LIVE RPSC-AE (DLB) Full Length Test Series

Civil Engineering
Full Length Paper - 3
Answer Key & Detailed Solution

Test Id - 503 **Date:- 26/03/2023**

1. (d)
2. (a)
3. (c)
4. (d)
5. (b)
6. (c)
7. (d)
8. (c)
9. (b)
10. (c)
11. (a)
12. (c)
13. (d)
14. (a)
15. (a)
16. (c)
17. (b)
18. (b)
19. (b)
20. (a)
21. (d)
22. (d)
23. (a)
24. (b)
25. (c)
26. (d)
27. (b)
28. (c)
29. (a)
30. (a)
31. (b)
32. (a)
33. (a)
34. (b)
35. (c)
36. (d)

37. (b)

38. (a)

39. (a)

40. (a)

41. (d)

Given data

Flow rate, $Q = 35 m^3/min$

$Gt = 4 \times 10^4$

Alum dosage $= 25 mg/lit.$

Alum quantity (kg) required for 30 days

$= 35 \times 10^3 \times 60 \times 24 \times 30 \times 25 \times 10^{-6}$

$= 37,800 kg$

42. (c)

- Proportional weir and Parshall flume are velocity control devices and it is provided at the end of the Grit chamber. Grit chambers are provided in order to carry out the removal of inorganic suspended solids.
- Fluoridation of water supplies to a level of 1 mg/l is safe and effective in reducing dental cavities. However, optimum concentration of fluoride has to be controlled because excessive amount leads to fluorosis, which caused decolouration of mottling of teeth and sometimes bone damage both in children and adults.
- Among all forms of nitrogen, nitrate is not harmful because it is fully oxidized. But too much of nitrate affects infants. The reason behind this is it causes blue baby disease or methemoglobinemia. Nitrate concentrations should not be more than 45 mg/l.
- Schmutzdecke is related to Slow sand filter. In slow sand filter when water passes through the filter medium, the upper layer of the medium is coated with sticky deposits of partially decompose of organic matter along with the nutrients, which promote the growth of algae that release O_2 during photosynthesis which is further utilized by the micro-organism to carry out the decomposition of organic matter. A thin biological layer over the filter medium, where this activity takes place is referred as Schmutzdecke.
- Solid's in water can be determined using the Gravimetric technique: Total solids can be determined by heating the test sample at 104°C. Suspended solids are determined by passing the test sample through the filter and heating the residue left over the filter at 104°C. Organic solids or volatile solids both in total and suspended form can be determined by heating the test sample and residue leftover the filter at 600-650°C respectively in muffle furnace.

43. (a)

Discharge in treatment plant = $1 m^3/s$

Loading rate to filter = $120\ m^3/day/m^2 = 120/86400 = 0.00138\ m^3/s/m^2$

Combined loading rate of all filters

$$= \frac{1}{6 \times 10} = 0.01667\ m^3/s/m^2$$

No. of filter units,

$$= \frac{\text{Combined loading rate of all filter}}{\text{Loading rate of one filter}}$$

So, no of filter units $= \frac{0.01667}{0.00138} = 12$

New loading rate after 2 filters are out of service

$$= \frac{0.01667}{10} \times 86400$$

$$= 144\ m^3/day/m^2$$

44. (c)

- **Large floating matter :** Primary treatment removes material that will either float or readily settle out by gravity. It includes the physical processes of screening, comminution, grit removal, and sedimentation. Screens are made of long, closely spaced, narrow metal bars.
- **Suspended inorganic matter :** Grit Chambers are long narrow tanks that are designed to slow down the flow so that solids such as sand, coffee grounds, and eggshells will settle out of the water. Grit causes excessive wear and tear on pumps and other plant equipment. Suspended solids that pass through screens and grit chambers are removed from the sewage in sedimentation tanks.

- **Suspended organic matter :** Primary clarifiers are used to separate settleable solids from the raw incoming wastewater. These are located downstream of the plant. The major function of the primary clarifier is the removal of all settleable and suspended solids waste which has a high oxygen demand.
- **Dissolved organic matter :** Trickling filters are used to remove dissolved organic matter from wastewater. The trickling filter is an aerobic treatment system that utilizes microorganisms attached to a medium to remove organic matter from wastewater.

45. (d)

Four types of settling occur depending on the tendency of particles to interact and the concentration of solids:

1. **Discrete settling**: Discrete settling occurs when particles do not change their size, shape or mass during settling. Grit, in wastewater, behaves like a discrete particle. Settling velocity of the discrete particle is determinable using stokes or transition law.
2. **Flocculent settling**: Flocculent particles coalesce during settling increasing the mass of particles that settle faster. Flocculent settling refers to settling of flocculent particles of low concentration usually less than 1000 mg/L. The overflow rates to achieve a given removal efficiency are determined using **settling column analysis**. e.g. Removal of raw sewage organic suspended solids in PST, settling of chemical flocs in settling tank and bio floc in the upper portion of SST are examples of flocculent settling.
3. **Hindered or zone settling**:- When the concentration of flocculated particles is in the intermediate range, they are close enough together so that their velocity fields overlap causing hindered settling. The settling of particles results in a significant upward displacement of water. Particles maintain their relative positions with respect to each other and the whole mass of particles settles as a unit or zone.
4. **Compression settling**:- In the compression zone, the concentration of particles becomes so high that particles are in physical contact with each other, the lower layers supporting the weight of the upper layers. Consequently any further settling results due to compression of the whole structure of particles and is accompanied by squeezing out of the water from the pores between solid particles. This settling phenomenon occurs at the bottom of deep sludge mass such as in the bottom of SST following TF, ASP and in tanks used for thickening of sludge.

46. (b)

- HOCl, OCl^- and Cl_2 are combined called freely available chlorine.
- Out of these forms of freely available chlorine, HOCl is most destructive. It is 80% more effective than OCl^- ion.
- Hence, pH of water should be maintained slightly below 7 to ensure HOCl is formed.

