ROYAL CIVIL SERVICE COMMISSION
BHUTAN CIVIL SERVICE EXAMINATION (BCSE) 2024
EXAMINATION CATEGORY: TECHNICAL

PAPER III: SUBJECT SPECIALISATION PAPER FOR CIVIL ENGINEERING

Date	: October 5, 2024
Total Marks	: 100
Writing Time	: 150 minutes (2.5 hours)
Reading Time	: 15 minutes (prior to writing time)

GENERAL INSTRUCTIONS:

1. Write your Registration Number clearly and correctly on the Answer Booklet.
2. The first 15 minutes is provided to check the number of pages of Question Paper, printing errors, clarify doubts and to read the instructions. You are NOT permitted to write during this time.
3. This paper consists of **TWO SECTIONS**, namely SECTION A & SECTION B:
   - **SECTION A** has two parts: Part I - 30 Multiple Choice Questions
     Part II - 4 Short Answer Questions

     All questions under SECTION A are COMPULSORY.
   - **SECTION B** consists of two Case Studies. Choose only **ONE** case study and answer the questions of your choice.
4. All answers should be written on the Answer Booklet provided to you. Candidates are not allowed to write anything on the question paper. If required, ask for additional Answer Booklet.
5. All answers should be written with correct numbering of Section, Part and Question Number in the Answer Booklet provided to you. Note that any answer written without indicating the Section, Part and Question Number will NOT be evaluated and no marks will be awarded.
6. Begin each Section and Part in a fresh page of the Answer Booklet.
7. You are not permitted to tear off any sheet(s) of the Answer Booklet as well as the Question Paper.
8. Use of any other paper including paper for rough work is not permitted.
9. **You must hand over the Answer Booklet to the Invigilator before leaving the examination hall.**
10. This paper has **14 printed pages**, including this instruction page.

GOOD LUCK

SECTION A

PART I: Multiple Choice Questions (30 marks)

Choose the correct answer and write down the letter of your chosen answer in the Answer Booklet against the question number e.g. 31 (d). Each question carries ONE mark. Any double writing, smudgy answers or writing more than one choice shall not be evaluated.

1. What is the meaning of soundness of cement?
   a) Ability to flow when mixed
   b) Ability to make ringing noise when struck
   c) Ability to form strong and sound structure
   d) Ability to retain volume after setting

2. In frame structure, what transfers the load to columns?
   a) Foundation
   b) Beams
   c) Slabs
   d) Roofs

3. In a truss structure, __________ bear tension.
   a) Joints
   b) Base
   c) Bottom chords
   d) Top chords

4. Hydrographic survey deal with the mapping of
   a) large water bodies
   b) mountainous region
   c) canal system
   d) movement of clouds

5. Which of the below is constructed above doors, windows?
   a) Joist
   b) Purlin
   c) Lintel
   d) Arch

6. ____________wall is used to resist lateral forces like severe wind.
   a) Knee
   b) Cavity
   c) Infill
   d) Shear

7. Contours can be found in a ___________ map.
   a) Political
   b) Topographical
   c) Physical
   d) Thematic

8. The horizontal angle between the true meridian and magnetic meridian at a place is called
   a) azimuth
   b) declination
   c) local attraction
   d) magnetic bearing

9. A critical path has
   a) zero slack
   b) minimum slack
   c) maximum slack
   d) infinite slack

10. The term ___________ in construction is applied to the finishing of mortar joints in masonry (stone or brick). In exposed masonry, these are considered to be the weakest part.
    a) painting
    b) deteriorating
    c) pointing
    d) finishing

11. M25 grade of concrete approximates
    a) 1 : 1: 2 mix
    b) 1: 1.5 : 3 mix
    c) 1: 3: 6 mix
    d) none of the above

12. Poisson's ratio is the ratio of:
    a) Axial stress to axial strain
    b) Lateral strain to axial strain
    c) Shear stress to shear strain
    d) Compressive stress to tensile stress

13. What is the unit of discharge in hydrology?
    a) Liters per minute (L/min)
    b) Gallons per hour (gal/hr)
    c) Cubic feet per minute (ft3/min)
    d) Cubic meters per second (m3/s)

14. Which of the following load is to be considered on liquid retaining structure?
    a) dynamic load
    b) earth pressure
    c) hydrostatic load
    d) wave and current load

