SUMMER– 19 EXAMINATION

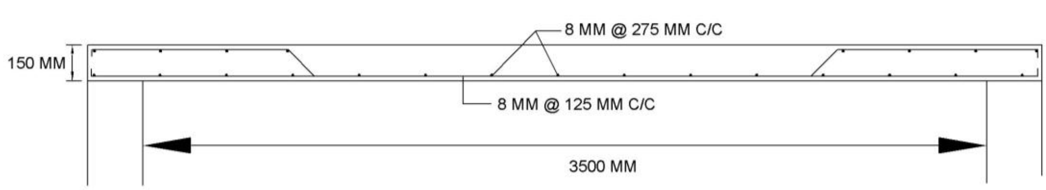
Subject Name: DESIGN OF R.C.C. STRUCTURES **Model Answer** Subject Code: 17604

Important Instructions to examiners:

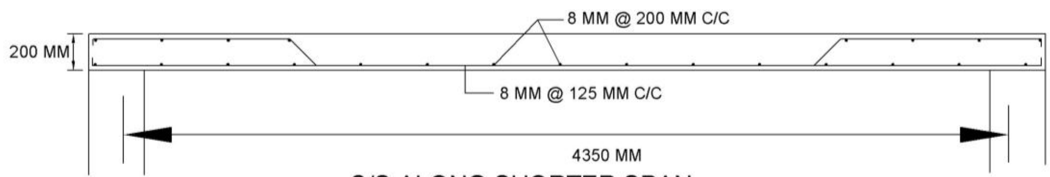
1) The answers should be examined by key words and not as word-to-word as given in the model answer scheme.
2) The model answer and the answer written by candidate may vary but the examiner may try to assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling errors should not be given more Importance (Not applicable for subject English and Communication Skills.
4) While assessing figures, examiner may give credit for principal components indicated in the figure. The figures drawn by candidate and model answer may vary. The examiner may give credit for any equivalent figure drawn.
5) Credits may be given step wise for numerical problems. In some cases, the assumed constant values may vary and there may be some difference in the candidate's answers and model answer.
6) In case of some questions credit may be given by judgement on part of examiner of relevant answer based on candidate's understanding.
7) For programming language papers, credit may be given to any other program based on equivalent concept.

Q. No.	Sub Q. N.	Answers	Marking Scheme
Q.1	(A) (a) Ans	***Solve any THREE:*** ***Explain the concept of limit state of flexure. State various limit states.*** Concept of limit state of flexure: It is to achieve an acceptable probability that a structure will not collapse in flexure in its life time, that is, it will not reach limit state of collapse (Flexure). Various limit states: 1. Limit state of collapse- i. Flexure/Bending. ii. Shear. iii. Torsion. iv. Axial load (Tension and compression). 2. Limit state of Serviceability- i. Deflection. ii. Cracking. iii. Vibration.	***(12)*** 02 M 01 M 01 M
Q.1	(A)(b) Ans	***Define 'characteristic strength' and 'characteristic load'.*** **Characteristic strength:** It is the value of the strength of material below which not more than 5 percent of the test results are expected to fall. **Characteristic load:** It is the value of load which has a 95 percent probability of not being exceeded during the life of the structure.	02 M 02 M
Q.1	(A)(c) Ans	***Write the requirements of ductility for flexural members as per IS: 13920-1993.*** Requirements of ductility for flexural members. 1. The factored axial stress on the member under earthquake loading shall not exceed 0.1 fck. 2. The member shall preferably have a width-to-depth ratio of more than 0.3. 3. The width of the member shall not be less than 200 mm. 4. The depth D of the member shall preferably be not more than l/4 of the clear	01 M for each