47. (d)

We know,

$$V_1(1 - P_1) = V_2(1 - P_2)$$

For sample A,

$$V_1(1 - 0.97) = V_2(1 - 0.95)$$

$$V_2 = \frac{0.03}{0.05} V_1 = 0.6V_1$$

$$\text{Decrease in volume} = \frac{V_1 - V_2}{V_1} \times 100$$

$$= \frac{V_1 - 0.6V_1}{V_1} \times 100 = 40\%$$

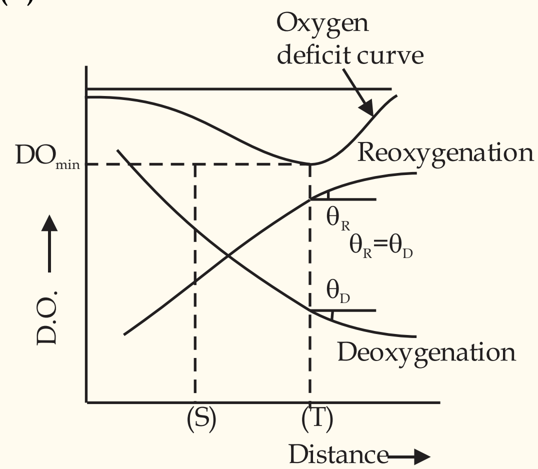
For sample B,

$$V_1(1 - 0.98) = V_2(1 - 0.96)$$

$$V_2 = \frac{0.02}{0.04} V_1 = 0.5V_1$$

$$\text{Decrease in volume} = \frac{V_1 - 0.5V_1}{V_1} \times 100 = 50\%$$

48. (d)



- Before point T, rate of aeration < rate of degradation, so DO continuously decrease from S till T.
- At point T, rate of aeration = rate of degradation. Hence DO is minimum at T.
- After point T, rate of aeration > rate of degration, so DO starts increasing.

Hence, DO is minimum at some point downstream of S.

49. **(a)**

Bacteria in the slime under flowing sewage convert sulphate in the sewage into sulphides. Sulphides in the liquid make their way to the surface of the sewage and reduced into the sewer atmosphere or Hydrogen Sulphide (H_2S) gas. Bacterial action converts atmospheric H_2S gas to Sulphuric acid which causes corrosion in the crown of the pipe and this corrosion is called crown corrosion.

50. (b)

Rectangular Bar

Given,

Area of bar = A

Length of bar = L

Poisson's ratio $= \mu = \dfrac{1}{m}$

Modulus of elasticity = E

As we know that -

Volumetric strain i.e. $\varepsilon_v = \dfrac{\sigma_x + \sigma_y + \sigma_z}{E}(1-2\mu)$

Where,

$$\mu = \frac{1}{m}$$

$$\sigma_y = \sigma_z = 0$$

$$\sigma_x = \frac{P}{A}$$

$$\therefore \quad \varepsilon_v = \frac{P}{AE}\left(1 - \frac{2}{m}\right)$$

51. (a)

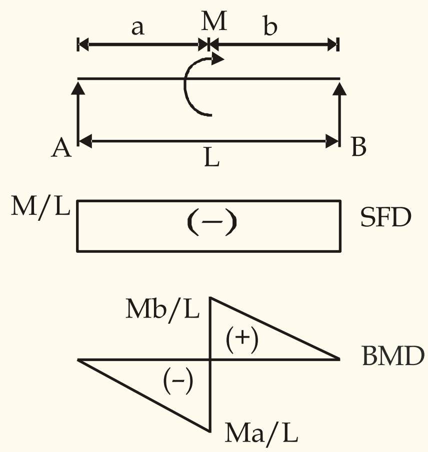
$$E = \frac{\sigma}{\varepsilon}$$

For perfectly rigid material, strain $(\varepsilon) = 0$

$\therefore \quad E \to \infty$

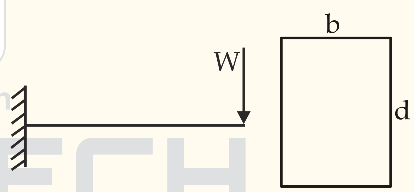
52. (c)

For moment applied at any point between the supports in simply supported beam the reaction generated at supports are opposite and equal to M/L.



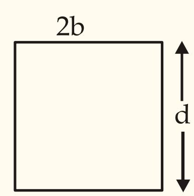
53. (d)

Case–I



$$\delta_{1\,max} = \frac{WL^3}{3EI} = \frac{WL^3}{3E\left(\dfrac{bd^3}{12}\right)}$$

Case–II



$$\delta_{2\,max} = \frac{WL^3}{3E\left(\dfrac{(2b)d^3}{12}\right)} = \frac{\delta_{1\,max}}{2}$$

54. (d)

Strain energy stored is equal to work done to rotate shaft by θ angle.

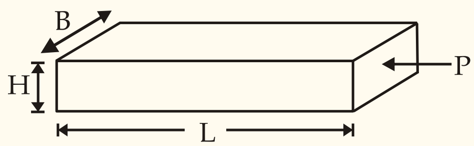
Strain energy (U) = Work done (W) to rotate shaft by θ angle

$$\text{Strain energy (U)} = \frac{1}{2}\times T\times\theta$$

$$= \frac{1}{2}\times T\times\frac{TL}{GJ}$$

$$= \frac{T^2L}{2GJ}$$

55. (d)



Initial volume i.e. V is

$V = LBH$

∵ Applied load is compressible so length will decrease

So, final volume i.e. V_f is

$$V_f = (L-\Delta L)(B+\Delta B)(H+\Delta H)$$

$$\because \quad \frac{\Delta L}{L} = \varepsilon,\ \frac{\Delta H}{H} = \mu\varepsilon = \frac{\Delta B}{B}$$

$$\text{Hence, } V_f = LBH\left(1-\frac{\Delta L}{L}\right)\left(1+\frac{\Delta B}{B}\right)\left(1+\frac{\Delta H}{H}\right)$$

$$V_f = V(1-\varepsilon)(1+\mu\varepsilon)(1+\mu\varepsilon)$$

$$V_f = V(1-\varepsilon)(1+\mu\varepsilon)^2$$

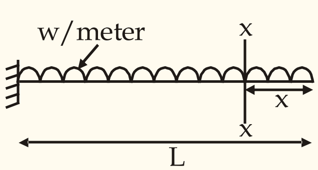
56. (a)

For any structure,

Strain energy = work done by load = Load × Displacement

Load is same for all beams. So the strain energy stored will be maximum in the beam for which sum of deflection of all the points is maximum.

