RPSC AEn-2024 Main Test Series

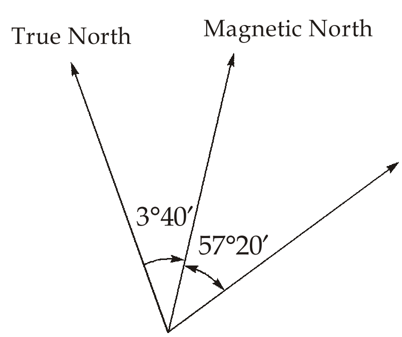
CIVIL ENGINEERING — Test 16

Test Mode : • Offline • Online

Subjects : Full Syllabus Test (Paper-II)

DETAILED EXPLANATIONS

1. Solution:



$$\text{True bearing} = \text{Magnetic bearing} + \text{Magnetic declination (East)}$$

$$\Rightarrow \quad T_B = 57°20' + 3°\,40' = 61°$$

2. Solution:

Biochemical Oxygen Demand is the oxygen required by microorganisms to decompose organic matter in water. It indicates the strength of sewage and degree of pollution.

3. Solution:

Viscosity is the property of a fluid that offers resistance to shear deformation or flow.

4. Solution:

Kor period is the initial critical period of crop growth during which the first irrigation must be supplied to ensure proper establishment and yield.

5. Solution:

A retarding reservoir temporarily stores flood water and releases it gradually through ungated spillways, reducing peak flood discharge and protecting downstream areas.

6. Solution:

Pressure head is the height of a fluid column equivalent to the pressure at a point.

7. Solution:

Space headway,

$$S = 0.278\ Vt + \frac{V^2}{254\ f} + L$$

$$= 0.278 \times 65 \times 2.5 + \frac{(65)^2}{254 \times 0.4} + 5$$

$$= 91.8 \text{ m}$$

Capacity,

$$C = \frac{1000\ V}{S} = \frac{1000 \times 65}{91.8}$$

$$= 708.06 \text{ veh/hr/lane}$$

8. Solution:

Specific energy is the total energy per unit weight of water measured with respect to the channel bed.

9. Solution:

Time of concentration is the time required for runoff to travel from the most distant point of a catchment to the outlet.

10. Solution:

Different types of Survey based on the desired accuracy are:

1. Plane Survey
2. Geodetic Survey

11. Solution:

Flaky aggregates are particles whose least lateral dimension is less than 0.6 times the mean sieve size.

12. Solution:

A reverse curve is a combination of two simple circular curves having opposite directions, joining at a common tangent point.

13. Solution:

Heart shake is a defect in timber caused by shrinkage of heartwood, producing cracks that originate at the pith and extend outward, and are wider at the centre.

14. Solution:

An equivalent pipe is a single pipe that replaces a compound pipeline having the same discharge or head loss.

15. Solution:

Toothing is a method of terminating a wall by leaving alternate projecting bricks in successive courses to ensure proper bonding when the wall is extended later.

16. Solution:

Flash point is the minimum temperature at which bitumen vapours ignite momentarily with a flame.

17. Solution:

Ruling gradient is the maximum desirable slope provided on roads under normal conditions.

18. Solution:

$$\text{BOD}_3\,(27°\text{C}) = \left(DO_i - DO_f\right) \times \left(\frac{V_1 + V_2}{V_1}\right) = 10\ \text{mg}/l \times 50$$

$$= 500\ \text{mg}/l$$

$$\therefore \quad \text{BOD}_3\,(27°\text{C}) = L_o(1 - e^{-kt})$$

$$\Rightarrow \quad 500 = L_o\,(1 - e^{-0.23 \times 3})$$

$$\Rightarrow \quad L_o = 1003\ \text{mg}/l$$

19. Solution:

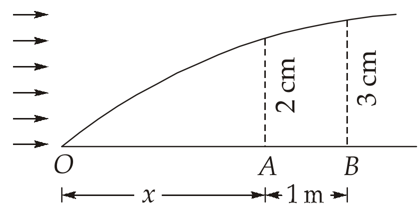
Break-point chlorination is the stage at which chlorine demand is satisfied and further chlorine addition produces free residual chlorine in water.

