RPSC AEn-2024 Main Test Series

CIVIL ENGINEERING

Test 1

Test Mode : • **Offline** • **Online**

Subjects : Fluid Mechanics + Building Materials

DETAILED EXPLANATIONS

1. Solution:

Surface tension is defined as the tensile force acting on the surface of a liquid in contact with a gas or on the surface between two immiscible liquids such that the contact surface behaves like a membrane under tension. It is expressed as force per unit length i.e.

$$\sigma = \frac{F}{L} \text{ (N/m)}$$

2. Solution:

- A model is a small scale representation or replica of a structure, machine or system used for study.
- A prototype is a full scale version of a structure, machine etc.

3. Solution:

The objective of determining the fineness modulus is to grade the aggregate properly for the required strength and workability with minimum cement consumption. Fineness modulus represents average size of particles in an aggregate sample.

4. Solution:

Weathering is the bevelled top surface provided to drain rainwater, while throating is the groove formed on the underside of a projection to prevent water from creeping along the wall surface.

5. Solution:

Coefficient of discharge is defined as the ratio of the actual discharge to the theoretical discharge of flow. Thus,

$$C_d = \frac{Q_{\text{Actual}}}{Q_{\text{Theoretical}}}$$

6. Solution:

Slaking of lime is the process in which quick lime (CaO) is sprinkled with water thereby causing an exothermic reaction that converts quick lime into slaked lime or calcium hydroxide [$Ca(OH)_2$].

$$CaO + H_2O \rightarrow Ca(OH)_2 + 15.6 \text{ kCal}$$

7. Solution:

Given, Stream function, $\psi = 2xy$

$$u = \frac{\partial \psi}{\partial y} = 2x$$

$$v = -\frac{\partial \psi}{\partial x} = -2y$$

At (1, 2),

$$u = 2 \times 1 = 2 \text{ unit}$$

$$v = -2 \times 2 = -4 \text{ unit}$$

$$\therefore \quad V = \sqrt{u^2 + v^2} = \sqrt{(2)^2 + (-4)^2}$$

$$\Rightarrow \quad V = 4.47 \text{ unit}$$

8. Solution:

A mitred closer is a brick whose one end is cut or splayed at an angle so that it forms a mitre across the full width, used to maintain proper bonding at corners.

9. Solution:

A Mansard truss consists of two pitches - an upper steep pitch (about 70°) and a lower flatter pitch (about 30°). It resembles a combination of king-post and queen-post trusses and provides additional attic space, though it is now rarely used due to its complicated shape.

10. Solution:

- **Metacentre:** The metacentre may be defined as the point at which the line of action of the force of buoyancy will meet the normal axis of the body when the body is given a small angular displacement.
- **Metacentric Height:** The distance between the centre of gravity of a floating body and the metacentre is called as metacentric height.

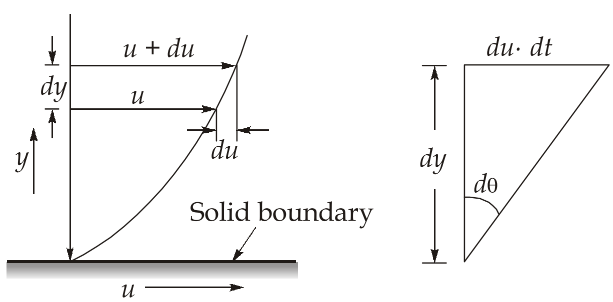
11. Solution:

Newton's Law of Viscosity: This law states that shear stress (τ) acting on a fluid element layer is directly proportional to the rate of shear strain i.e.

$$\tau \propto \frac{d\theta}{dt}$$

$$\Rightarrow \quad \tau = \mu\left(\frac{du}{dy}\right)$$

Derivation: Let there be two layers of fluid, at a distance dy apart, move one over the other at different velocities u and $u + du$.



Velocity profile

$$\tan(d\theta) = \frac{du dt}{dy}$$

For very small angle, $\tan(d\theta) \simeq d\theta$

Also, $$d\theta = \frac{du\, dt}{dy}$$

$$\Rightarrow \quad \frac{d\theta}{dt} = \frac{du}{dy}$$

$\Rightarrow$ Rate of shear strain = Velocity gradient

Mathematically, $$\tau \propto \frac{du}{dy} \text{ or } \tau = \mu\frac{du}{dy}$$

where, μ = Constant of proportionality and is known as coefficient of dynamic viscosity or viscosity.

