| **Two short edges discontinuous** | | | | | | | | | |
| Continuous edge | 0.40 | 0.43 | 0.45 | 0.47 | 0.48 | 0.49 | 0.52 | 0.54 | — |
| Discontinuous edge | — | — | — | — | — | — | — | — | 0.26 |
| **Two long edges discontinuous** | | | | | | | | | |
| Continuous edge | — | — | — | — | — | — | — | — | 0.40 |
| Discontinuous edge | 0.26 | 0.30 | 0.33 | 0.36 | 0.38 | 0.40 | 0.44 | 0.47 | — |
| **Three edges discontinuous (one long edge discontinuous)** | | | | | | | | | |
| Continuous edge | 0.45 | 0.48 | 0.51 | 0.53 | 0.55 | 0.57 | 0.60 | 0.63 | — |
| Discontinuous edge | 0.30 | 0.32 | 0.34 | 0.35 | 0.36 | 0.37 | 0.39 | 0.41 | 0.29 |
| **Three edges discontinuous (one short edge discontinuous)** | | | | | | | | | |
| Continuous edge | — | — | — | — | — | — | — | — | 0.45 |
| Discontinuous edge | 0.29 | 0.33 | 0.36 | 0.38 | 0.40 | 0.42 | 0.45 | 0.48 | 0.30 |
| **Four edges discontinuous** | | | | | | | | | |
| Discontinuous edge | 0.33 | 0.36 | 0.39 | 0.41 | 0.43 | 0.45 | 0.48 | 0.50 | 0.33 |

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## Table 2: Bending moment coefficient for rectangular panels supported on four sides with provision for torsion at corners

Table 3.14 — Bending moment coefficients for rectangular panels supported on four sides with provision for torsion at corners

| Type of panel and moments considered | Short span coefficients, $\beta_{sx}$ | | | | | | | | Long span coefficients, $\beta_{sy}$ for all values of $l_y/l_x$ |
|---|---|---|---|---|---|---|---|---|---|
| | Values of $l_y/l_x$ | | | | | | | | |
| | 1.0 | 1.1 | 1.2 | 1.3 | 1.4 | 1.5 | 1.75 | 2.0 | |
| **Interior panels** | | | | | | | | | |
| Negative moment at continuous edge | 0.031 | 0.037 | 0.042 | 0.046 | 0.050 | 0.053 | 0.059 | 0.063 | 0.032 |
| Positive moment at mid-span | 0.024 | 0.028 | 0.032 | 0.035 | 0.037 | 0.040 | 0.044 | 0.048 | 0.024 |
| **One short edge discontinuous** | | | | | | | | | |
| Negative moment at continuous edge | 0.039 | 0.044 | 0.048 | 0.052 | 0.055 | 0.058 | 0.063 | 0.067 | 0.037 |
| Positive moment at mid-span | 0.029 | 0.033 | 0.036 | 0.039 | 0.041 | 0.043 | 0.047 | 0.050 | 0.028 |
| **One long edge discontinuous** | | | | | | | | | |
| Negative moment at continuous edge | 0.039 | 0.049 | 0.056 | 0.062 | 0.068 | 0.073 | 0.082 | 0.089 | 0.037 |
| Positive moment at mid-span | 0.030 | 0.036 | 0.042 | 0.047 | 0.051 | 0.055 | 0.062 | 0.067 | 0.028 |
| **Two adjacent edges discontinuous** | | | | | | | | | |
| Negative moment at continuous edge | 0.047 | 0.056 | 0.063 | 0.069 | 0.074 | 0.078 | 0.087 | 0.093 | 0.045 |
| Positive moment at mid-span | 0.036 | 0.042 | 0.047 | 0.051 | 0.055 | 0.059 | 0.065 | 0.070 | 0.034 |
| **Two short edges discontinuous** | | | | | | | | | |
| Negative moment at continuous edge | 0.046 | 0.050 | 0.054 | 0.057 | 0.060 | 0.062 | 0.067 | 0.070 | — |
| Positive moment at mid-span | 0.034 | 0.038 | 0.040 | 0.043 | 0.045 | 0.047 | 0.050 | 0.053 | 0.034 |
| **Two long edges discontinuous** | | | | | | | | | |
| Negative moment at continuous edge | — | — | — | — | — | — | — | — | 0.045 |
| Positive moment at mid-span | 0.034 | 0.046 | 0.056 | 0.065 | 0.072 | 0.078 | 0.091 | 0.100 | 0.034 |
| **Three edges discontinuous (one long edge continuous)** | | | | | | | | | |
| Negative moment at continuous edge | 0.057 | 0.065 | 0.071 | 0.076 | 0.081 | 0.084 | 0.092 | 0.098 | — |
| Positive moment at mid-span | 0.043 | 0.048 | 0.053 | 0.057 | 0.060 | 0.063 | 0.069 | 0.074 | 0.044 |
| **Three edges discontinuous (one short edge continuous)** | | | | | | | | | |
| Negative moment at continuous edge | — | — | — | — | — | — | — | — | 0.058 |
| Positive moment at mid-span | 0.042 | 0.054 | 0.063 | 0.071 | 0.078 | 0.084 | 0.096 | 0.105 | 0.044 |
| **Four edges discontinuous** | | | | | | | | | |
| Positive moment at mid-span | 0.055 | 0.065 | 0.074 | 0.081 | 0.087 | 0.092 | 0.103 | 0.111 | 0.056 |