(i) Strain energy in cantilever:



$$\text{S.E(U)} = \int_0^L \frac{M_x^2dx}{2EI}$$

Where, M_x is the BM at section 'x-x'

$$\text{So, } M_x = \frac{wx^2}{2}$$

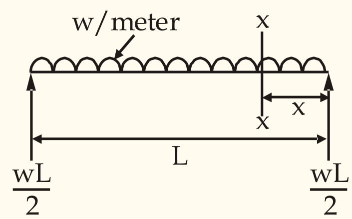
$$\text{Hence, S.E(U)} = \frac{1}{2EI}\int_0^L\left(\frac{wx^2}{2}\right)^2dx$$

$$= \frac{w^2}{8EI}\int_0^L x^4dx$$

$$= \frac{w^2}{8EI}\frac{L^5}{5}$$

$$= \frac{w^2L^5}{40EI}$$

(ii) Strain energy in simply supported beam:



$$\text{S.E(U)} = \int_0^L \frac{M_x^2dx}{2EI}$$

Where, M_x is the BM at section 'x-x'

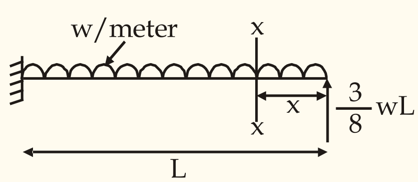
$$\text{So, } M_x = \frac{wL}{2}x-\frac{wx^2}{2}$$

$$\text{Hence, S.E(U)} = \frac{1}{2EI}\int_0^L\left[\frac{wL}{2}x-\frac{wx^2}{2}\right]^2dx$$

$$= \frac{w^2}{8EI}\int_0^L\left(Lx-x^2\right)^2dx$$

$$= \frac{w^2L^5}{240EI}$$

(iii) Strain energy in propped cantilever beam:



$$\text{S.E(U)} = \int_0^L \frac{M_x^2dx}{2EI}$$

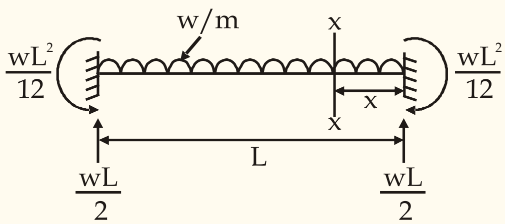
Where, M_x is the BM at section 'x-x'

So, $M_x = \frac{3}{8}wLx - \frac{wx^2}{2}$

Hence, $S.E(U) = \frac{1}{2EI}\int_0^L \left(\frac{3}{8}wLx - \frac{wx^2}{2}\right)^2 dx$

$= \frac{w^2L^5}{690\,EI}$

(iv) Strain energy in fixed beam:



$S.E(U) = \frac{1}{2EI}\int_0^L M_x^2 dx$

Where, M_x is the BM at section 'x-x'

So, $M_x = -\frac{wL^2}{12} - \frac{wx^2}{2} + \frac{wL}{2} - x$

Hence, $S.E(U) = \frac{1}{2EI}\int_0^L \left[-\frac{wL^2}{12} - \frac{wx^2}{2} + \frac{wL}{2} - x\right]^2 dx$

$= \frac{W^2L^5}{1440EI}$

Thus cantilever beam will contain maximum strain energy for same load.

57. (d)

Concept:-

According to the principle of superposition

For a linearly elastic structure, the load effects caused by two or more loadings are the sum of the load effects caused by each loading separately.

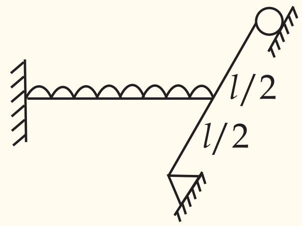
Note that the principle is limited to:

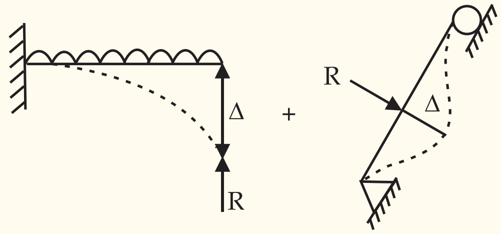
- Linear material behaviour only.
- Structures undergoing small deformations only (linear geometry)

It is not applicable when:

1. The material does not obey Hooke's law.
2. The effect of temperature changes are taken into consideration.
3. The structure is being analysed for the effect of support settlement.