20. Solution:

A causeway is a submersible bridge having no span for passing water below it. It allows flood water to pass over it.

21. Solution:

Thickness (δ) of laminar boundary layer at a distance 'x' from theleading edge is given by



$$\delta = \frac{5x}{\sqrt{\text{Re}_x}}$$

$$\Rightarrow \quad \delta_A \propto \sqrt{x} \qquad \left[\because \text{Re}_x = \frac{\rho V x}{\mu}\right]$$

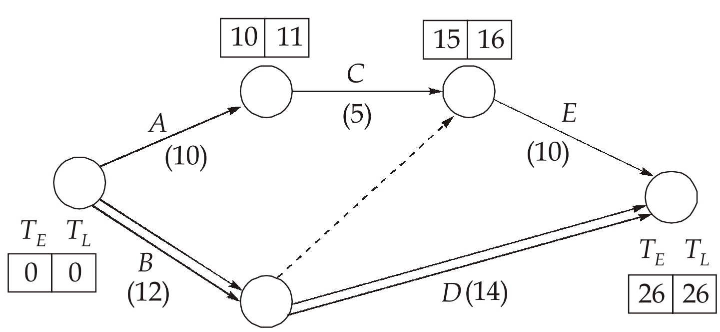
$$\therefore \quad \delta_A \propto \sqrt{x}\,; \qquad \delta_B \propto \sqrt{x+1}$$

$$\frac{\delta_A}{\delta_B} = \sqrt{\frac{x}{x+1}}$$

$$\sqrt{\frac{x}{x+1}} = \frac{2}{3}; \qquad \frac{x}{x+1} = \frac{4}{9}$$

$$9x = 4x + 4; \quad x = 0.8 \text{ m}$$

22. Solution:



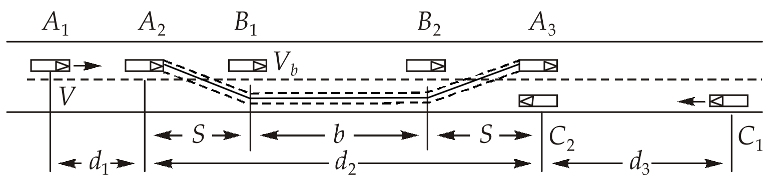
Total float for activity E is given by

$$F_T = T_L^j - T_E^i - t^{ij}$$
$$= 26 - 15 - 10 = 1 \text{ day}$$

Alternatively,

$$F_T = \text{LST} - \text{EST}$$
$$= 16 - 15 = 1 \text{ day}$$
$$F_T = \text{LFT} - \text{EFT}$$
$$= 26 - 25 = 1 \text{ day}$$

23. Solution:



Overtaking Manoeuvre

Overtaking Sight Distance (OSD)

$$= d_1 + d_2 + d_3$$

$$V_b = (V - 16) = (100 - 16) = 84 \text{ km/hr}$$

$$d_1 = 0.278\, V_b t \qquad (\because t = 2 \text{ sec for OSD})$$

$$= 0.278 \times 84 \times 2 = 46.704 \text{ m}$$

$$d_2 = 0.278 V_b T + \frac{1}{2} a T^2 = 0.278 V_b T + 2S$$

and $$T = \sqrt{\frac{4S}{a}}$$

also, $$S = 0.2\, V_b + 6$$

$$= 0.2 \times 84 + 6 = 22.8 \text{ m}$$

$\Rightarrow$ $$T = \sqrt{\frac{4 \times 22.8}{0.53}} = 13.118 \text{ sec}$$

$\therefore$ $$d_2 = (0.278 \times 84 \times 13.118) + \frac{1}{2} \times 0.53 \times (13.118)^2$$

$$= 306.331 + 45.60 = 351.931 \text{ m}$$

$$d_3 = 0.278\, V_c T$$

$$= 0.278 \times 100 \times 13.118 = 364.68 \text{ m}$$

$\therefore$ $$\text{OSD} = d_1 + d_2 + d_3$$

$$= 46.704 + 351.931 + 364.68$$

$$= 763.315 \text{ m}$$

24. Solution:

1. Parking Demand: Estimated by counting parked vehicles, recording duration and accumulation during peak hours.
2. Parking Characteristics: Study of existing parking practices, problems faced, parking pattern and interference to traffic flow.
3. Parking Space Study: Survey of area to assess on-street and off-street facilities and plan adequate parking provision.