$\frac{du}{dy}$ = Rate of shear deformation or velocity gradient

12. Solution:

Shakes are longitudinal separations of wood fibres occurring between or along the annual rings, commonly caused by abnormal growth, frost, or rapid drying. They may appear as heart shakes, cup shakes or star shakes depending on the pattern of separation. Shakes significantly reduce the allowable shear strength of timber and may weaken it when they lie near the neutral plane of a beam. Diagonal shakes also reduce tensile strength. Though they have minor effect on compressive strength, their presence makes timber structurally unreliable and undesirable where appearance is most important.

13. Solution:

For equipotential, $d\phi = 0$

Differentiating, $$\frac{\partial \phi}{\partial x}dx + \frac{\partial \phi}{\partial y} \times \partial y = 0$$

$$\Rightarrow \quad -udx + (-v) \times dy = 0 \qquad \left(\because \frac{\partial \phi}{\partial x} = -u \text{ and } \frac{\partial \phi}{\partial y} - v\right)$$

$$\Rightarrow \quad \frac{dy}{dx} = -\frac{u}{v} = \text{Slope of equipotential line}$$

For constant stream function, $d\psi = 0$

Differentiating, $$\frac{\partial \psi}{\partial x}dx + \frac{\partial \psi}{\partial y}dy = 0$$

$$\Rightarrow \quad -vdx + (u) \times dy = 0 \qquad \left(\because \frac{\partial \psi}{\partial x} = -v \text{ and } \frac{\partial \psi}{\partial y} = u\right)$$

$$\Rightarrow \quad \frac{dy}{dx} = \frac{v}{u} = \text{Slope of equipotential line}$$

Now, slope of streamline × slope of equipotential line

$$= \left(\frac{v}{u}\right) \times \left(-\frac{u}{v}\right) = -1$$

The product of the slope of the equipotential line and the slope of the streamline of the point of intersection is equal to – 1.

Thus the equipotential lines are orthogonal to the streamlines at all points of intersection.

14. Solution:

Given:

Diameter at inlet, $d_1 = 150$ mm

Diameter at throat, $d_2 = 75$ mm

Specific gravity of oil, $G_{oil} = 0.9$

Specific gravity of mercury, $G_{Hg} = 13.6$

Reading of differential manometer, $x = 175$ mm

Now,difference of pressure head, $h = x\left(\dfrac{G_{Hg}}{G_{oil}} - 1\right)$

$$\Rightarrow \quad h = 0.175\left(\frac{13.6}{0.9} - 1\right) = 2.4694 \text{ m}$$

$$\because \quad d_1 = 2d_2$$

$$\therefore \quad A_1 = 4A_2$$

Now, discharge through verturimeter is given by,

$$Q = C_d \frac{A_1 A_2}{\sqrt{A_1^2 - A_2^2}}\sqrt{2gh}$$

$$\Rightarrow \quad Q = C_d \times \frac{4A_2 A_2}{\sqrt{16A_2^2 - A_2^2}}\sqrt{2gh}$$

$$\Rightarrow \quad Q = C_d \times \frac{4}{\sqrt{15}} A_2 \sqrt{2gh}$$

$$\Rightarrow \quad Q = 0.97 \times \frac{4}{\sqrt{15}} \times \frac{\pi}{4}(0.075)^2 \sqrt{2 \times 9.81 \times 2.4694}$$

$$\Rightarrow \quad Q = 0.030807 \text{ m}^3/\text{sec}$$

$$\Rightarrow \quad Q = 30.81 \ lt/\text{sec}$$

15. Solution:

We know,

$$\text{Gel space ratio} = \frac{0.657C\alpha}{0.319C\alpha + W}$$

and, Theoretical strength $= 240x^3$

Here,

Volume of mixing water, $W = 480 \times 0.45 = 216$ ml

Now, for 100% hydration,

$$\text{Gel space ratio, } x_1 = \frac{0.657 \times 480 \times 1}{0.319 \times 480 \times 1 + 216} = 0.854$$

Theoretical strength of concrete,

$$S_1 = 240 \times (0.854)^3 = 149.48 \text{ N/mm}^2$$

Now, for 70% hydration,

$$\text{Gel space ratio, } x_2 = \frac{0.657 \times 480 \times 0.70}{0.319 \times 480 \times 0.70 + 216} = 0.683$$

Theoretical strength of concrete,

$$S_2 = 240 \times (0.683)^3 = 76.47 \text{ N/mm}^2$$

16. Solution:

Advantages of non-destructive testing (NDT) over conventional destructive testing methods are:

1. NDT is performed directly on the structure, so representative samples are not required as in destructive testing.
2. The member remains intact, allowing repeated testing at the same location without weakening the element.
3. Variations in concrete quality due to curing, ageing, weathering or chemical attack can be studied over time.
4. NDT enables examination of uniformity and detection of weak zones across extended portions of the structure.
5. Unlike destructive testing, NDT does not require casting or extracting specimens, making it economical and suitable for testing the existing structures.