15. The last reading taken from the instrument is called:
    a) End sight
    b) Free sight
    c) Fore sight
    d) Back sight

16. In PERT analysis, event means
    a) start or finish of a task
    b) time taken for a task
    c) end of an activity
    d) work involved in the project

17. The point in the cross section of beam through which if load acts there will not be any twisting of the beam but there will be only bending is known as
    a) centre of gravity
    b) centroid
    c) shear centre
    d) all the above

18. The main object of a preliminary survey
    a) to collect the necessary physical information and details of topography, drainage and soil properties.
    b) to estimate cost of alternative alignment.
    c) to finalise the best alignment.
    d) all the above.

19. Benchmark is established by
    a) hypsometry
    b) barometric leveling
    c) spirit leveling
    d) trigonometric leveling

20. What is the initial setting time of cement?
    a) 1 hour
    b) 30 minutes
    c) 15 minutes
    d) 30 hours

21. A channel section has
    a) two webs one flange
    b) one web two flanges
    c) one web one flange
    d) two webs and two flanges

22. The centre of gravity of the volume of liquid displaced is called
    a) centre of pressure
    b) centre of buoyancy
    c) metacentre
    d) None of these

23. The property of a material to resist scratching and abrasion is known as:
    a) Toughness
    b) Hardness
    c) Elasticity
    d) Plasticity

24. Loss of prestress due to friction occurs
    a) only in pre-tensioned beams
    b) only in post-tensioned beams
    c) in both pre-tensioned and post-tensioned beams
    d) none of the above

25. For the design of retaining walls, the minimum factor of safety against overturning is taken as
    a) 2
    b) 1.4
    c) 1.5
    d) 3.0

26. Efflorescence in cement is caused due to an excess of
    a) Alumina
    b) Iron oxide
    c) Silica
    d) Alkalies

27. If the modulus of elasticity is zero, the material is said to be
    a) rigid
    b) elastic
    c) flexible
    d) plastic

28. What is the primary purpose of reinforcement in RCC?
    a) To resist tensile forces
    b) To increase concrete strength
    c) To enhance thermal properties
    d) To reduce construction cost

29. What is the purpose of 'weep holes' in retaining walls?
    a) Aesthetic appeal
    b) Structural reinforcement
    c) Drainage of accumulated water
    d) Ventilation

30. It is more often preferable that a beam section be designed as :
    a) reinforced concrete section
    b) balanced section
    c) underreinforced section
    d) overreinforced section

PART II: Short Answer Questions (20 marks)

This part has 4 Short Answer Questions. Answer ALL the questions. Each question carries 5 marks.

1. What is the density of steel and why is density important for steel? Compute the weight of MS plate of 250mmx250mmx10 mm?

2. What is RCC Beam and determine the self-weight of a RCC beam which have a span of 8m with a cross section of 400mmx800mm.

3. A simply supported beam of span 6m carries uniformly distributed load (udl) of 1.5kN/m over entire span and a point load of 2 KN at 2 m from the right support. Determine the reactions at left and right support and the moment at 2 m from the right support.

4. What is the basic difference between Slump test and Compression test? Briefly explain the procedures of slump test for concrete.

SECTION B: Case Study (50 marks)

Choose either CASE I or CASE II from this section. Each case study carries 50 marks. Marks for each sub-questions is indicated in the brackets.

CASE I

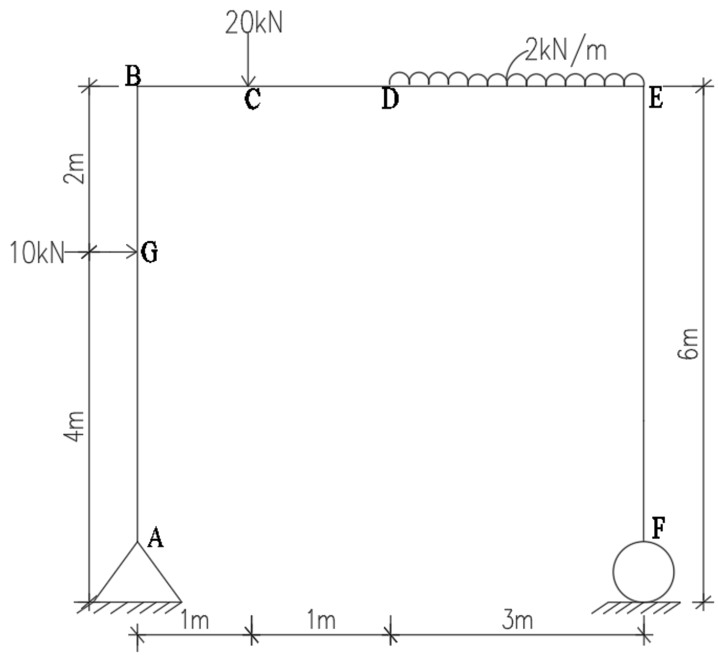
1. As a civil engineer, you are assigned to evaluate an existing building, which do not full fil the current seismic requirements, may suffer extensive damage or even collapse if shaken by a severe ground motion. Elaborate and explain the methodology how you are going to assess and evaluate the existing building. **[30 marks]**