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**Table 2: Minimum dimensions and axis distances for simply supported beams made with reinforced and prestressed concrete (Source: Table 5.5 *BS EN 1992 -1-2)***

| Standard fire resistance | Minimum dimensions (mm) | | | | | | |
|---|---|---|---|---|---|---|---|
| | Possible combinations of $a$ and $b_{min}$ where $a$ is the average axis distance and $b_{min}$ is the width of beam | | | | Web thickness $b_w$ | | |
| | | | | | Class WA | Class WB | Class WC |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| R 30 | $b_{min}$= 80<br>$a$ = 25 | 120<br>20 | 160<br>15* | 200<br>15* | 80 | 80 | 80 |
| R 60 | $b_{min}$= 120<br>$a$ = 40 | 160<br>35 | 200<br>30 | 300<br>25 | 100 | 80 | 100 |
| R 90 | $b_{min}$= 150<br>$a$ = 55 | 200<br>45 | 300<br>40 | 400<br>35 | 110 | 100 | 100 |
| R 120 | $b_{min}$= 200<br>$a$ = 65 | 240<br>60 | 300<br>55 | 500<br>50 | 130 | 120 | 120 |
| R 180 | $b_{min}$= 240<br>$a$ = 80 | 300<br>70 | 400<br>65 | 600<br>60 | 150 | 150 | 140 |
| R 240 | $b_{min}$= 280<br>$a$ = 90 | 350<br>80 | 500<br>75 | 700<br>70 | 170 | 170 | 160 |
| $a_{sd} = a$ + 10mm (see note below) | | | | | | | |

For prestressed beams the increase of axis distance according to 5.2(5) should be noted.

$a_{sd}$ is the axis distance to the side of beam for the corner bars (or tendon or wire) of beams with only one layer of reinforcement. For values of $b_{min}$ greater than that given in Column 4 no increase of $a_{sd}$ is required.

* Normally the cover required by EN 1992-1-1 will control.

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**Table 3: Minimum dimensions and axis distances for reinforced and prestressed concrete simply supported one-way and two-way solid slabs (Source Table 5.8: *BS EN 1992 -1-2)***

(1) Table 5.8 provides minimum values of axis distance to the soffit of simply supported slabs for standard fire resistances of R 30 to R 240,

(2) In two-way spanning slabs *a* denotes the axis distance of the reinforcement in the lower layer.

| Standard fire resistance | Minimum dimensions (mm) | | | |
|---|---|---|---|---|
| | slab thickness $h_s$ (mm) | axis-distance *a* | | |
| | | one way | two way: $l_y/l_x \leq 1,5$ | two way: $1,5 < l_y/l_x \leq 2$ |
| 1 | 2 | 3 | 4 | 5 |
| REI 30 | 60 | 10* | 10* | 10* |
| REI 60 | 80 | 20 | 10* | 15* |
| REI 90 | 100 | 30 | 15* | 20 |
| REI 120 | 120 | 40 | 20 | 25 |
| REI 180 | 150 | 55 | 30 | 40 |
| REI 240 | 175 | 65 | 40 | 50 |

$l_x$ and $l_y$ are the spans of a two-way slab (two directions at right angles) where $l_y$ is the longer span.