17. Solution:

Specific energy:

The total energy of a channel flow with respect to a datum is given by,

$$H = Z + y\cos\theta + \alpha(v^2/2g)$$

If the datum coincides with the channel bed at a section, then the resulting expression is known as specific energy and is denoted by E. Thus

$$E = y\cos\theta + \alpha(v^2/2g)$$

When, $\cos\theta = 1$ and $\alpha = 1$

$$E = y + \left(\frac{v^2}{2g}\right)$$

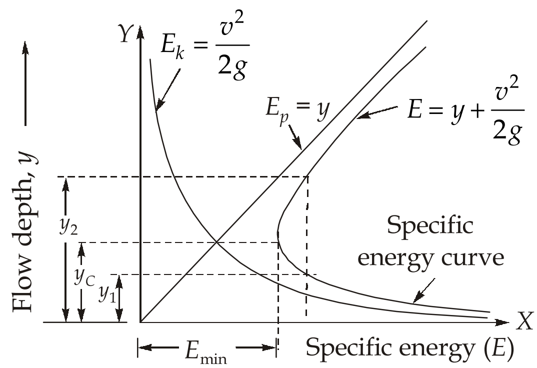
Specific energy curve: It is defined as the curve which shows the variation of specific energy with depth of flow.

The specific energy of a flowing liquid is,

$$E = y + \frac{v^2}{2g} = E_p + E_k$$

where, E_p = Potential energy of flow = y

and E_k = Kinetic energy of flow = $\frac{v^2}{2g}$



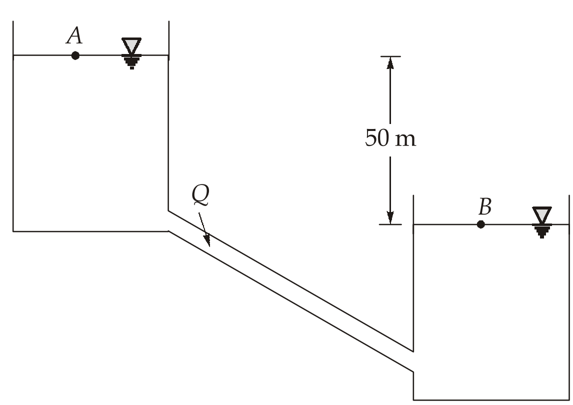
Specific energy diagram

18. Solution:

Shoring provides temporary support to unsafe or weakened walls. The main types are:

1. **Raking shores:** These are inclined members supporting dangerous or bulging walls.
2. **Flying shores:** These are horizontal struts used when two parallel walls need support without obstructing the space between.
3. **Dead shores:** These are vertical props used when the lower portion of a wall is removed for openings or reconstruction.

19. Solution:



Diameter, d = 0.25 m

Length, $L = 5000$ m,

$f = 0.00645$

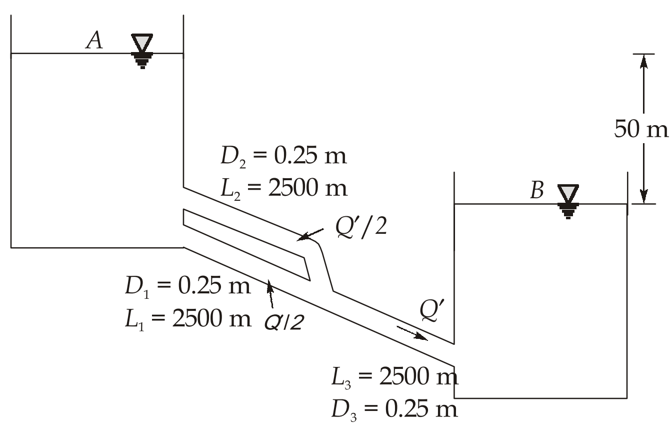
Apply Bernoulli's equation between (A) and (B),

$$\frac{P_A}{\rho g}+\frac{V_A^2}{\rho g}+Z_A = \frac{P_B}{\rho g}+\frac{V_B^2}{\rho g}+Z_B+h_f \qquad (\because P_A = P_B = 0;\ V_A = V_B = 0)$$

