THE PAPUA NEW GUINEA UNIVERSITY OF TECHNOLOGY

DEPARTMENT OF CIVIL ENGINEERING – 3rd YEAR DEGREE

SECOND SEMESTER FINAL EXAMINATIONS - 2023

CE 322 – Concrete Design

DATE: THURSDAY, 26th OCTOBER 2023 – 8:20 A.M

VENUE: C004/5

TIME ALLOWED: 3 HOURS

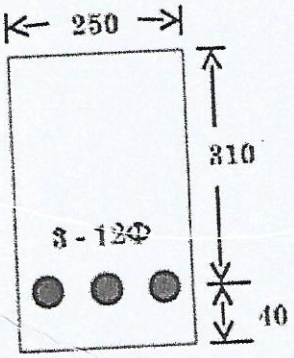
INFORMATION FOR CANDIDATES

1. You have 10 minutes to read the paper before the examination starts. You must **not** begin writing during this time.
2. **Answer any 5 questions. There are 7 questions; all questions are of equal marks (20 marks for each).**
3. Use only ink. Do not use pencils for writing except for drawings and sketches.
4. Only Calculator is allowed in the examination room. MOBILE PHONE is not allowed (**Switch your Mobile Phones OFF**). Notes and textbooks are not allowed.
5. Start each question on a new page and show all your calculations in the answer book provided. No other material will be accepted.
6. **Write your NAME and clearly on the front page. Do it now.**

QUESTION 1 [20 MARKS] SLO 1- Use the properties of concrete and steels in concrete design as well as to analyze the loading on, and design of concrete beam to meet failure and serviceability requirements through the application of contemporary design codes and standards.

(a) Determine the moment of resistance for the section shown in figure. **10 marks**

(i) $f_{ck} = 20$ N/mm^2, $f_y = 415$ N/mm^2



Given:

Force of compression $= 0.36\, f_{ck}\, b\, x$

Force of Tension $= 0.87\, f_y\, A_t$

x = depth of neutral axis, A_t = area of steel ; and the limiting (maximum) values of the neutral axis depth x_m for the different grade of steels are as follows:

f_y	x_m
415	0.48d
500	0.46d

Lever arm z $= d - 0.42x$

Moment of resistance w.r.t steel $= 0.87 f_y A_t z$

(b) Design a rectangular beam to resist a bending moment equal to 45 kNm usig M15 concrete and mild steel. **10 Marks**

For balanced section,

Moment of resistance $M_u = 0.36\, f_{ck}\, b\, x_m (d - 0.42\, x_m)$

Grade for mild steel is Fe250

For Fe250 steel,

$x_m = 0.53d$

For balanced section, the moment of resistance is calculated by the following equation:

$$\text{Minimum area of steel } A_o = 0.85\frac{bd}{f_y}$$

Where b = width and d = depth of beam, f_y = Characteristic strength of steel and A_t = Area of tensile steel.

QUESTION 2 [20 MARKS] SLO 2 Analyze and design continuous beam and one-way slabs in buildings

(a) Design the one-way continuous slab of Fig.1 subjected to uniformly distributed imposed loads of 4 kN/m² using M 20 and Fe 415. The load of floor finish is 1kN/m². The span dimensions shown in the figure are effective spans. The width of beams at the support = 250 mm. **10 marks**

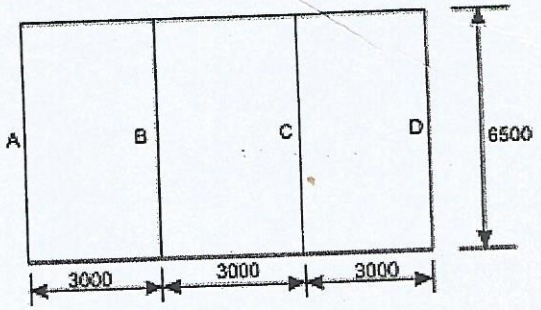


Fig.1 one-way continuous slab

For determination of effective and total depths of slab, use the following formula:

$$M_{u,lim} = R_{,lim}\, bd^2 \text{ where } R_{,lim} \text{ is 2.76 N/mm}^2.$$

Table 19 of IS 456 gives τ_c = 0.28 N/mm² for the lowest percentage of steel in the slab.

use the coefficient k of cl. 40.2.1.1 of IS 456 as 1.3.

Table 20 of IS 456 gives $\tau_{c,\max}$ = 2.8 N/mm². For this problem $\tau_v = \frac{V_u}{bd}$

For determination of the area of steel,

$$M_u = 0.87 f_y A_{st} d \{1 - (A_{st})(f_y)/(f_{ck})(bd)\}$$

For distribution steel, minimum area of steel required is 0.12% of A_g,

where A_g = gross cross-sectional area of the section.

(b) Determine the moment of resistance of an existing beam having the following data: b=350 mm; d=900mm; d' =50mm. Tension reinforcement: 5-20mm HYSD bars (Fe 415); compression reinforcement 2-20 HYSD bars (Fe 415); grade of concrete M15.