58. (c)





$$\frac{wl^4}{8EI} - \frac{Rl^3}{3EI} = \frac{Rl^3}{48EI}$$

or, $$\frac{wl^4}{8EI} = \frac{Rl^3}{48EI} + \frac{Rl^3}{3EI}$$

or, $$\frac{wl^4}{8EI} = \frac{Rl^3}{3EI}\left(\frac{1}{16} + 1\right)$$

or, $$\frac{wl^4}{8EI} = \frac{Rl^3}{3EI} \times \frac{17}{16}$$

$\therefore \quad R = \frac{6wl}{17}$

59. (a)

Distribution factor

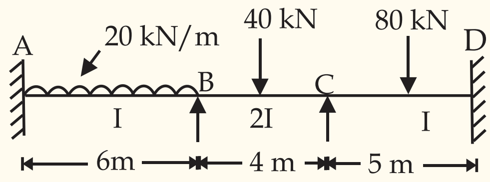
- The distribution factor at a joint for a particular member is defined as the ratio of the stiffness of that member to the total stiffness of all the members meeting at that joint.
- The summation of D.F. of all the members meeting at a joint is always one.
- D.F. is a property of rigid joint, it is not the property of hings joint.

$$\text{Distribution factor} = \frac{k_i}{\sum_{i=1}^{n} k_i}$$

Here,

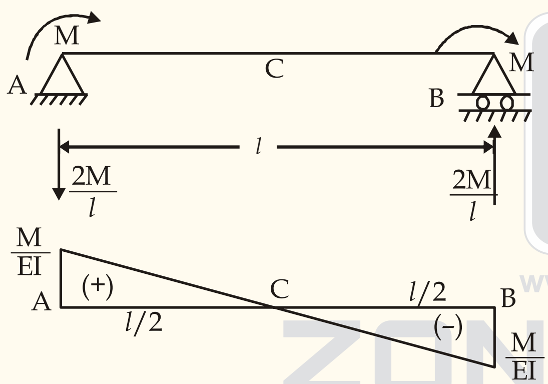
k_i = Stiffness of i[th] member meeting at the joint

Now,



Joint	Member	Member Stiffness	Joint Stiffness	D.F.
B	BA	$\frac{4EI}{6}$	$\frac{8EI}{3}$	1/4
	BC	$\frac{4E(2I)}{4}$		3/4

60. (c)



By moment area I theorem

$$\theta_C - \theta_A = \text{Area of } \frac{M}{EI} \text{ diagram between A\&C}$$

$$\because \quad \theta_A = \frac{Ml}{6EI}$$

$$\because \quad \theta_C + \frac{Ml}{6EI} = \frac{1}{2} \times \frac{Ml}{EI} \times \frac{l}{2}$$

$$\because \quad \theta_C = \frac{Ml}{12EI}$$

$$\text{Hence,} \quad \frac{\theta_A}{\theta_C} = \frac{\left(\frac{Ml}{6EI}\right)}{\left(\frac{Ml}{12EI}\right)} = 2$$

61. **(c)**

In case of rigid frame,

$$D_k = 3J - R_e$$

Where,

$$J = \text{No. of joints} = 4$$

$$R_e = \text{No. of reactions} = 9$$

Hence, $D_k = 3 \times 4 - 9 = 3$

62. (a)

- An unconformity is a buried erosional or non-depositonal surface seperating two rock masses or strata of different ages, indicating that sediment deposition was not continuous.

63. (b)

Given % of soil particle Passing through 0.75 mm Sieve = 65%

$$W_L = 45\%$$

$$W_P = 20\%$$

So, $I_P = 45 - 20 = 25\%$

Equation of A-Line Plasticity index i.e. I_P,

$$I_P = 0.73\ (W_L - 20)$$

So, I_P of A-Line is

$I_P = 0.73\ (W_L - 20) = 0.73\ (45 - 20) = 18.25\% > 7\%$

Given soil I_P is greater than A-Line I_P

Hence, soil is inorganic clay i.e. C

Liquid limit, of 45% lies between 35-50%, hence, soil is medium compressible i.e. I

∴ Soil is CI

64. (a)

Given -

$$A = 20\ cm^2$$
$$L = 5\ cm$$
$$a = 1\ cm^2$$
$$H_1 = 100\ cm$$
$$H_2 = 10\ cm$$
$$t = 6 \text{ minute and } 20 \text{ seconds}$$

So, $$K = 2.303\ \frac{aL}{At} \log\left(\frac{H_1}{H_2}\right)$$

$$K = \frac{2.303 \times 1 \times 5}{20 \times 380} \log\left(\frac{100}{10}\right)$$

$$= 1.52 \times 10^{-3}\ cm/sec$$

65. (b)

GIven:

$$L = 1.5 \text{ m}$$
$$G = 2.67$$
$$e = 0.67$$

If h is the head required to produce a quick sand condition then Critical hydraulic gradient i.e. i_c

$$i_c = \frac{h}{L} = \frac{G-1}{1+e} = \frac{2.67}{1+0.67} = \frac{1.67}{1.67} = 1$$

So, $\frac{h}{L} = 1$

$\therefore$ $h = 1 \times 1.5 \text{ m} = 1.5 \text{ m}$

66. (d)

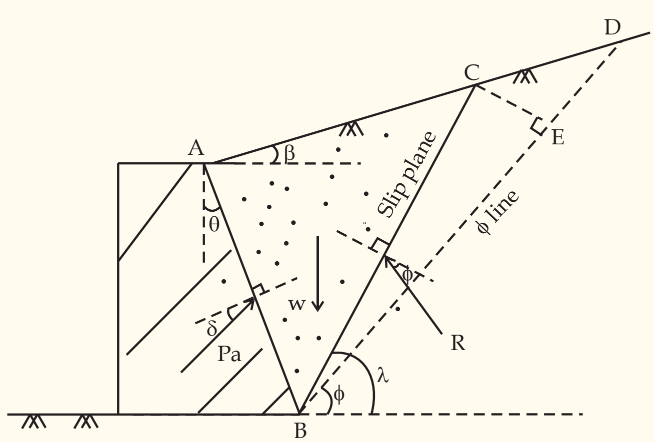
Ultimate settlement or Total settlement (ΔH) does not depends on any condition, it remains constant for a particular soil. means it is a constant value for any soil.

So, it is given ultimate settlement (Total settlement) of 5 cm for one way drainage, then total settlement for two way drainage is also 5 cm

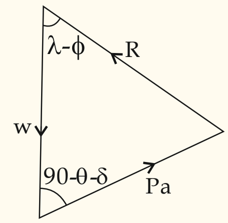
67. (d)

The force acting on the wedge of soil are as follows:

1. Weight of soils wedge 'w' acting vertically downward.
2. Resultant thrust 'Pa' between the soil and wall acting at downward angle 'δ' with the normal to the inclined face of wall.
3. Resultant soil reaction 'R' acting at downward acting of 'ϕ' with the normal to slip plane.