$$\Rightarrow \quad Z_A - Z_B = h_f = \frac{8Q^2}{\pi^2 g}\cdot\frac{fL}{D^5}$$

$$\Rightarrow \quad 50 = \frac{8\times Q^2}{\pi^2 g}\left[\frac{0.00645\times 5000}{(0.25)^5}\right]$$

$$\Rightarrow \quad Q = 0.13537 \text{ m}^3/\text{sec.} = 135.37 \text{ lps}$$



Apply Bernoulli's equation between (A) and (B),

$$\frac{P_A}{\rho g}+\frac{V_A^2}{2g}+Z_A = \frac{P_B}{\rho g}+\frac{V_B^2}{2g}+Z_B+h_f$$

$$\Rightarrow \quad 50 = \frac{8(Q'/2)^2}{\pi^2 g}\times\frac{f\cdot L_1}{D_1^5}+\frac{8\times[Q']^2}{\pi^2 g}\cdot\frac{fL_3}{D^5}$$

$$\Rightarrow \quad 50 = \frac{8(Q')^2}{\pi^2 g}\times\frac{f\cdot L}{D^5}\left[\frac{1}{4}\times\frac{1}{2}+\frac{1}{2}\right]$$

$$\Rightarrow \quad 50 = \frac{8(Q')^2}{\pi^2\times 9.81}\times\frac{0.00645\times 5000}{(0.25)^5}\left(\frac{5}{8}\right)$$

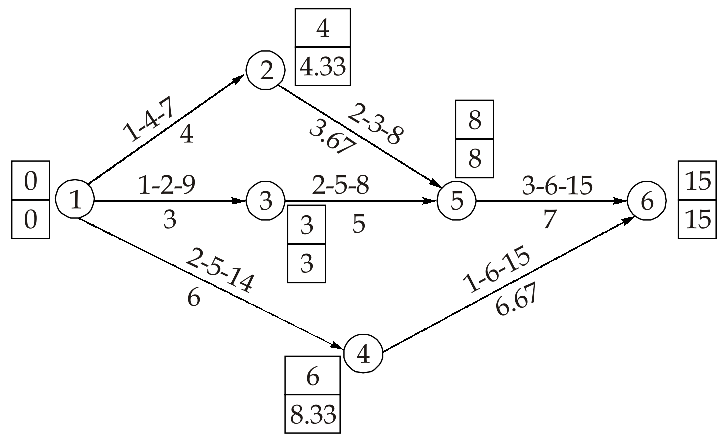
$$\Rightarrow \quad Q' = 0.17123 \text{ m}^3/\text{sec}$$

$$\Rightarrow \quad Q' = 171.23 \text{ lps}$$

$\therefore$Increase in discharge, $\Delta Q = Q' - Q$

$= 171.23 - 135.37 = 35.86$ lps

20. Solution:



Activity	Optimistic time (t_o) (weeks)	Most likely time (t_m) (weeks)	Pessimistic time (t_p) (weeks)	Expected duration (t_e) (weeks)	Standard deviation (σ_{ij}) (weeks) $\left(\frac{t_p - t_o}{6}\right)$	Variance (V_{ij}) (weeks^2)
1 - 2	1	4	7	4	1	1
1 - 3	1	2	9	3	1.33	1.77
1 - 4	2	5	14	6	2	4
2 - 5	2	3	8	3.67	1	1
3 - 5	2	5	8	5	1	1
4 - 6	1	6	15	6.67	2.33	5.43
5 - 6	3	6	15	7	2	4

$$\text{Expected duration, } t_e = \frac{t_o + 4t_m + t_p}{6}$$

$$\text{Standard deviation, } \sigma_{ij} = \frac{t_p - t_o}{6}$$

$$\text{Variance, } V_{ij} = (\sigma_{ij})^2$$

Critical path for this project is 1 - 3 - 5 - 6

Critical duration is 15 weeks

$$\text{Variance of the project} = \text{Sum of variances of critical activities}$$

$$\Rightarrow \quad V_t = 1.77 + 1 + 4 = 6.77 \text{ weeks}^2$$

Standard deviation of the project = $\sqrt{V_t} = \sqrt{6.77} = 2.602$ weeks

For completion of project in expected in expected duration i.e. $T_s = T_E$,

$$Z = \frac{T_S - T_E}{\sigma_t} = 0$$

For $Z = 0$, the probability is 50% for any given project.

For 95% probability of completion,

$$Z = \frac{T_S - T_E}{\sigma_t}$$

$$\Rightarrow \quad 1.64 = \frac{T_S - 15}{2.602}$$

$$\Rightarrow \quad T_S = 19.27 \text{ weeks}$$

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