25. Solution:

1. Arithmetic Mean Method: It is the simple average of rainfall recorded at all gauge stations. It is suitable when rainfall is uniformly distributed and stations are evenly spaced.
2. Thiessen Polygon Method: Each gauge is assigned a weight based on its area of influence. It is suitable when stations are unevenly distributed.
3. Isohyetal Method: Rainfall contours are drawn and the weighted average is calculated. It is the most accurate method as it considers spatial variation.

26. Solution:

Hydraulic jump is a phenomenon in which supercritical flow suddenly changes to subcritical flow, causing a rapid rise in water surface. It is accompanied by intense turbulence and energy dissipation.

Main characteristics are:

1. Sudden increase in depth
2. Significant loss of energy
3. Formation of rollers and eddies

27. Solution:

Standard rate trickling filters (because of their low hydraulic loading rate) face the following operational problems:

1. Fly nuisance: Larvae of insects act as food for flies. As the filter medium is open to atmosphere, insects grow over the surface of the filter.
2. Odour problem: Due to anaerobic decomposition of wastewater during intermittent flow.
3. Ponding problem: Due to choking of the voids as sloughing does not take place because of low HLR.

28. Solution:

Vehicle, also called binder, is the liquid constituent of paint in which the base and pigments are mixed. It holds the particles in suspension, spreads paint over the surface and forms a continuous film on drying. It imparts durability, toughness, gloss and water resistance to the paint coating.

29. Solution:

Average error for the first 1500 m,

$$e = \frac{0+12}{2} = 6 \text{ cm} = 0.06 \text{ m}$$

True length, $$l_1 = \frac{i}{L} \times l$$

$$l_1 = \frac{30+0.06}{30} \times 1500 = 1503 \text{ m}$$

Average error for the next 2100 m,

$$e = \frac{12+21}{2} = 16.5 \text{ cm} = 0.165 \text{ m}$$

True length, $$l_2 = \frac{30+0.165}{30} \times 2100 = 2111.55 \text{ m}$$

True distance,

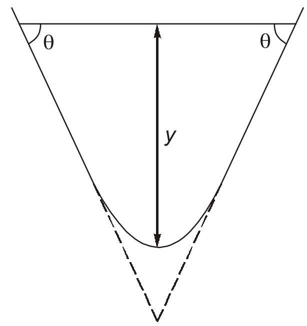
$$l_1 + l_2 = 1503 + 2111.55 = 3614.55 \text{ m}$$

30. Solution:

GI sheets	AC sheets
Sheets are thin	Not as thin as GI sheets
Lightweight	Slightly heavier
Unbreakable and easy handling	Chances of breaking cannot be ruled out
Chances of corrosion cannot be ruled out	No problem of corrosion
More noisy, if something falls over them	Less noisy
Low fire-resistance	Good fire resistance
Low resistance to acid	More resistance to acid
High initial cost	Less initial cost

31. Solution:

$$A = y^2(\theta + \cot\theta) \quad [\theta = 45°]$$
$$P = 2y(\theta + \cot\theta)$$



$$A = y^2\left(\frac{\pi}{4}+1\right)$$
$$P = 2y\left(\frac{\pi}{4}+1\right)$$
$$R = \frac{A}{P} = \frac{y}{2}$$

From Manning's equation

$$Q = \frac{1}{n} A R^{2/3} S^{1/2}$$
$$25 = \frac{1}{0.018}\times y^2\left(\frac{\pi}{4}+1\right)\left(\frac{y}{2}\right)^{2/3}\left(\frac{1}{6000}\right)^{1/2}$$
$$y^{8/3} = 30.99$$
$$y = 3.62 \text{ m}$$

32. Solution:

1. Design sufficient length of impervious floor to reduce exit gradient.
2. Provide sheet piles on upstream and downstream sides.
3. Ensure adequate floor thickness to counter uplift pressure.
4. Provide energy dissipators and concrete blocks downstream.
5. Provide loose talus or filter to prevent washing of soil.