Using the properties of vector, we can resolve the forces as follows:



Where,

β = Surcharge angle

θ = Angle made by inclined face of wall with vertical.

δ = Angle of friction between wall and soil

ϕ = Friction angle of soil

λ = Angle made by slip plane with horizontal

Hence, the resultant active earth pressure 'Pa' inclined to the vertical 'w' at an angle of,

$$= 90 - \theta - \delta$$
$$= 90 - 6 - 8 = 76°$$

68. **(c)**

In General, shear strength of soil is governed by the following factors:

1. Interlocking between the particles e.g. Gravel and Dense Sand.
2. Friction between the particles due to sliding or rolling between them e.g. Sand, Silt, Gravel.
3. Intermolecular force of attraction called cohesion e.g. Silt and clay.

For plastic undrained clays, angle of internal friction is zero, therefore shear strength is the function of cohesion only.

69. **(a)**

Transmissivity,

$$T = kD$$

where, $$k = \frac{Q\ln\left(\frac{r_2}{r_1}\right)}{2\pi D\left(h_2 - h_1\right)}$$

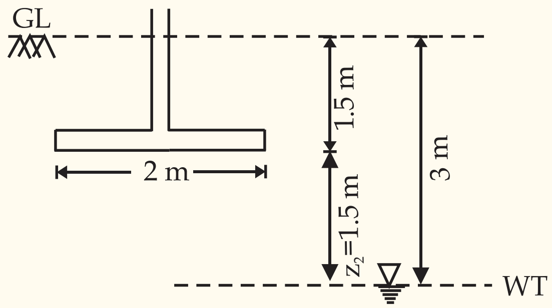
$$\Rightarrow \quad T = \frac{Q\ln\left(\frac{r_2}{r_1}\right)}{2\pi\left(S_1 - S_2\right)}$$

where, $(h_2 - h_1)$ = Difference in piezometric heads

$= (S_1 - S_2)$

= Difference in drawdowns.

70. **(a)**



$$R_\gamma = \frac{1}{2}\left(1+\frac{z_2}{B}\right)$$

$$= 0.5 + 0.5 \times \frac{1.5}{2} = 0.875$$

71. **(d)**

For cohesionless soil,

$$S_f = S_p\left[\frac{B_f\left(B_p+0.3\right)}{B_p\left(B_f+0.3\right)}\right]^2$$

$$= 5\left[\frac{5\left(0.3+0.3\right)}{0.3\left(5+0.3\right)}\right]^2 = 17.8 \text{ mm}$$

Note:- For clayey soil $\frac{S_f}{S_p} = \frac{B_f}{B_p}$

72. (d)

Ultimate bearing capacity of stiff footing is

$q_u = CN_C + \gamma D_f N_q + 0.5B\gamma N_\gamma$

Case I :

For cohesionless soil i.e. sand (C = 0)

$q_u = \gamma D_f N_\gamma + 0.5B\gamma N_\gamma$

Hence, in case of sand, ultimate bearing capacity is proportional to width of foundation.

If water table rises to ground level

$q_u = \gamma' D_f N_q + 0.5\, B\gamma' N_\gamma$

Case II :

For cohesive soil (clay)

For pure clay, angle of internal friction, $\phi = 0$

For $\phi = 0$, $N_C = 5.7$, $N_q = 1$ & $N_\gamma = 0$

$q_u = 5.7C + \gamma D_f$

Hence, in case of clay ultimate bearing capacity is independent of width of footing.

If water table rises to ground level, then q_u is

$q_u = 5.7C + \gamma' D_f$

If water table rises to ground level, then q_{nu} is

$q_{nu} = 5.7C + \gamma' D_f - \gamma' D_f = 5.7C$

Hence, net ultimate bearing capacity of footing on pure clay is nearly unaffected due to rise of water table.

73. (c)

The overall length of chain should be within the limits given below

Chain Length	Tolerance Limit
5m	± 3mm
10m	± 3mm
20m	± 5mm
30m	± 8mm

74. (a)

Permissible closing error i.e E is

$E = C\sqrt{K}$

Where,

K = Distance in kilometer

C = 4 → For precise levelling

= 12 → Accurate levelling

= 24 → Ordinary levelling

= 100 → Rough levelling

75. (c)

Prismatic Compass : The prismatic compass is a magnetic compass in which there is a prism for taking observations.

- The prismatic compass is generally smaller in size than a surveyor's compass.
- The prismatic compass consists of a circular box, about 85 to 100 mm diameter.
- The magnetic needle used in a prismatic compass is of broad in shape.
- An aluminum ring graduated in degrees and half degrees is directly attached with the needle.
- The graduations on the aluminium ring increase clockwise from 0° to 360°, with the zero of the graduations co-inciding with the south end of the needle, 90° graduation is at the west, 180° graduation at the north and 270° graduation at the east as shown below in the figure.