		span.	
Q.1	(A)(d) Ans	***Explain pre-tensioning and post-tensioning.*** **Pre-tensioning method:** It is done by stressing wires or strands, called tendons, to predetermine amount by stretching them between two anchorages called abutments prior to placing the concrete. The concrete is then placed and tendons become bonded to concrete throughout their length. After the concrete has hardened, the tendons are released by cutting them at the anchorages. The tendons tend to regain their original length by shortening and transfer compressive stress to concrete through bond. **Post-tensioning method:** In this method first tendons are placed in position passing through flexible tube then concrete is placed in the mould. After gaining strength by concrete, tendons are stretched against concrete itself and then anchored at both ends. In this method, stress is transferred through bearing at ends of tendons.	02 M 02 M
Q.1	(A)(e) Ans	***State various forms of shear reinforcement in beams.*** Shear reinforcement in beams can be provided in any one of the forms given below. 1. Vertical stirrups. 2. Inclined stirrups. 3. Bent up bars with stirrups.	04 M
Q.1	(B) (a) Ans	***Solve any ONE:*** ***A beam having dimension 230 x 450 mm effective is reinforced with 4 bars of 16 mm diameter on tension side. Calculate the ultimate moment of resistance of the beam if M20 grade concrete and Fe415 steel are used.*** b = 230 mm, d = 450 mm, Ast = 16 mm-4 bars., M-20, Fe-415, Mu = ? Ast = 4 x π x ϕ^2 / 4 = 4 x π x 16^2 / 4 = 804.25 mm^2 Actual neutral axis xu = (0.87 x fy x Ast) / (0.36 x fck x b) = (0.87 x 415 x 804.25) / (0.36 x 20 x 230) = 175.35 mm. Xumax = 0.48 x d = 0.48 x 450 = 216 mm. Xu < xumax, hence beam is under reinforced. Mu = 0.87 x fy x Ast (d – 0.42xu) = 0.87 x 415 x 804.25 (450 – 0.42 x 175.35) = 109.28 x 10^6 N-mm. **OR** Mu = 0.36 x fck x b x xu (d – 0.42xu) = 0.36 x 20 x 230 x 175.35 (450 – 0.42 x 175.35) = 109.28 x 10^6 N-mm	**(06)** 01 M 01 M 01 M 01 M 02 M
Q.1	(B)(b) Ans	***A beam 300 mm x 500 mm effective size carries a factored bending moment of 175 kN-m. If concrete M20 & Steel grade Fe500 are used, find area 0f steel required.*** b = 300 mm, d = 500 mm, Mu = 175 kN-m, M-20, Fe-500, Ast = ? Mulim = 0.134 x fck x b x d^2 = 0.134 x 20 x 300 x 500^2 = 201 x 10^6 N-mm Mu < Mulim, Hence beam is Under reinforced. Ast = 0.5 x fck x b x d {1 – SQRT[1 – (4.6 x Mu) / (fck x b x d^2)]} / fy	 02 M 01 M 01 M

		= 0.5 x 20 x 300 x 500 {1 – SQRT[1 – (4.6 x 175 x 10^6) / (20 x 300 x 500^2)]} / 500 = 957.94 mm^2.	01 M 01 M
Q.2		***Solve any TWO:***	**(16)**
	(a)	***Design one way slab with following data, width of support = 230 mm, clear span = 3.5 m, Live load = 2 kN/m^2, Floor finish = 1 kN/m^2, concrete M20 & steel 415, M.F. = 1.4. Sketch c/s of slab showing reinforcement details (No checks are required)***	
	Ans	Support width = 230 mm, Clear span = 3.5 m, L.L. = 2 kN/m^2, F.F. = 1 kN/m^2, M-20, Fe-415, M.F. = 1.4. Depth of slab required = span / (M.F. x 20) = 3500 / (1.4 x 20) = 125 mm. Assuming cover 25 mm, **(Note: Students may assume different cover)** D = 125 + 25 = 150 mm. Effective span: 1) Clear span + d = 3.5 + 0.125 = 3.625 m. 2) Clear span + support width = 3.5 + 0.23 = 3.73 m. Lesser is 3.625 m. Hence le = 3.625 m. Loading: 1) Live load = 2.0 kN/m^2 2) Floor finish = 1.0 kN/m^2 3) Self weight = 0.15 x 25 = 3.75 kN/m^2 Total = 6.75 kN/m^2 Factored load = 1.5 x 6.75 = 10.125 kN/m^2 Mu = 10.125 x 3.625^2 / 8 16.63 kN-m. Depth required for strength = SQRT[Mu / (0.138 x fck x b)] = SQRT[16.63 x 10^6 / (0.138 x 20 x 1000)] = 77.62 mm < assumed hence O.K. Provide D = 150 mm d = 125 mm. Ast = 0.5 x fck x b x d {1 – SQRT[1 – (4.6 x Mu) / (fck x b x d^2)]} / fy = 0.5 x 20 x 1000 x 125 {1 – SQRT[1 – (4.6 x 16.63 x 10^6) / (20 x 1000 x 125^2)]} / 415 = 394.5 mm^2. Providing 8 mm dia. Bars Area of one bar A1 = π x ϕ^2 / 4 = π x 8^2 / 4 = 50.27 mm^2 **(Note: Students may assume different bar dia.)** Spacing = 1000 x A1 / Ast = 1000 x 50.27 / 394.5 = 127.4 mm. Provide 8 mm dia. @ 125 mm c/c. Distribution steel: Area = 0.12 x 1000 x 150 / 100 = 180 mm^2. Spacing for 8 mm dia. Bars = 1000 x 50.27 / 180 = 279.3 mm Provide 8 mm dia. @ 275 mm c/c.  	 01 M 01 M 01 M 01 M 01 M 01 M Fig. 02 M