33. Solution:

We know that boundary conditions which must be satisfied by any velocity profile whether it is in laminar layer zone, or in turbulent boundary layer zone are:

(i) At $y = 0$, $u = 0$

(ii) At $y = \delta$, $u = U$

(iii) At $y = \delta$, $\frac{du}{dy} = 0$

Given: $$\frac{u}{U} = a + b\left(\frac{y}{\delta}\right) + c\left(\frac{y}{\delta}\right)^2$$

From (i) $$u = 0 \text{ at } y = 0$$

∴ $$0 = a + 0 + 0$$

⇒ $$a = 0$$

∴ $$\frac{u}{U} = b\left(\frac{y}{\delta}\right) + c\left(\frac{y}{\delta}\right)^2$$

From (ii) $$u = U \text{ at } y = \delta$$

∴ $$\frac{U}{U} = b\left(\frac{\delta}{\delta}\right) + c\left(\frac{\delta}{\delta}\right)^2$$

⇒ $$1 = b + c$$

or $$b + c = 1$$

...(iv)

From (iii) $$\frac{du}{dy} = 0 \text{ at } y = \delta$$

Now, $$u = U\left[b\left(\frac{y}{\delta}\right) + c\left(\frac{y}{\delta}\right)^2\right]$$

∴ $$\frac{du}{dy} = U\left[b\left(\frac{1}{\delta}\right) + \frac{c}{\delta^2}2y\right]$$

∴ $$0 = U\left[\frac{b}{\delta} + \frac{c}{\delta^2}2\delta\right]$$

[∵ U is constant]

⇒ $$\frac{b}{\delta} + \frac{2c}{\delta} = 0$$

⇒ $$b + 2c = 0$$

...(v)

Solving eq. (iv) and (v) we get

$$b = 2$$

$$c = -1$$

$$\therefore \quad \frac{u}{U} = 2\left(\frac{y}{\delta}\right) - \left(\frac{y}{\delta}\right)^2$$

The shear stress, on the plate is given by Newton's law of viscosity as

$$\tau_0 = \mu\left(\frac{du}{dy}\right)_{y=0}$$

$$u = U\left[\frac{2y}{\delta} - \frac{y^2}{\delta^2}\right]$$

$$\left(\frac{du}{dy}\right)_{y=0} = U\left[\frac{2}{\delta} - \frac{2\times(0)}{\delta^2}\right] = \frac{2U}{\delta}$$

$$\therefore \quad \tau_0 = \mu \times \frac{2U}{\delta} = \frac{2\mu U}{\delta}$$

...(vi)

Given $\tau_0 = k\frac{\mu U}{\delta}$

...(vii)

Comparing (vi) and (vii), $k = 2$

34. Solution:

Sum of internal angles = ∠A + ∠B + ∠C + ∠D
= 92°38′ + 104°33′ + 92°38′ + 104°33′
= 360°04′

Error = 360°04′ – 360° = 0°04′

Correction = –0°04′

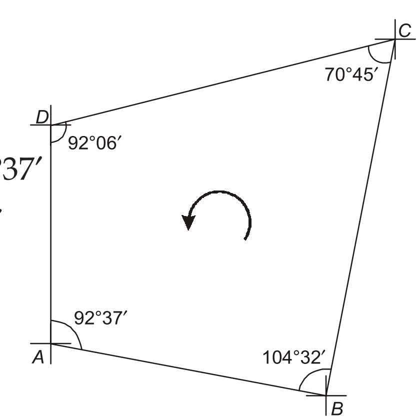
Correction per angle = $\frac{-0°04'}{4} = -0.01'$