For prestressed slabs the increase of axis distance according to 5.2(5) should be noted.

The axis distance *a* in Column 4 and 5 for two way slabs relate to slabs supported at all four edges. Otherwise, they should be treated as one-way spanning slab.

* Normally the cover required by EN 1992-1-1 will control.

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**Table 4: Design ultimate bending moments and shear forces**
**(Source: Table 3.5 *BS 8110 -1: 1997*)**

| | At outer support | Near middle of end span | At first interior support | At middle of interior spans | At interior supports |
|---|---|---|---|---|---|
| Moment | 0 | $0.09Fl$ | $-0.11Fl$ | $0.07Fl$ | $-0.08Fl$ |
| Shear | $0.45F$ | - | $0.6F$ | - | $0.55F$ |

NOTE: $l$ is the effective span;
$F$ is the total design ultimate load ($1.35G_k + 1.5\ Q_k$)
No redistribution of the moment calculated from this table should be made.

**Table 5: Ultimate bending moment and shear force in one-way spanning slabs**
**(Source: *BS 8110 -1: 1997*)**

| | End support/slab connection | | | | At first interior support | Middle interior spans | Interior supports |
|---|---|---|---|---|---|---|---|
| | Simple | | Continuous | | | | |
| | At outer support | Near middle of end span | At outer support | Near middle of end span | | | |
| Moment | 0 | $0.086Fl$ | $-0.04Fl$ | $0.075Fl$ | $-0.086Fl$ | $0.063Fl$ | $-0.063Fl$ |
| Shear | $0.45F$ | - | $0.46F$ | - | $0.6F$ | - | $0.5F$ |

NOTE: $l$ is the effective span;
$F$ is the total design ultimate load ($1.35G_k + 1.5\ Q_k$)

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**Table 6: Cross Sectional Area (mm$^2$) according to Size and Numbers of Bar**

| Bar Size (mm) | Number of Bar | | | | | | | | Perimeter (mm) |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | |
| 6 | 28.3 | 56.6 | 84.9 | 113 | 141 | 170 | 198 | 226 | 18.9 |
| 8 | 50.3 | 101 | 151 | 201 | 251 | 302 | 352 | 402 | 25.1 |
| 10 | 78.6 | 157 | 236 | 314 | 393 | 471 | 550 | 629 | 31.4 |
| 12 | 113 | 226 | 339 | 453 | 566 | 679 | 792 | 905 | 37.7 |
| 16 | 201 | 402 | 603 | 805 | 1207 | 1207 | 1408 | 1609 | 50.3 |
| 20 | 314 | 629 | 943 | 1257 | 1571 | 1886 | 2200 | 2514 | 62.9 |
| 25 | 491 | 982 | 1473 | 1964 | 2455 | 2946 | 3438 | 3929 | 78.6 |
| 32 | 805 | 1609 | 2414 | 3218 | 4023 | 4827 | 5632 | 6437 | 100.6 |
| 40 | 1257 | 2514 | 3771 | 5029 | 6286 | 7543 | 8800 | 10057 | 125.7 |

**Table 7: Cross Sectional Area (mm$^2$) for every meter width at distance between Bar**

| Bar Size (mm) | Distance between Bar (mm) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 50 | 75 | 100 | 125 | 150 | 175 | 200 | 250 | 300 |
| 6 | 566 | 377 | 283 | 226 | 189 | 162 | 141 | 113 | 94 |
| 8 | 1006 | 670 | 503 | 402 | 335 | 287 | 251 | 201 | 168 |
| 10 | 1571 | 1048 | 786 | 629 | 524 | 449 | 393 | 314 | 262 |
| 12 | 2263 | 1509 | 1131 | 905 | 754 | 647 | 566 | 453 | 377 |
| 16 | 4023 | 2682 | 2011 | 1609 | 1341 | 1149 | 1006 | 805 | 670 |
| 20 | 6286 | 4190 | 3143 | 2514 | 2095 | 1796 | 1571 | 1257 | 1048 |
| 25 | 9821 | 6548 | 4911 | 3929 | 3274 | 2806 | 2455 | 1964 | 1637 |
| 32 | 16091 | 10728 | 8046 | 6437 | 5364 | 4598 | 4023 | 3218 | 2682 |
| 40 | 25143 | 16762 | 12571 | 10057 | 8381 | 7184 | 6286 | 5029 | 4190 |