Q.2	(b)	***Design a reinforced concrete slab panel for 6.55 m x 4.35 m simply supported on all four sides. It carries a live load 2 kN/m2 & Floor finish load 1.0 kN/m2. Use M20 concrete & Fe415 steel. Sketch the c/s of slab along shorter span showing steel details (No checks). Use αx = 0.104, αy = 0.046. M.F. = 1.3.***	
	Ans	Shorter span = 4.35 m, Longer span = 6.55 m, L.L. = 2 kN/m^2, F.F. = 1 kN/m^2, M-20, Fe-415, M.F. = 1.3, αx = 0.104, αy = 0.046. Aspect ratio = Longer span / Shorter span = 6.55 / 4.35 = 1.51 < 2.0 Hence Two way slab. Depth of slab required = shorter span / (M.F. x 20) = 4350 / (1.3 x 20) = 167.31 mm.	01 M
		Assuming cover 25 mm, **(Note: Students may assume different cover)** D = 167.31 + 25 = 192.3 mm. Assume overall depth (D) = 200 mm and Effective depth (d) = 175 mm. Loading: 1) Live load = 2.0 kN/m^2 2) Floor finish = 1.0 kN/m^2 3) Self weight = 0.20 x 25 = 5.0 kN/m^2 Total = 8.0 kN/m^2 Factored load = 1.5 x 8.0 = 12.0 kN/m^2	01 M
		Ultimate bending moment calculations: Mux = αx x wu x lex^2 = 0.104 x 12 x 4.35^2 = 23.62 kN-m	01 M
		Muy = αy x wu x lex^2 = 0.046 x 12 x 4.35^2 = 10.45 kN-m.	01 M
		Depth required for strength = SQRT[Mux / (0.138 x fck x b)] = SQRT[23.62 x 10^6 / (0.138 x 20 x 1000)] = 92.51 mm < assumed hence O.K. Provide D = 200 mm dx = 175 mm. and dy = 175 – 10 = 165 mm (assuming bar dia. 10 mm)	01 M
		Astx = 0.5 x fck x b x dx {1 – SQRT[1 – (4.6 x Mux) / (fck x b x dx^2)]} / fy = 0.5 x 20 x 1000 x 175 {1 – SQRT[1 – (4.6 x 23.62 x 10^6) / (20 x 1000 x 175^2)]} / 415 = 392.3 mm^2. Providing 8 mm dia. Bars Area of one bar A1 = π x ϕ^2 / 4 = π x 8^2 / 4 = 50.27 mm^2 **(Note: Students may assume different bar dia.)** Spacing = 1000 x A1 / Ast = 1000 x 50.27 / 392.3 = 128 mm. Provide 8 mm dia. @ 125 mm c/c along shorter span.	01 M
		Asty = 0.5 x fck x b x dy {1 – SQRT[1 – (4.6 x Muy) / (fck x b x dy^2)]} / fy = 0.5 x 20 x 1000 x 165 {1 – SQRT[1 – (4.6 x 10.45 x 10^6) / (20 x 1000 x 165^2)]} / 415 = 179.6 mm^2. Minimum Ast = 0.12 x 1000 x 200 / 100 = 240 mm^2. Asty < Min. Ast, Hence provide minimum Ast. Providing 8 mm dia. Bars Area of one bar A1 = π x ϕ^2 / 4 = π x 8^2 / 4 = 50.27 mm^2 **(Note: Students may assume different bar dia.)** Spacing = 1000 x A1 / Ast = 1000 x 50.27 / 240 = 209.5 mm. Provide 8 mm dia. @ 200 mm c/c along longer span.	01 M



C/S ALONG SHORTER SPAN

01 M for fig.

Q.2 (c) ***Design a cantilever slab for Chajja with following data. Span = 1.5 m, L.L. = 2 kN/m^2, F.F. = 0.5 kN/m^2, Adopt M20 & Fe415, Modification factor = 1.3.***

Ans

Span = 1.5 m, L.L. = 2 kN/m^2, F.F. = 0.5 kN/m^2, M-20, Fe-415, M.F. = 1.3.

Depth of slab required = span / (M.F. x 7)
= 1500 / (1.3 x 7) — 01 M
= 164.8 mm.

Assuming cover 25 mm, **(Note: Students may assume different cover)**
D = 164.8 + 25 = 189.8 mm.

Assume overall depth = 190 mm and effective depth = 165 mm.