∴ Correct interior angles, ∠A = 92°38′ – 0°01′ = 92°37′

∠B = 104°33′ – 0°01′ = 104°32′

∠C = 70°46′ – 0°01′ = 70°45′

∠D = 92°07′ – 0°01′ = 92°06′



FB of AB = 92°37′

FB of BC = 104°32′ + 2°37′ – 90° = 17°09′

FB of CD = 17°09′ + 70°45′ – 180° = 267°54′

FB of DA = 180°

Line	Length (L′) (in m)	Fore bearing	Latitude (L)	Correction	Corrected latitude	Departure (D)	Correction	Correction departure
AB	27.15	92°37′	−1.239	−0.054	−1.293	27.1216	−0.09218	27.029
BC	52.16	17°09′	49.84	−0.104	49.736	15.3806	−0.17709	15.203
CD	41.96	267°54′	−1.537	−0.083	−1.62	−41.9318	−0.14246	−42.074
DA	46.73	180°	−46.73	−0.093	−46.823	0	−0.15865	−0.15865
	$\sum L' = 168$ m		$\sum L = 0.334$	$\sum C = 0.334$		$\sum D = 0.5704$	$\sum C' = -0.5704$	

$$e_x = \sum D = 0.5704$$

$$e_y = \sum L = 0.334$$

$$\text{Closing error} = \sqrt{(0.5704)^2 + (0.334)^2} = 0.661$$

$$\theta = \tan^{-1}\left(\left|\frac{e_x}{e_y}\right|\right) = 59.65°$$

35. Solution:

$$N_1 = -\frac{1}{50}$$

$$N_2 = -\frac{1}{20}$$

As $N_1 < N_2$

So, curve required wil be a summit curve.

Deviation angle, $N = N_1 - N_2$

$$= -\frac{1}{50} - \left(-\frac{1}{20}\right) = \frac{3}{100}$$

Design speed (v) = 80 kmph = 22.22 m/s

(I) Stopping sight distance (SSD) calculation:

$$\text{SSD} = vt + \frac{v^2}{2gfb}, \quad \text{[Consider brake efficiency } b = 100\%]$$

Coefficient of longitudinal friction, $f = 0.35$

Assume reaction time = 2.5 seconds

$$\therefore \quad \text{SSD} = 22.22 \times 2.5 + \frac{(22.22)^2}{2 \times 9.81 \times 0.35} = 127.448 \text{ m}$$

(II) Overtaking sight distance (OSD) calculation:

Since speed of overtaken vehicle V_b is not given,

$$\therefore \quad V_b = (V - 4.5) \text{ m/s} = 17.72 \text{ m/s}$$

OSD for two lane, two-way highway = $d_1 + d_2$

$$d_1 = V_b \times t_r$$

[Assume, reaction time of driver, t_r = 2 sec]

$\therefore$ $d_1 = 17.72 \times 2 = 35.44$ m

$d_2 = b + 2s,$

where $S = 0.7V_b + 6$

$\therefore$ $S = 0.7 \times 17.72 + 6 = 18.404$ m

Also, $b = V_b \times T$, where $T = \sqrt{\dfrac{4S}{a}}$

$a = 3.6$ km/hr/sec (given)

$$\therefore \quad T = \sqrt{\frac{4 \times 18.404}{3.6 \times \frac{5}{18}}} = 8.5799 \text{ sec}$$

$\therefore$ $b = 17.72 \times 8.5799 = 152.037$ m

$\therefore$ $d_2 = b + 2s = 152.037 + 2 \times 18.404 = 188.845$ m

$d_3 = vT = 22.22 \times 8.5799 = 190.645$ mm

Hence, OSD $= d_1 + d_2 + d_3$

$= 35.44 + 188.845 + 190.645$

$= 414.93 \text{ m} \simeq 415$ m

Case 1 : Assume (L_C > SSD)

$$L_C = \frac{NS^2}{4.4} = \frac{\left(\frac{3}{100}\right) \times 127.448^2}{4.4}$$

$= 110.747 \text{ m} < 127.448$ m

Hence, our assumption is wrong.