2. What is Nondestructive Testing (NDT) method and explain the types of NDT for building and building materials. **[15 marks]**

3. What do you mean by flood and its effects? Briefly explain how to reduce the impact of floods**. [5 marks]**

CASE II

Analyse the following frame with the loading and support conditions as indicated in the given figure.



1. Compute the support reactions at A and F. Draw the free body diagram, axial force diagram, shear force diagram and bending moment diagram for the frame. **[20 marks]**

2. Calculate the quantity of cement, sand and aggregate in a member EF and BE. Take the concrete grade as M20 and assume the size of the column (EF) as 500mmx500mm and beam (BE) as 300mmx500mm. **[10 marks]**

3. Design a rectangular reinforced concrete beam supported on 300mm wall with a clear span of 6000mm. Consider the Live Load (LL) as 12kN/m, the concrete grade as M20, reinforcement grade as Fe415 and clear cover to reinforcement as 30mm. Take the width of the beam as 300mm.**[20 marks]**

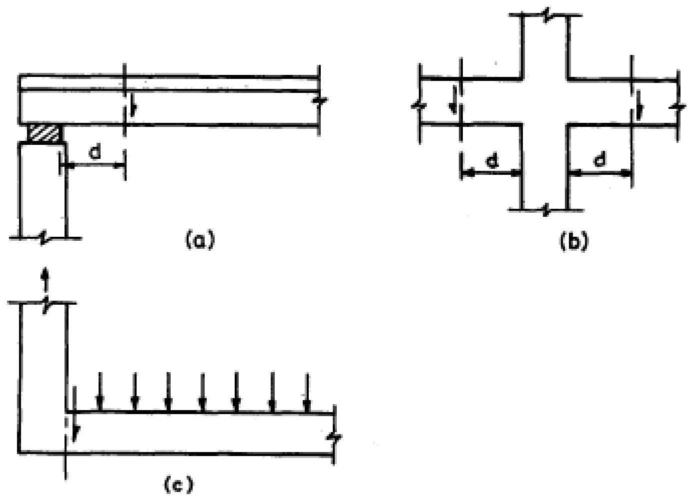


FIG. 2 TYPICAL SUPPORT CONDITIONS FOR LOCATING FACTORED SHEAR FORCE

but in no case greater than the breadth of the web plus half the sum of the clear distances to the adjacent beams on either side.

a) For T-beams, $b_f = \frac{l_0}{6} + b_w + 6\,D_f$

b) For L-beams, $b_f = \frac{l_0}{12} + b_w + 3\,D_f$

c) For isolated beams, the effective flange width shall be obtained as below but in no case greater than the actual width:

$$\text{T} - \text{beam}, b_f = \frac{l_0}{\left(\frac{l_0}{b}\right)+4} + b_w$$

$$\text{L} - \text{beam}, b_f = \frac{0.5\ l_0}{\left(\frac{l_0}{b}\right)+4} + b_w$$

where

b_f = effective width of flange,

l_0 = distance between points of zero moments in the beam,

b_w = breadth of the web,

D_f = thickness of flange, and

b = actual width of the flange.

NOTE — For continuous beams and frames, 'l_0' may be assumed as 0.7 times the effective span.