Effective span:

1) Clear span + d/2 = 1.5 + 0.165/2 = 1.5825 m. **(Note: Students may consider given span as effective span)**

Loading:
1) Live load = 2.0 kN/m^2
2) Floor finish = 0.5 kN/m^2 — 01 M
3) Self weight = 0.19 x 25 = 4.75 kN/m^2
Total = 7.25 kN/m^2

Factored load = 1.5 x 7.25 = 10.875 kN/m^2

Mu = 10.875 x 1.5825^2 / 2 — 01 M
= 13.62 kN-m.

Depth required for strength = SQRT[Mu / (0.138 x fck x b)]
= SQRT[13.62 x 10^6 / (0.138 x 20 x 1000)] — 01 M
= 70.25 mm < assumed hence O.K.

Provide D = 190 mm
d = 175 mm.

Ast = 0.5 x fck x b x d {1 – SQRT[1 – (4.6 x Mu) / (fck x b x d^2)]} / fy
= 0.5 x 20 x 1000 x 175 {1 – SQRT[1 – (4.6 x 13.62 x 10^6) / (20 x 1000 x 175^2)]} / 415 — 02 M
= 235.7 mm^2.

Minimum Ast = 0.12 x 1000 x 190 / 100 = 228 mm^2.

Ast > Min. Ast, Hence O.K.

Providing 8 mm dia. Bars Area of one bar A1 = π x ϕ^2 / 4 = π x 8^2 / 4 = 50.27 mm^2
(Note: Students may assume different bar dia.)

Spacing = 1000 x A1 / Ast
= 1000 x 50.27 / 235.7 = 213.3 mm.

Provide 8 mm dia. @ 210 mm c/c. — 02 M

Distribution steel: Area = 0.12 x 1000 x 190 / 100
= 228 mm^2.

Spacing for 8 mm dia. Bars = 1000 x 50.27 / 228 = 220.5 mm

Provide 8 mm dia. @ 220 mm c/c.

Q.3 ***Attempt any FOUR:*** **(16)**

	(a) Ans	***What is flange width of T-beam as per IS: 456? State meaning of each term used therein.*** Flange width of T-beam = $(l_0/6) + b_w + 6D_f$ but not greater than the width of web plus half the sum of the clear distance to the adjacent beams on either side. L_0 = Distance between points of zero moments in the beam. b_w = width of web. D_f = Depth of flange.	 02 M 02 M
Q.3	(b) Ans	***Find the moment of resistance of (T) beam with following data: Df = 100 mm, bf = 1200 mm, bw = 250 mm, d = 500 mm, Ast = 1600 mm², M25 concrete and Fe415 steel.*** Df = 100 mm, bf = 1200 mm, bw = 250 mm, d = 500 mm, Ast = 1600 mm^2, M-25, Fe-415. Actual neutral axis xu = (0.87 x fy x Ast) / (0.36 x fck x bf) = (0.87 x 415 x 1600) / (0.36 x 25 x 1200) = 53.49 mm. Xumax = 0.48 x d = 0.48 x 500 = 240 mm. Xu < xumax, hence beam is under reinforced. Mu = 0.87 x fy x Ast (d – 0.42xu) = 0.87 x 415 x 1600 (500 – 0.42 x 53.49) = 275.9 x 10^6 N-mm. **OR** Mu = 0.36 x fck x bf x xu (d – 0.42xu) = 0.36 x 25 x 1200 x 53.49 (500 – 0.42 x 53.49) = 275.9 x 10^6 N-mm	 01 M 01 M 02 M
Q.3	(c) Ans	***Diameter of steel bar is 16 mm, Use Fe415 and design bond stress is 1.2 mPa. For plain bar in tension. Find development length in tension and compression.*** ϕ = 16 mm, Fe-415, Design bond stress = 1.2 mPa. Bond stress for deformed bars in tension = 1.2 x 1.6 = 1.92 mPa. Bond stress for deformed bars in compression = 1.2 x 1.6 x 1.25 = 2.4 mPa. Development length in tension = 0.87 x 415 x 16 / (4 x 1.92) = 752.2 mm. Development length in compression = 0.87 x 415 x 16 / (4 x 2.4) = 601.75 mm.	 01 M 01 M 01 M 01 M
Q.3	(d) Ans	***Define the development length. How it is calculated.*** **Development length:** It is an additional length of a bar of given diameter that required beyond a section for proper anchorage through bond. Development length is calculated using following expression. Ld = Actual stress in steel x ϕ /4 x design bond stress.	 02 M 02 M
Q.3	(e) Ans	***Design an axially loaded column 400 mm x 400 mm pinned at both ends with an unsupported length of 3 m for carrying a factored load of 2500 kN. Use M20 grade concrete and Fe415 steel.*** Column 400 mm x 400 mm, le = 3 m, Pu = 2500 kN, M-20, Fe-415. Ag = 400 x 400 = 160000 mm^2 Ac = Ag – Asc = 160000 – Asc Pu = (0.4 x fck x Ac) + (0.67 x fy x Asc) 2500 x 10^3 = [0.4 x 20 x (160000 – Asc)] + (0.67 x 415 x Asc) = 1280000 – 8Asc + 278.05Asc Asc = (2500 x 10^3 – 1280000)/ 270.05	*(16)* 01 M 01 M