$\therefore$ L_C < SSD

$$L_C = 2S - \frac{4.4}{N} = 2 \times 127.448 - \frac{4.4}{\left(\frac{3}{100}\right)}$$

Length of summit curve based on SSD;

$L_C = 108.23$ m

Case 2 : Assume, (L_C > OSD)

$$L_C = \frac{NS^2}{9.6} = \frac{\left(\frac{3}{100}\right) \times 415^2}{9.6} = 538.20 \text{ m}$$

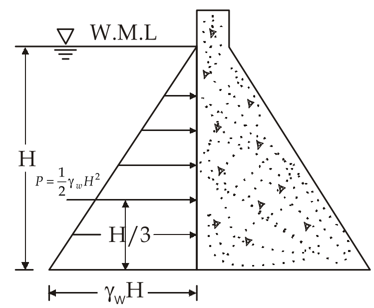
Hence, our assumption is correct.

Length of summit curve based on OSD = 538.20 m

36. Solution:

Forces Acting on Gravity Dam

(i) Water Pressure



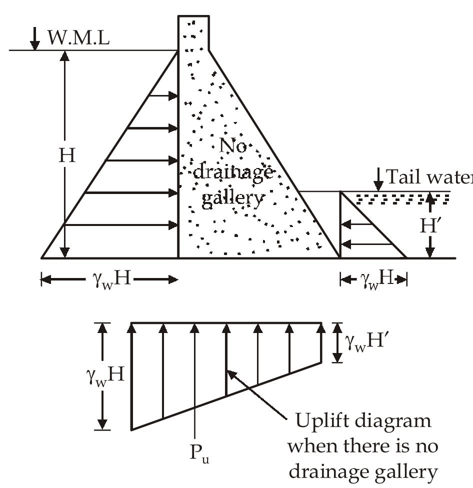
$$P = \frac{1}{2}\gamma_w H^2$$

Acting at $\frac{H}{3}$ from base

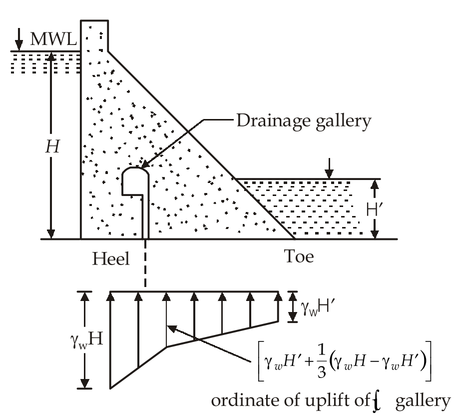
where γ_w = Unit weight of water.

(ii) Uplift Pressure

(a) When Drainage Gallery is not Provided



(b) When Drainage Gallery is Provided



(iii) Earthquake Force

$$\alpha_H = 0.1\,g \text{ to } 0.2\,g$$
$$\alpha_v = 0.75\alpha_H$$
$$\alpha = \beta I \alpha_0$$

where, α_H = Horizontal acceleration, α_v = Vertical acceleration
α = Seismic coefficient, β = Soil foundation system factor
I = Importance factor
α_0 = Basic seismic coefficient which depends upon seismic zone of country.

$$F_g = \frac{w}{g}(g \pm \alpha_v)$$

where, F_g = Body force
g = Acceleration due to gravity, +ve for upward and –ve for downward.

(a) Hydrodynamic force

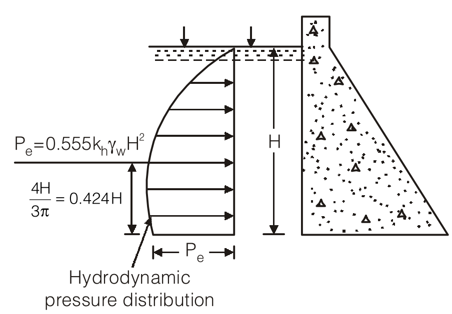
(i) $F_H = \left(\frac{w}{g}\right)\alpha_H$ F_H = Horizontal Inertia force.