23.2 Control of Deflection

The deflection of a structure or part thereof shall not adversely affect the appearance or efficiency of the structure or finishes or partitions. The deflection shall generally be limited to the following:

a) The final deflection due to all loads including the effects of temperature, creep and shrinkage and measured from the as-cast level of the supports of floors, roofs and all other horizontal members, should not normally exceed span/250.

b) The deflection including the effects of temperature, creep and shrinkage occurring after erection of partitions and the application of finishes should not normally exceed span/350 or 20 mm whichever is less.

23.2.1 The vertical deflection limits may generally be assumed to be satisfied provided that the span to depth ratios are not greater than the values obtained as below:

a) Basic values of span to effective depth ratios for spans up to 10 m:

Cantilever	7
Simply supported	20
Continuous	26

b) For spans above 10 m, the values in (a) may be multiplied by 10/span in metres, except for cantilever in which case deflection calculations should be made.

c) Depending on the area and the stress of steel for tension reinforcement, the values in (a) or (b) shall be modified by multiplying with the modification factor obtained as per Fig. 4.

d) Depending on the area of compression reinforcement, the value of span to depth ratio be further modified by multiplying with the modification factor obtained as per Fig. 5.

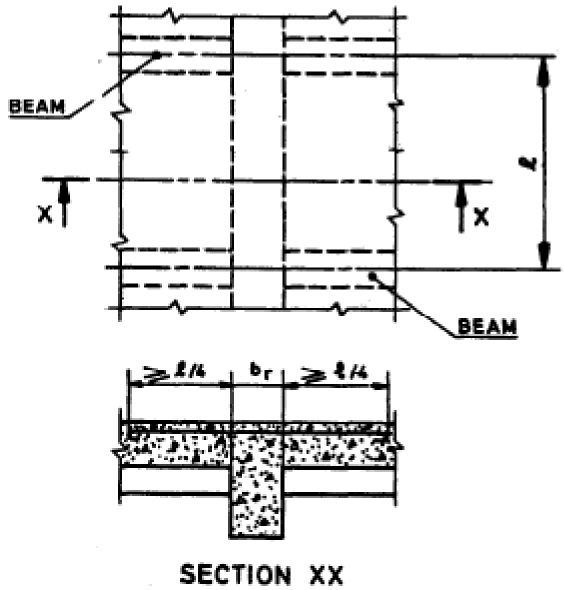
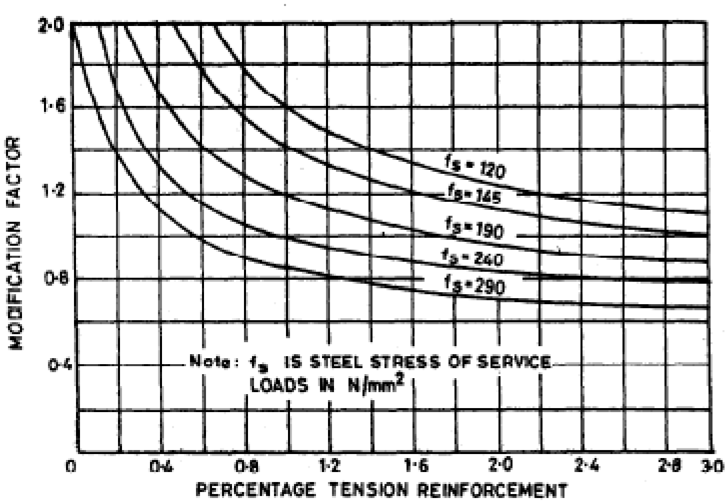


FIG. 3 TRANSVERSE REINFORCEMENT IN FLANGE OF T-BEAM WHEN MAIN REINFORCEMENT OF SLAB IS PARALLEL TO THE BEAM

e) For flanged beams, the values of (a) or (b) be modified as per Fig. 6 and the reinforcement percentage for use in Fig. 4 and 5 should be based on area of section equal to $b_f\, d$.

NOTE—When deflections are required to be calculated, the method given in Annex C may be used.



$$f_s = 0.58\, f_y \frac{\text{Area of cross-section of steel required}}{\text{Area of cross-section of steel provided}}$$

FIG. 4 MODIFICATION FACTOR FOR TENSION REINFORCEMENT used the horizontal distance between bars of a group may be reduced to two-thirds the nominal maximum size of the coarse aggregate, provided that sufficient space is left between groups of bars to enable the vibrator to be immersed.

c) Where there are two or more rows of bars, the bars shall be vertically in line and the minimum vertical distance between the bars shall be 15 mm, two-thirds the nominal maximum size of aggregate or the maximum size of bars, whichever is greater.