		= 4517.7 mm^2. Min. Asc = 0.8 x 400 x 400 / 100 = 1280 mm^2. Max. Asc = 6 x 400 x 400 / 100 = 9600 mm^2. Min. Asc < Asc < Max. Asc Hence O. K. Provide 22 mm dia. 12 bars. **(Note: Students may provide different combination of no. and dia. Of bars.)** Lateral Ties: Diameter of bar: (Greater of below) i. ¼ of main bar dia. = 22/4 = 5.5 mm ii. 6 mm. Provide 6 mm dia. bars. Pitch: (Least of below) i. 16 times dia. Of main bar = 16 x 22 = 352 mm. ii. Least lateral dim. = 400 mm. iii. 300 mm. Provide pitch 300 mm. Hence provide 6 mm dia. @ 300 mm c/c.	01 M 01 M
Q.4	(A) (a) Ans	***Attempt any THREE:*** ***State any four losses in pre-stressing and describe any one.*** Losses in pre-stressing: 1. Due to elastic shortening. 2. Due to creep of concrete. 3. Due to shrinkage of concrete. 4. Due to relaxation of steel. 5. Due to friction. 6. Due to slip of anchorages. **1. Elastic shortening:** When pre-stress is applied to the concrete, an elastic shortening of concrete takes place. This results in an equal and simultaneous shortening of pre-stressing steel. This loss occurs in pre-tensioning method while in post-tensioning method this loss can be avoided by stretching all tendons simultaneously. **2. Creep of concrete:** Creep is the property of concrete by which it continues to deform with time under sustained load at unit stresses within the accepted elastic range. Due to creep, shortening of concrete takes place. This results in an equal and simultaneous shortening of pre-stressing steel. **3. Shrinkage of concrete:** Shrinkage is defined as decrease in volume of concrete due to loss in moisture. Due to shrinkage, shortening of concrete takes place. This results in an equal and simultaneous shortening of pre-stressing steel. **4. Relaxation of steel:** Relaxation is assumed to mean the loss of stress in steel under nearly constant strain at constant temperature. It is similar to creep of concrete. **5. Friction:** This loss occurs only in post-tensioning method. There are small frictional losses in the jacking equipment. There is also friction between tendons and surrounding materials. **6. Slip of anchorages:** This loss occurs only in post-tensioning method. After stretching and anchoring, tendons are released and the force is transferred to the anchorages. Due to this load, anchorages pierce in the concrete resulting	**(12)** Any four 01/2 M for each Any one 02 M

		shortening of tendons. This shortening of tendons results in decreasing stress in tendons.	
Q.4	(A)(b) Ans	***Calculate working load carrying capacity of column 300 mm x 450 mm in dimension and provided with 8-16 mm diameter bars. Use M20 & Fe500 steel.*** Column 300 mm x 450 mm, M-20, Fe-500, Asc = 16 mm dia. 8 bars. Ag = 300 x 450 = 135000 mm^2 Asc = 8 x π x 16^2 / 4 = 1608.5 mm^2 Ac = Ag – Asc = 135000 – 1608.5 = 133391.5 Pu = (0.4 x fck x Ac) + (0.67 x fy x Asc) = (0.4 x 20 x 133391.5) + (0.67 x 500 x 1608.5) = 1605979.5 N. = 1605.98 kN. Working load = Pu / F.O.S. = 1605.98 / 1.5 = 1070.65 kN	 01 M 02 M 01 M
Q.4	(A)(c) Ans	***State the values of partial factor of safety for steel and concrete.*** 1) Partial factor of safety for steel = 1.15 2) Partial factor of safety for concrete = 1.5	 02 M 02 M
Q.4	(A)(d) Ans	***State four situations where doubly reinforced section is preferred.*** Situations where doubly reinforced section is preferred. 1. When depth of beam is restricted and strength of beam having restricted depth is inadequate. 2. When the section are subjected to reversal of bending moment. 3. In continuous T-beam where the portion of beam over intermediate supports has to be designed as doubly reinforced. 4. When the beams are subjected to eccentric loading, shocks or impact loads.	 01 M for each
Q.4	(B) (a) Ans	***Attempt any ONE:*** ***An R.C.C. beam 230 mm x 450 mm effective is subjected to a factored moment of 140 kN-m. Calculate area of steel in tension and compression zone. Use M20 gratd concrete & Fe415 steel. (Assume d' 45 mm and d'/d = 0.1, fsc = 353 N/mm^2)*** b = 230 mm, d = 450 mm, Mu = 140 kN-m, M-20, Fe-415, d' = 45 mm, fsc = 353 N/mm^2. Mulim = Mu_1 = 0.138 x fck x b x d^2 = 0.138 x 20 x 230 x 450^2 = 128.547 x 10^6 N-mm. Mu_2 = 140 x 10^6 – 128.547 x 10^6 = 11.453 x 10^6 N-mm Xumax = 0.48 x 450 = 216 mm. Ast_1 = Mu_1 / [0.87 x fy x (d – 0.42 xumax)] = 128.547 x 10^6 / [0.87 x 415 x (450 – 0.42 x 216)] = 990.97 mm^2 Asc = Mu_2 / [fsc x (d – d')] = 11.453 x 10^6 / [353 x (450 – 45)] = **80.11 mm^2**. Ast_2 = Mu_2 / [0.87 x fy x (d – d')] = 11.453 x 10^6 / [0.87 x 415 x (450 – 45)] = 78.3 mm^2. **<u>OR</u>** Ast_2 = (fsc x Asc) / (0.87 x fy) = (353 x 80.11) / (0.87 x 415)	**(06)** 01 M 01 M 01 M 01 M 01 M