- The prismatic compass is used for the determination of the whole circle bearings (W.C.B.) of the lines.
- Readings are taken through a prism attached to the box.
- It may be noted that in a prismatic compass, the sighting of the object and the reading of the bearing are done simultaneously

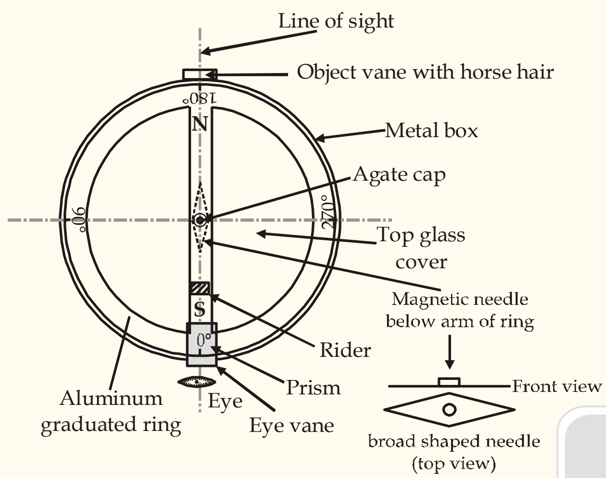
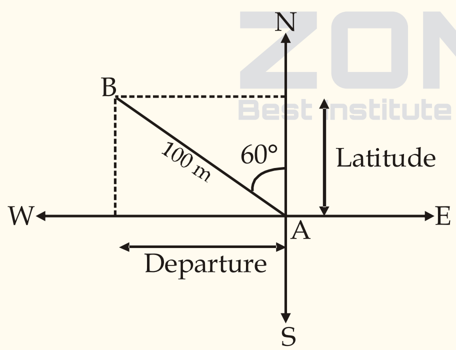


Fig: Prismatic Compass (Plan)

76. (c)



$\therefore$ Latitude = + 100 cos 60°

= + 50 m

$\therefore$ Departure = – 100 sin60°

= – 86.6 m

77. (a)

Transiting : The process of turning the telescope in vertical plane through 180° about the trunnion axis or horizontal axis. It is also known as plunging or reversing.

Note :

Horizontal axis (or) Trunnion axis: Axis about which the telescope and vertical circle rotate in vertical plane.

Swinging the telescope : Process of turning the telescope in horizontal plane.

Changing face : Operation of bringing the face of the telescope from left to right and vice versa. It is done by transiting.

78. (d)

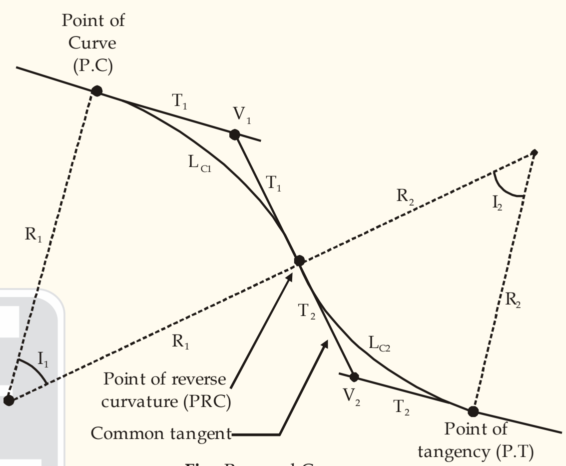


Fig.: Reversed Curves

79. (a)

As per IS 800: 2007, CL 8.6.1.2, in order to avoid buckling of the compression flange into the web, web thickness shall satisfy the following:

1. **When transverse stiffeners are not provided**:

$$\frac{d}{t_w} \leq 345 \in_f^2$$

2. When transverse stiffeners are provided: (C=spacing between stiffners)

   a. When C ≥ 1.5d

$$\frac{d}{t_w} \leq 345 \in_f^2$$

   b. When C < 1.5 d

$$\frac{d}{t_w} \leq 345 \in_f$$

80. (b)

As per IS 800: 2007 Clause 7.1.2.1,

The design compressive stress, f_{cd}, of axially loaded compression members shall be calculated using the following equation:

$$f_{cd} = \frac{f_y/\gamma_{m0}}{\phi + \left[\phi^2 - \lambda^2\right]^{0.5}} = \chi f_y/\gamma_{m0} \le f_y/\gamma_{m0}$$

where

$\phi = 0.5\,[1 + \alpha(\lambda - 0.2) + \lambda^2]$

λ = non-dimensional effective slenderness ratio

$$= \sqrt{f_y / f_{cc}} = \sqrt{\frac{f_y \left(\frac{KL}{r}\right)^2}{\pi^2 E}}$$

Where,

KL/r = effective slenderness ratio or ratio of effective length, KL to appropriate radius of gyration, r.

α = Imperfection factor given in table below,

$$\chi = \text{Stress reduction factor} = \frac{1}{\left[\phi + \left(\phi^2 - \lambda^2\right)^{0.5}\right]}$$

λ_{m0} = partial safety factor for material strength.

$$f_{cc} = \text{Euler buckling stress} = \frac{\pi^2 E}{\left(\frac{KL}{r}\right)^2}$$

Table 7 Imperfection factor, α

(Clauses 7.1.1 and 7.1.2.1)

Buckling Class	a	b	c	d
α	0.21	0.34	0.49	0.76

81. (c)

Modes of failures of Tension Members

A tension member can fail in a variety of ways, and the section of the member should be designed to prevent failure in any of these ways. The three types of failure in tension members are gross section yielding, net section rupture, and block shear failure.

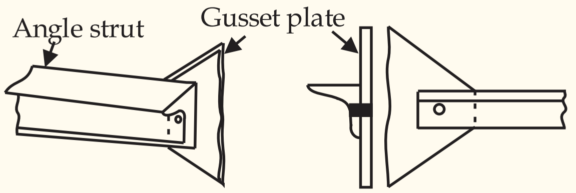
1. **Gross section yielding**: A tension member can fail due to either excessive deformation or net section rupture. A tension member with no bolt holes, in general, can withstand loads up to the ultimate load without failing. A member of this type will deform significantly in the longitudinal direction before fracture. A structure becomes unusable after such a large deformation. As a result, one of the limiting values in the design strength corresponds to the yielding of the gross cross-section.
2. **Net section rupture**: A tension member is often connected to the main or other members by bolts/welds. The presence of a bolt hole in a tension member causes stress to flow around the hole. This will cause various type of stresses adjacent to the hole to be larger than the average stress at the bolt hole. Since the bolt holes have reduced the cross-sectional area, these bolts have stress concentration adjacent to bolt holes at service loads.
3. **Block shear failure**: A piece of the block gets separated from the member in this type of tension member failure. This occurs when the material bearing strength (high-strength plate) and bolt shear strength are higher. Only a few bolts are required when high-strength bolts connect high-strength plates. Due to this, the length of connection required will be less. This increases the probability of block shear failure. In block shear failure, the failure occurs along a path involving tension on one plane and shear on a perpendicular plane (along with the fasteners).