(ii) It effect of water pressure due to earthquake distribution of pressure is parabolic.

$$P_e = 0.555\,\alpha\,\gamma_w H^2$$

at 0.424 H from base.

$$\alpha = 0.1\text{g to } 0.2\text{g}$$



(iv) Silt Pressure

$$F_{silt} = \frac{1}{2} k_a \gamma_{sub} \cdot h_s^2$$

where, h_s = Height of silt from the base.

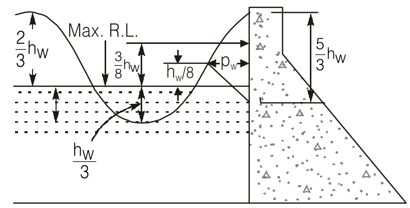
k_a = Coefficient of active earth pressure = $\frac{1-\sin\phi}{1+\sin\phi}$

γ_{sub} = Submerged unit weight.

According to U.S.B.R

$$F_{silt} = \frac{360\,h_s^2}{2}(kg\,f)$$

(v) Wave Pressure



$$P_w = 2\cdot 4\gamma_w h_w$$

Acts at $\frac{h_w}{8}$ from still water level.

where, P_w = Resultant wave pressure.

$$F_w = 2\gamma_w h_w^2 \text{ acts at } \frac{3h}{8} \text{ from still water surface.}$$

where F_w = Total wave force.

$$h_w = 0.032\sqrt{VF} + 0.763 - 0.271(F)^{3/4} \text{ if } F < 32 \text{ km.}$$

$$h_w = 0.032\sqrt{VF} \text{ when } F > 32 \text{ km.}$$

where, F = Length of reservoir in km

h_w = Height of wave in meter

V = Wind velocity in km/hr.

(vi) Self Weight of Dam

$$w = \gamma_c V$$

where, γ_c = Unit weight of concrete

V = Volume of dam body per unit length

37. Solution:

For wastewater

Discharge, $Q = 12000 \text{ m}^3/\text{day} = 0.139 \text{ m}^3/\text{s}$

$BOD_5 = 30$ mg/L

DO = 1 mg/L

Temperature, $T = 27°C$

For stream

Discharge, $Q = 0.4 \text{ m}^3/\text{s}$

$BOD_5 = 4$ mg/L

DO = 7 mg/L

Temperature = 25°C

Now, $$BOD_{mix} = \frac{0.139 \times 30 + 0.4 \times 4}{0.139 + 0.4} = 10.70 \text{ mg/L}$$

Ultimate BOD of mix, $$L_0 = \frac{BOD_{mix}}{1 - e^{-k_1 \times t}}$$

where k_1 is deoxygenation rate constant for mix

$$= \frac{10.7}{1-e^{-0.2\times5}} = 16.93 \text{ mg/L}$$

Now, $$DO_{mix} = \frac{0.139\times1+0.4\times7}{0.139+0.4}$$

$$= 5.45 \text{ mg/L}$$

$$T_{mix} = \frac{0.139\times27°+0.4\times25°}{0.139+0.4}$$

$$= 25.52°C$$

Now, $$k_{1@25.52°C} = k_{1@20°C} \times (1.047)^{T-20°}$$

$$= 0.2 \times (1.047)^{25.52° - 20°}$$

$$= 0.26 \text{ /day}$$

$$k_{2@25.52°C} = k_{2@20°C} \times (1.016)^{T-20°}$$

$$= 0.4 \times (1.016)^{25.52 - 20°}$$

$$= 0.44 \text{ /day}$$

Now, equilibrium concentration of DO after mixing = 8.3 mg/L

So, initial oxygen deficit, D_O = 8.3 – 5.45 = 2.85 mg/L

Deficit after 2 days at 25.52°C, $D_t = \frac{k_1L_0}{k_2-k_1}\left(e^{-k_1t}-e^{-k_2t}\right)+D_0e^{-k_2t}$

$$= \frac{0.26\times16.93}{0.44-0.26}\left(e^{-0.26\times2}-e^{-0.44\times2}\right)+2.85\times e^{-0.44\times2}$$

$$= 4.395 + 1.182 = 5.58 \text{ mg/L}$$

So, DO after 2 days of mixing = 8.3 – 5.58 = 2.72 mg/L

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