		= 78.3 mm^2. Total Ast = 990.97 + 78.3 = **1069.27 mm^2**.	01 M
Q.4	(B)(b) Ans	***A beam 240 mm x 500 mm effective, it is reinforced with 4-16 mm diameter tension side and 2-12 mm in compression zone, each an effective cover of 40 mm. Use M20 concrete & Fe415 steel. Find ultimate moment of resistance. Assume fsc = 352 N/mm^2.*** b = 240 mm, d = 500 mm, Ast = 16 mm- 4, Asc = 12 mm – 2, M-20, Fe-415, d' = 40 mm, fsc = 352 N/mm^2. Ast = 4 x π x ϕ^2 / 4 = 4 x π x 16^2 / 4 = 804.25 mm^2 Ast = 2 x π x ϕ^2 / 4 = 2 x π x 12^2 / 4 = 226.19 mm^2 Actual neutral axis xu = [(0.87 x fy x Ast) – (fsc x Asc)] / (0.36 x fck x b) = [(0.87 x 415 x 804.25) – (352 x 226.19)]/ (0.36 x 20 x 240) = 121.97 mm. Xumax = 0.48 x d = 0.48 x 500 = 240 mm. Xu < xumax, hence beam is under reinforced. Mu = 0.36 x fck x b x xu (d – 0.42xu) + fsc x Asc (d – d') = 0.36 x 20 x 240 x 121.97 (500 – 0.42 x 121.97) + 352 x 226.19 (500 – 40) = 131.21 x 10^6 N-mm.	01 M 02 M 01 M 02 M
Q.5	 (a) Ans	***Attempt any TWO:*** ***Design a doubly reinforced rectangular beam 300 mm x 660 mm overall size, for an effective span of 5 m. The beam is subjected to udl of 55 kN/m. Assume effective cover 60 mm. Use M20 & Fe415 steel. d'/d = 0.1, fsc = 353 N/mm^2.*** Le = 5 m., w = 55 kN/m, b = 300 mm, D = 660 mm, M-20, Fe-415, d' = 60 mm, fsc = 353 N/mm^2. Factored load = 1.5 x 55 = 82.5 kN/m Mu = 82.5 x 5^2 / 8 = 257.81 kN-m. Effective depth d = 660 -60 = 600 mm. Mulim = 0.138 x 20 x 300 x 600^2 = 298.08 kN-m Mu < Mulim, Hence singly under reinforced beam is to be designed. Ast = 0.5 x fck x b x d {1 – SQRT[1 – (4.6 x Mu) / (fck x b x d^2)]} / fy = 0.5 x 20 x 300 x 600 {1 – SQRT[1 – (4.6 x 257.812 x 10^6) / (20 x 300 x 600^2)]} / 415 = 235.71424.7 mm^2	01 M 02 M 01 M 01 M 01 M 02 M
Q.5	(b) Ans	***A beam 250 mm x 400 mm deep effective is reinforced with 3 bars of 16 mm diameter of grade Fe415. The shear force at the support is 60 kN. Design the shear reinforcement if grade of concrete used is M20. Use 6 mm or 8 mm diameter vertical stirrups.*** b = 250 mm, d = 400 mm, Ast = 16-3, Fe-415, V = 60 kN, M-20. Vu = 1.5 x 60 = 90 kN Nominal shear stress = Vu / (b x d) = 90 x 10^3 / (250 x 400) = 0.9 N/mm^2 Ast = 3 x π x 16^2 / 4 = 603.19 mm^2 Pt% = 603.19 x 100 / (25 x 400) = 0.60%	01 M 01 M