10 Marks

Given,

Force of tension =

Force of compression $C_u = 0.36 f_{ck} x_u b + f_{sc} A_{sc} - 0.446 f_{ck} A_{sc}$

assume x_u =230mm

$$\varepsilon_{sc} = \frac{0.0035(x_u - d')}{x_u}$$

to change

For A_{st2} $A_{st1} = \dfrac{M_{u,\lim}}{0.87 f_y (d - d')}$

$$A_{sc}(f_{sc} - f_{cc}) = A_{st2}(0.87 f_y)^{ax})$$

$$A_{st} = A_{st1} + A_{st2}$$

$\varepsilon_{sc} = 0.00274$, f_{sc} =351 N/mm^2 and

$\varepsilon_{sc} = 0.00258$, f_{sc} =347 N/mm^2

QUESTION 3 [20 MARKS] SLO 3 Analyze and design concrete members subjected to compression and bending in buildings.

(a) Will the effective length l_e of a rectangular reinforced concrete column of cross-sectional dimensions b and D be the same in both the directions of b and D? support your answer with logic. 1+1 = 2 Marks

(b) Define slenderness ratio for a rectangular column. 3 Marks

(c) Define short column as per IS 456. 3 Marks

(d) Design the reinforcement to be provided in the short column is subjected to P_u= 2000 kN, M_{ux} = 130 kNm (about the major principal axis) and M_{uy} = 120 kNm (about the minor principal axis). For reinforcement, Mu = 203.456 kNm. The unsupported length of the column is 3.2 m, width b = 400 mm and depth D = 500 mm. Use M 25 and Fe 415 for the design. **12 Marks**

Given,

d′ = 60 mm, and for d'/D = 0.12, p/f_{ck} = 0.06. and

$M_{ux1}/f_{ck}bD^2$ = 0.09044.

For d'/b = 58/400 = 0.145, $M_{uy1}/f_{ck}Db^2$ = 0.0858

P_{uz} = 0.45 $f_{ck}A_c$ + 0.75 $f_y A_{sc}$ = 0.45 A_g + (0.75 f_y - 0.45 f_{ck}) A_{sc} with usual notations.

α^n = 1.658 (for P_u/ P_{uz} = 0.5916)

QUESTION 4 [20 MARKS] SLO 4 Analyze and design for serviceability conditions in buildings

a) What is meant by "Serviceability Limit state"? in the design of concrete structures? 2 Marks
b) List the serviceability limit states to be satisfied in the design of reinforced concrete structures. 2 Marks
c) Write the expressions for the deflection control of simply supported RC beam for a span up to 10 m and beyond 10 m. 4 Marks
d) Define the term "creep" of concrete under serviceability limit state. 2 Marks
e) Write the purposes of providing nominal cover in RCC design. 2 Marks
f) Define design strength of materials (f_d) and write the expression of it. 2 Marks
g) On which factors, does the partial safety factor depend? 2 Marks
h) Write the value of partial safety factor for concrete and steels which are to be used in limit state method of design. 4 Marks

QUESTION 5 [20 marks] SLO 5 Analyze and design two-way-slabs and walls in buildings.

(a) Design a R.C. slab for a room measuring 4mx5m size. The slab is simply supported on all the four edges, with corners held down and carries a super-imposed load of 3 KN/m² inclusive of floor finish etc. Use M20 grade of concrete and Fe 415 grade of steel. **15 Marks**

Given,

m.f. = 1.68, unit weight of RCC = 25 kN/m³, α_x =0.072, α_y =0.056, R_u = 2.76

Min p_t = 0.12% of gross cross sectional aera

$A_{stx} = 0.5f_{ck}/f_y\,[1-\sqrt{(1-(4.6M_{ux})/(f_{ck}bd^2))}]bd$

(b) Design and detail torsional reinforcement at corner, show the reinforcement details in a diagram with all important features like the extensions, curtailments and layers of bars clearly. **5 Marks**

QUESTION 6 [20 marks] SLO 6 Identify basic concepts in the analysis & design of steel/concrete composite sections and prestressed concrete.

(a) Write the definitions, and the mathematical expressions of the different types of losses with explaining the notations used for the following losses in pre-stress concrete:
i) Elastic shortening
ii) Shrinkage of concrete
iii) Creep of concrete
iv) Frictional losses
v) Relaxation of steel **10 Marks**

(b) Define bond/anchorage type of shear connector. Draw bond/anchorage type of shear connector for a connection between steel girder and concrete sab.
Draw typical cross sections of four types of composite columns. **2+2+6 = 10 Marks**

QUESTION 7 [20 marks] SLO 2 + SLO 1

(a)

(i) Why and when beams are to be doubly reinforced? 3 Marks

(ii) Whether the bending moment at or near the support of a continuous beam be sagging or hogging moment and why? 3 Marks

(iii) Whether the tensile reinforcements at and near the support of the beam are to be provided at the top or bottom of the section and why? 3 marks

(iv) Define continuous a beam. 1 Mark

(b)

(i) Which between the under reinforced and over reinforced section will you prefer for the LSM of reinforced concrete design and why? 2 Marks

(ii) Suppose, steel bars of diameter 8 mm and above are available in the market. Will you prefer smaller or bigger diameter of steel bar in RC slab design? Justify your answer. 2 Marks

(iii) Define characteristic compressive strength of concrete 2 Marks

(iv) What is the purpose of providing steel reinforcement at the compression side of doubly reinforced RC beam section? 2 Marks

(v) Enumerate the roles of water cement ratio in concrete manufacturing. 2 Marks