26.3.3 *Maximum Distance Between Bars in Tension*

Unless the calculation of crack widths shows that a greater spacing is acceptable, the following rules shall be applied to flexural members in normal internal or external conditions of exposure.

a) *Beams* — The horizontal distance between parallel reinforcement bars, or groups, near the tension face of a beam shall not be greater than the value given in Table 15 depending on the amount of redistribution carried out in analysis and the characteristic strength of the reinforcement.

b) *Slabs*

1) The horizontal distance between parallel main reinforcement bars shall not be more than three times the effective depth of solid slab or 300 mm whichever is smaller.

2) The horizontal distance between parallel reinforcement bars provided against shrinkage and temperature shall not be more than five times the effective depth of a solid slab or 450 mm whichever is smaller.

26.4 Nominal Cover to Reinforcement

26.4.1 *Nominal Cover*

Nominal cover is the design depth of concrete cover to all steel reinforcements, including links. It is the dimension used in design and indicated in the drawings. It shall be not less than the diameter of the bar.

26.4.2 *Nominal Cover to Meet Durability Requirement*

Minimum values for the nominal cover of normal-weight aggregate concrete which should be provided to all reinforcement, including links depending on the condition of exposure described in **8.2.3** shall be as given in Table 16.

26.4.2.1 However for a longitudinal reinforcing bar in a column nominal cover shall in any case not be less than 40 mm, or less than the diameter of such bar. In the case of columns of minimum dimension of 200 mm or under, whose reinforcing bars do not exceed 12 mm, a nominal cover of 25 mm may be used.

26.4.2.2 For footings minimum cover shall be 50 mm.

26.4.3 *Nominal Cover to Meet Specified Period of Fire Resistance*

Minimum values of nominal cover of normal-weight aggregate concrete to be provided to all reinforcement including links to meet specified period of fire resistance shall be given in Table 16A.

26.5 Requirements of Reinforcement for Structural Members

26.5.1 *Beams*

26.5.1.1 *Tension reinforcement*

a) *Minimum reinforcement*—The minimum area of tension reinforcement shall be not less than that

Table 15 Clear Distance Between Bars
(*Clause* 26.3.3)

f_y	Percentage Redistribution to or from Section Considered				
	- 30	- 15	0	+ 15	+ 30
	Clear Distance Between Bars				
N/mm²	mm	mm	mm	mm	mm
250	215	260	300	300	300
415	125	155	180	210	235
500	105	130	150	175	195

NOTE — The spacings given in the table are not applicable to members subjected to particularly aggressive environments unless in the calculation of the moment of resistance, f_y has been limited to 300 N/mm² in limit state design and σ_{st} limited to 165 N/mm² in working stress design.

Table 16 Nominal Cover to Meet Durability Requirements
(*Clause* 26.4.2)

Exposure	Nominal Concrete Cover in mm not Less Than
Mild	20
Moderate	30
Severe	45
Very severe	50
Extreme	75

NOTES

1 For main reinforcement up to 12 mm diameter bar for mild exposure the nominal cover may be reduced by 5 mm.

2 Unless specified otherwise, actual concrete cover should not deviate from the required nominal cover by $^{+10}_{\ 0}$ mm

3 For exposure condition 'severe' and 'very severe', reduction of 5 mm may be made, where concrete grade is M35 and above.

Table 16A
Nominal Cover to Meet Specified Period of Fire Resistance
(*Clauses* 21.4 *and* 26.4.3 and *Fig.* 1)

Fire Resistance	Nominal Cover						
	Beams		Slabs		Ribs		Columns
	Simply supported	Continuous	Simply supported	Continuous	Simply supported	Continuous	
h	mm	mm	mm	mm	mm	mm	mm
0.5	20	20	20	20	20	20	40
1	20	20	20	20	20	20	40
1.5	20	20	25	20	35	20	40
2	40	30	35	25	45	35	40
3	60	40	45	35	55	45	40
4	70	50	55	45	65	55	40

NOTES

1 The nominal covers given relate specifically to the minimum member dimensions given in Fig. 1.

2 Cases that lie below the bold line require attention to the additional measures necessary to reduce the risks of spalling (*see* **21.3.1**).

given by the following:

$$\frac{A_s}{bd} = \frac{0.85}{f_y}$$

where

A_s = minimum area of tension reinforcement.

b = breadth of beam or the breadth of the web of T-beam,

d = effective depth, and

f_y = characteristic strength of reinforcement in N/mm^2.

b) *Maximum reinforcement*—The maximum area of tension reinforcement shall not exceed 0.04 *bD*.