Note: Values of permissible shear stress are not given; hence students may assume different values. Hence accordingly marks shall be given)

Pt%	0.50	0.75
Permissible shear stress N/mm^2	0.48	0.56

01 M

For 0.6%, Permissible shear stress = 0.48 + {[(0.56 – 0.48) / (0.75 – 0.50)] x (0.60 – 0.50)}
= 0.512 N/mm^2

Nominal shear stress > permissible shear stress, hence shear reinforcement is to be designed.

Vus = Vu – permissible shear stress x b x d
= 90 x 10^3 – (0.512 x 250 x 400)
= 38800 N. 01 M

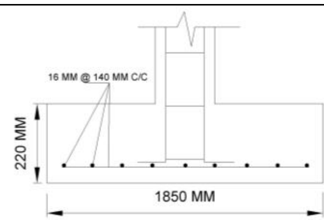
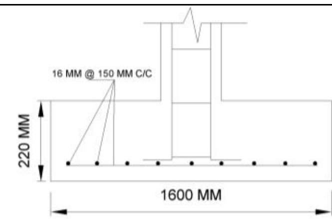
	For 6 mm dia. Stirrups	For 8 mm dia. stirrups	
Asv = 2 x π x ϕ^2 / 4	56.54 mm^2	100.54 mm^2	
Spacing = 0.87 x fy x Asv x d) / Vus	210.5 mm	374.23 mm	01 M
Spacing for min. stirrups = (0.87 x fy x Asv) / (0.4 x b)	204 mm	363 mm	01 M
Max. spacing o.75 d or 300 mm whichever lesser.	300 mm 300 mm	300 mm 300 mm	01 M
Provide	6 mm dia. @ 200 mm c/c	8 mm dia. @ 300 mm c/c	01 M

Q.5 (c) ***Design an isolated square footing for a square reinforced concrete column section 250 mm size to carry an axial factored load 700 kN. The S.B.C. of the soil is 150 kN/m^2. Calculate the depth and steel required of footing from bending moment consideration only. Show reinforcement details. Use M20 & Fe415.***

Ans Column 250 mm x 250 mm, Pu = 700 kN, SBC of soil = 150 kN/m^2, M-20, Fe-415.

Note: Students may assume ultimate bearing capacity as 1.5 times or 2 times SBC.

Ultimate bearing capacity	1.5 x 150 = 225 kN/m^2	2.0 x 150 = 300 kN/m^2	
Self-weight of footing = 5% of load on column.	35 kN	35 kN	
Total ultimate load on soil	735 kN	735 kN	01 M
Area of footingrequired = Total ultimate load on soil / Ultimate bearing capacity of soil	735 / 225 = 3.27 m^2	735 / 300 = 2.45 m^2	
Size = SQRT(Area)	1.81 m	1.565 m.	01 M
Provide size	1.85 m x 1.85 m	1.6 m x 1.6 m	
Actual area provided	3.4225 m^2	2.56 m^2	
Net ultimate upward pressure (qnu) = Ultimate load on column / Actual area provided	700 / 3.4225 = 204.5 kN/m^2	700 / 2.56 = 273.5 kN/m^2	01 M
Projection (a)	1.85 – 0.25 / 2 = 0.8 m	1.6 – 0.25 / 2 = 0.675 m.	
Mu = qnu x a^2 / 2	65.44 kN.m	62.31 kN-m	01 M
d required = SQRT(Mu / 0.138 x fck x b)	SQRT(65.44 / 0.138 x 20 x 1000) = 154 mm	SQRT(62.31 / 0.138 x 20 x 1000) = 150 mm	01 M
Overall depth D = d + cover 60 mm	214 mm	210 mm	

Provide	D = 220 mm & d = 160 mm	D = 220 mm & d = 160 mm	
Ast = 0.5 x fck x b x d {1 – SQRT[1 – (4.6 x Mu) / (fck x b x d^2)]} / fy	0.5 x 20 x 1000 x 160 {1 – SQRT[1 – (4.6 x 65.44 x 10^6) / (20 x 1000 x 160^2)]} / 415 = 1380.5 mm^2	0.5 x 20 x 1000 x 160 {1 – SQRT[1 – (4.6 x 62.31 x 10^6) / (20 x 1000 x 160^2)]} / 415 = 1297.5 mm^2	01 M
Spacing for 16 mm dia. Bars = 1000 x A1 / Ast	145.6 mm	155 mm	01 M
Provided	16 mm dia. @ 140 mm c/c	16 mm dia. @ 150 mm c/c	
			01 M for fig.