82. (d)

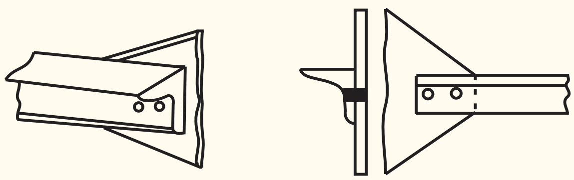
For compression member consisting of angle sections:

Sections	Type
1. Single or double angle.	Continuous
2. Single-angle connected with one bolt.	Discontinuous
3. Single-angle connected with more than one bolt or welded.	Discontinuous
4. Double angles placed back to back on opposite sides of gusset plate.	Discontinuous
5. Double angles placed back to back on same side of gusset plate.	Discontinuous

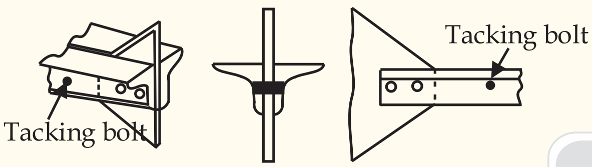
(a) Single-angle strut connected by one bolt



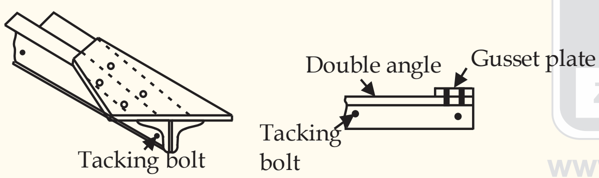
(b) Single-angle strut connected by more than one bolt



(c) Double-angle strut on opposite side of gusset

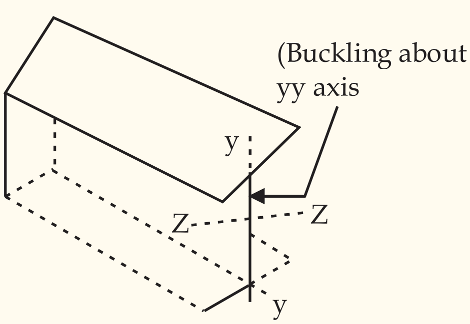


(d) Double-angle strut on same side of gusset



83. **(b)**

- Radius of gyration about the major axis of the section will not affect the lateral buckling strength of a steel I-section undergoing bending about its major axis because **buckling always occurs about the minor principle axis or minimum radius of gyration or maximum slenderness ratio.**



ZZ is Major axis & yy is minor azis (buckling will occur about yy axis).

- Laterally unsupported length of the compression flange, radius of gyration about minor axis and boundary condition at the ends will affect the buckling strength as follows:

(i) More fixidity at end supports

→ Increased strength in lateral buckling

(ii) More unsupported length of compression flange

→ Increased chances of local buckling of compression flange.

(iii) More radius of gyration of minor principle axis

→ Increased strength in lateral buckling

84. (d)

As per table-6 of IS 456 : 2000

Maximum size of Aggregate	Adjustment to minimum cement content (kg/m^3)
10 mm	+ 40
20 mm	0
40 mm	- 30

Hence, if you are changing maximum size of aggregate from 20 mm to 40 mm, the minimum cement content can be reduced by $R = 30\ kg/m^3$.

85. (a)

As per IS 456 : 2000, ANNEX B-5.5.1,

Shear failure at sections of beams and cantilevers without shear r/f will normally occur on plane inclined at an angle 30° to the horizontal.

86. (b)

The moments and the shear forces for a continuous beam and one-way slab can be calculated using moment coefficients and shear force coefficients respectively only when the following conditions are satisfied.

- Continuous spans should be at least three in number.
- Supports should be fairly rigid and should not themselves deflect.
- All the spans should have the same cross sections.
- The effective length of each span should be more or less the same and at any rate, should not differ by more than 15% of the largest effective span.
- The loading on all the spans should be substantially uniformly distributed.
- No redistribution of moments is permitted.

87. (d)

Given: Cured temperature = 15^0C

Time of curing = 28 days

Origin temperature = -11°C

We know, Maturity = $\sum$ Time $\times$ Temperature

$= 28 \times (15 - (-11)) = 28 \times 26 = 728^0$C days.

88. (c)

Permissible bending tensile stress (σ_{cbt}) in concrete for vertical wall of RC water tank is as follows:

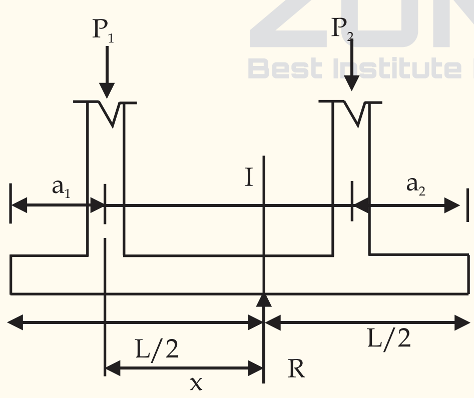
Grade	σ_{cbt} (N/mm²)
M20	1.7
M25	1.8
M30	2.0

89. (c)

Combined Footings

Whenever two or more columns in a straight line are carried on a single spread footing, it is called a combined footing. Isolated footings for each column are generally the economical. Combined footings are provided only when it is absolutely necessary, as

1. When two columns are close together, causing overlap of adjacent isolated footings.
2. Where soil bearing capacity is low, causing overlap of adjacent isolated footings.
3. Proximity of building line or existing building or sewer, adjacent to a building column.