26.5.1.2 *Compression reinforcement*

The maximum area of compression reinforcement shall not exceed 0.04 *bD*. Compression reinforcement in beams shall be enclosed by stirrups for effective lateral restraint. The arrangement of stirrups shall be as specified in **26.5.3.2**.

26.5.1.3 *Side face reinforcement*

Where the depth of the web in a beam exceeds 750 mm, side face reinforcement shall be provided along the two faces. The total area of such reinforcement shall be not less than 0.1 percent of the web area and shall be distributed equally on two faces at a spacing not exceeding 300 mm or web thickness whichever is less.

26.5.1.4 *Transverse reinforcement in beams for shear and torsion*

The transverse reinforcement in beams shall be taken around the outer-most tension and compression bars. In T-beams and I-beams, such reinforcement shall pass around longitudinal bars located close to the outer face of the flange.

26.5.1.5 *Maximum spacing of shear reinforcement*

The maximum spacing of shear reinforcement measured along the axis of the member shall not exceed 0.75 *d* for vertical stirrups and *d* for inclined stirrups at 45°, where *d* is the effective depth of the section

NOTES

1 A column may be considered braced in a given plane if lateral stability to the structure as a whole is provided by walls or bracing or buttressing designed to resist all lateral forces in that plane. It should otherwise be considered as unbraced.

2 In the case of a braced column without any transverse loads occurring in its height, the additional moment shall be added to an initial moment equal to sum of 0.4 M_{u1} and 0.6 M_{u2} where M_{u2} is the larger end moment and M_{u1} is the smaller end moment (assumed negative if the column is bent in double curvature). In no case shall the initial moment be less than 0.4 M_{u2} nor the total moment including the initial moment be less than M_{u2}. For unbraced columns, the additional moment shall be added to the end moments.

3 Unbraced compression members, at any given level or storey, subject to lateral load are usually constrained to deflect equally. In such cases slenderness ratio for each column may be taken as the average for all columns acting in the same direction.

39.7.1.1 The values given by equation **39.7.1** may be multiplied by the following factor:

$$k = \frac{P_{uz} - P_u}{P_{uz} - P_b} \leq 1$$

where

P_u = axial load on compression member,

P_{uz} = as defined in **39.6**, and

P_b = axial load corresponding to the condition of maximum compressive strain of 0.003 5 in concrete and tensile strain of 0.002 in outer most layer of tension steel.

40 LIMIT STATE OF COLLAPSE : SHEAR

40.1 Nominal Shear Stress

The nominal shear stress in beams of uniform depth shall be obtained by the following equation:

$$\tau_v = \frac{V_u}{b_d}$$

where

V_u = shear force due to design loads;

b = breadth of the member, which for flanged section shall be taken as the breadth of the web, b_w; and

d = effective depth.

40.1.1 *Beams of Varying Depth*

In the case of beams of varying depth the equation shall be modified as:

$$\tau_v = \frac{V_u \pm \frac{M_u}{d} \tan\beta}{bd}$$

where

τ_v, V_u, b and d are the same as in **40.1**,

M_u = bending moment at the section, and

β = angle between the top and the bottom edges of the beam.

The negative sign in the formula applies when the bending moment M_u increases numerically in the same direction as the effective depth d increases, and the positive sign when the moment decreases numerically in this direction.

40.2 Design Shear Strength of Concrete

40.2.1 The design shear strength of concrete in beams without shear reinforcement is given in Table 19.

40.2.1.1 For solid slabs, the design shear strength for concrete shall be $\tau_c k$, where k has the values given below:

Overall Depth of Slab, mm	300 or more	275	250	225	200	175	150 or less
k	1.00	1.05	1.10	1.15	1.20	1.25	1.30

NOTE — This provision shall not apply to flat slabs for which **31.6** shall apply.