Q.6 **_Attempt any FOUR:_** **(16)**

(a) **_An R.C. T-beam section reinforced for tension has the following dimension bf = 1250 mm, bw = 300 mm, d = 550 mm, Df = 100 mm, Ast = 1884 mm2. Use of M20 & steel Fe415 is made. Calculate the limiting moment of resistance._**

Ans Df = 100 mm, bf = 1250 mm, bw = 300 mm, d = 550 mm, Ast = 1884 mm^2, M-250, Fe-415.

Actual neutral axis xu = (0.87 x fy x Ast) / (0.36 x fck x bf)

= (0.87 x 415 x 1884) / (0.36 x 20 x 1250) 01 M

= 75.58 mm.

xumax = 0.48 x d

= 0.48 x 550 01 M

= 264 mm.

xu < xumax, hence beam is under reinforced.

Mu = 0.87 x fy x Ast (d – 0.42xu)

= 0.87 x 415 x 1884 (550 – 0.42 x 75.58)

= 352.53 x 10^6 N-mm. 02 M

OR

Mu = 0.36 x fck x bf x xu (d – 0.42xu)

= 0.36 x 20 x 1250 x 75.58 (550 – 0.42 x 75.58)

1) = 352.53 x 10^6 N-mm

Q.6 (b) **_State the I.S. specification for,_**

i) Maximum reinforcement in beams & slabs.
ii) Minimum reinforcement in slab.
iii) Minimum shear reinforcement.
iv) Cover to reinforcement in beam and slab.

Ans

i. Maximum reinforcement in slab and beam = 4% of gross area. (0.04 x b x D) 01 M
ii. Minimum reinforcement in slab = 0.15 % for M.S. and 0.12% for deformed bars, of gross area. 01 M
iii. Minimum shear reinforcement, [Asv / (b x sv)] > or = [0.4 / (0.87 x fy)] 01 M
iv. Cover to reinforcement in beams & slab.
For beams, 20 mm to 70 mm depending upon fire resistance required. 01 M
For slabs, 20 mm to 55 mm depending upon fire resistance required.

Q.6 (c) **_Calculate effective flange width for T-beam for following details._**
Width of web = 230 mm.

	Ans	***Slab thickness = 100 mm.*** ***Size of hall = 12 m x 6 m.*** ***Width of support for beam = 230 mm.*** ***C/c spacing of beams = 3 m.*** bw = 230 mm, Df = 100 mm, Hall size = 12 m x 6 m., Support = 230 mm, C/c spacing of beam = 3 m. le = 6 + 0.23 = 6.23 m. Hence l_0 = 6.23 m. bf = (l_0/6) + bw + 6Df = (6230/6) + 230 + 6 x 100 = 1868.3 mm. < C/c spacing (3000 mm) Hence bf = 1868.3 mm.	01 M 02 M 01 M
Q.6	(d) Ans	***Write four I.S. specifications for the longitudinal reinforcement in columns.*** 1. Minimum area of longitudinal reinforcement = 0.8% of gross area. 2. Maximum area of longitudinal reinforcement = 6.0% of gross area. 3. Minimum number of bars = 04 for square column, 06 for circular column and 06 for column with helical reinforcement. 4. Minimum diameter of bar = 12 mm. 5. Maximum spacing of bars measured along periphery of column = 300 mm.	Any four, 01 M for each
Q.6	(e) Ans	***Calculate the area of longitudinal steel for short circular column of diameter 400 mm with effective length 4.5 m to carry a factored load of 900 kN. Use M20 and Fe500.*** Column 400 mm diameter, le = 4.5 m, Pu = 900 kN, M-20, Fe-500. Ag = π x 400^2 / 4 = 125663.71 mm^2 Ac = Ag – Asc = 125663.71 – Asc Pu = (0.4 x fck x Ac) + (0.67 x fy x Asc) 900 x 10^3 = [0.4 x 20 x (125663.71 – Asc)] + (0.67 x 500 x Asc) = 1005309.68 – 8Asc + 335Asc Asc = (900 x 10^3 – 1005309.68)/ 327 = (-) 322 mm^2. Required area of compression steel is negative; hence minimum area of steel is to be provided. Min. Asc = 0.8 x 125663.71 / 100 = 1005.3 mm^2. Provide Asc = 1005.3 mm^2	01 M 02 M 01 M