40.2.2 *Shear Strength of Members under Axial Compression*

For members subjected to axial compression P_u, the design shear strength of concrete, given in Table 19, shall be multiplied by the following factor :

$$\delta = 1 + \frac{3P_u}{A_g f_{ck}} \text{ but not exceeding } 1.5$$

where

P_u = axial compressive force in Newtons,

A_g = gross area of the concrete section in mm^2, and

f_{ck} = characteristic compressive strength of concrete.

40.2.3 *With Shear Reinforcement*

Under no circumstances, even with shear reinforcement, shall the nominal shear stress in beams τ_v exceed $\tau_{c max}$ given in Table 20.

40.2.3.1 For solid slabs, the nominal shear stress shall not exceed half the appropriate values given in Table 20.

40.3 Minimum Shear Reinforcement

When τ_v is less than τ_c given in Table 19, minimum shear reinforcement shall be provided in accordance with **26.5.1.6**.

40.4 Design of Shear Reinforcement

When τ_v exceeds τ_c given in Table 19, shear reinforcement shall be provided in any of the following forms:

a) Vertical stirrups,

b) Bent-up bars along with stirrups, and

Table 19 Design Shear Strength of Concrete, τ_c, N/mm²

(*Clauses* 40.2.1, 40.2.2, 40.3, 40.4, 40.5.3, 41.3.2, 41.3.3 *and* 41.4.3)

$100\frac{A_s}{bd}$	Concrete Grade					
	M 15	M 20	M 25	M 30	M 35	M 40 and above
(1)	(2)	(3)	(4)	(5)	(6)	(7)
≤ 0.15	0.28	0.28	0.29	0.29	0.29	0.30
0.25	0.35	0.36	0.36	0.37	0.37	0.38
0.50	0.46	0.48	0.49	0.50	0.50	0.51
0.75	0.54	0.56	0.57	0.59	0.59	0.60
1.00	0.60	0.62	0.64	0.66	0.67	0.68
1.25	0.64	0.67	0.70	0.71	0.73	0.74
1.50	0.68	0.72	0.74	0.76	0.78	0.79
1.75	0.71	0.75	0.78	0.80	0.82	0.84
2.00	0.71	0.79	0.82	0.84	0.86	0.88
2.25	0.71	0.81	0.85	0.88	0.90	0.92
2.50	0.71	0.82	0.88	0.91	0.93	0.95
2.75	0.71	0.82	0.90	0.94	0.96	0.98
3.00 and above	0.71	0.82	0.92	0.96	0.99	1.01

NOTE — The term A_s is the area of longitudinal tension reinforcement which continues at least one effective depth beyond the section being considered except at support where the full area of tension reinforcement may be used provided the detailing conforms to 26.2.2 and 26.2.3

Table 20 Maximum Shear Stress, $\tau_{c\,max}$, N/mm²

(*Clauses* 40.2.3, 40.2.3.1, 40.5.1 *and* 41.3.1)

Concrete Grade	M 15	M 20	M 25	M 30	M 35	M 40 and above
$\tau_{c\,max}$, N/mm²	2.5	2.8	3.1	3.5	3.7	4.0

c) Inclined stirrups.

Where bent-up bars are provided, their contribution towards shear resistance shall not be more than half that of the total shear reinforcement.

Shear reinforcement shall be provided to carry a shear equal to $V_u - \tau_c\, bd$ The strength of shear reinforcement V_{us} shall be calculated as below:

a) For vertical stirrups:

$$V_{us} = \frac{0.87 f_y A_{sv} d}{s_v}$$

b) For inclined stirrups or a series of bars bent-up at different cross-sections:

$$V_{us} = \frac{0.8.7 f_y A_{sv} d}{s_v} (\sin\alpha + \cos\alpha)$$

c) For single bar or single group of parallel bars, all bent-up at the same cross-section:

$$V_{us} = 0.87 f_y A_{sv} \sin \alpha$$

where

A_{sv} = total cross-sectional area of stirrup legs or bent-up bars within a distance s_v,

s_v = spacing of the stirrups or bent-up bars along the length of the member,

τ_v = nominal shear stress,

τ_c = design shear strength of the concrete,

b = breadth of the member which for flanged beams, shall be taken as the breadth of the web b_w,

f_y = characteristic strength of the stirrup or bent-up reinforcement which shall not be taken greater than 415 N/mm²,

α = angle between the inclined stirrup or bent- up bar and the axis of the member, not less than 45°, and

d = effective depth.

TASHI DELEK