Combined footing with loads

- The combined footing may be rectangular, trapezoidal or Tee-shaped in plan.
- The geometric proportions and shape are so fixed that the centeroid of the footing area coincides with the resultant of the column loads. This results in **uniform pressure** below the entire area of footing.
- Trapezoidal footing is provided when one column load is much more than the other. As a result, the both projections of footing beyond the faces of the columns will be restricted.
- Rectangular footing is provided when one of the projections of the footing is restricted or the width of the footing is restricted.

90. (d)

Design shear stress (τ_c) is given as:

$$\tau_c = 0.85\sqrt{0.8f_{ck}}\frac{\sqrt{1+5\beta}-1}{6\beta}$$

Where, $\beta = \dfrac{0.8f_{ck}}{6.89P_t}$,

$P_t \rightarrow$ % tensile steel reinforcement

So, τ_c depends on

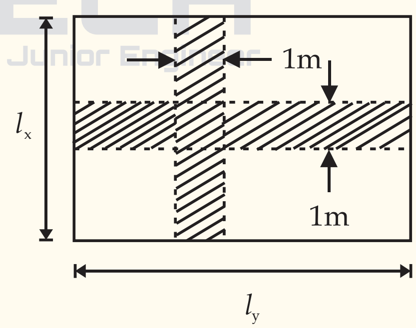
1. Grade of concrete
2. % tension reinforcement (Only tension reinforcement, compressive reinforcement need not to be considered)

91. (b)

Two way slab

$$M_x = \alpha_x w l_x^2$$

$$M_y = \alpha_y w l_x^2$$



l_y = Length on longer side

l_x = Length on shorter side

Here, for $\dfrac{l_y}{l_x} = \dfrac{4.4}{4} = 1.1$,

$\alpha_x = 0.074$

$\alpha_y = 0.061$

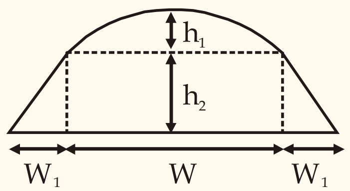
Hence, $M_x = 0.074 \times 8 \times 1 \times 4^2 = 9.472$ kNm

& $M_y = 0.061 \times 8 \times 1 \times 4^2 = 7.81$ kNm

92. (a)

For parabolic camber

$$h_1 = \frac{W}{2N}$$



For straight camber

$$h_2 = \frac{W_1}{N}$$

Height of composite crown i.e. H is

$$H = h_1 + h_2 = \frac{W}{2N} + \frac{W_1}{N}$$

Total width of road = 14m

W = width of parabolic section = $\frac{14}{2} = 7\,m$

So, width of straight line on either side i.e. W_1 is

$$W_1 = \left(\frac{14 - W}{2}\right) = 3.5m$$

For heavy rainfall for high type bituminous surface, camber = 1 in 50

$$\therefore \quad H = h_1 + h_2$$

$$= \frac{W}{2N} + \frac{W_1}{N}$$

$$= \frac{7}{2 \times 50} + \frac{3.5}{50}$$

$$= 0.14\ m \text{ or } 14\ cm$$

93. (c)

- Softening point denotes the temperature at which the bitumen attains a particular degree of softening under the specifications of the test. The test is conducted by using the Ring and Ball apparatus.
- Viscosity denotes the fluid property of bituminous material and is a measure of resistance to flow. At the application temperature, this characteristic greatly influences the strength of paving mixes.
- Penetration value measures the hardness or softness of bitumen by measuring the depth in tenths of a millimeter to which a standard loaded needle will penetrate vertically in 5 seconds.
- The softening point of sample B_1 is 45 and softening point of sample B_2 is 60
- The softening point of sample B_1 is lower than B_2 so at the same temperature viscosity of B_1 will be lower than that of B_2, hence the penetration value of B_1 will be more than that of B_2.

94. (d)

Tie bars are used across the longitudinal joint of cement concrete pavement. These bars are not used to act as load transfer devices, designed to withstand tensile stresses. Their length is smaller than dowel bars and are placed at regular intervals

95. **(a)**

For a driver having 6/6 vision can see the board from distance 48 m.

For a driver having 6/9 vision can see the board from distance 48 × $\frac{6}{9} = 32m$

Vehicle requires 174 m to slow down to 30 km/hr.

So minimum distance of X from the start of Y zone

$= 174 - 32 = 142$ m

Note :

A person with 6/9 vision can recognise or see somethings placed at a distance of 6 m, what a normal person can recognise or see when placed at a distance of 9 m.

96. **(d)**

The maximum flow may be calculated as

$$q_{max} = \frac{\text{free flow speed} \times \text{jam density}}{4}$$

$$= \frac{80 \times 100}{4} = 2000 \text{ vehicles per hour}$$

Maximum flow occurs when the speed becomes half of the free flow speed i.e.

$$\text{Speed at } q_{max} = \frac{\text{free flow speed}}{2}$$

$$= \frac{80}{2} = 40 \text{ km per hour}$$

Note :

At max flow (traffic capacity)

$$q_{max} = \frac{1}{4} V_f k_j$$

$$\text{Speed} = \frac{V_f}{2}$$

$$\text{Traffic density} = \frac{k_j}{2}$$

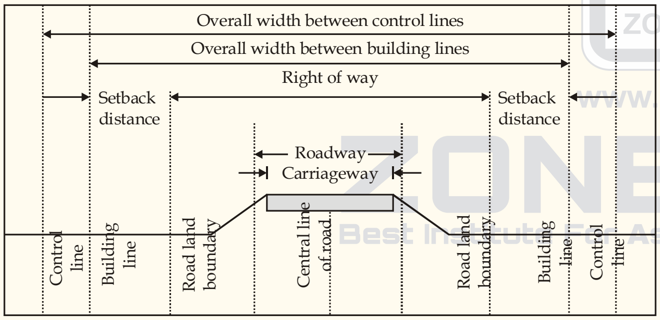
where V_f = Free flow speed
k_j = Jam density

97. (a)

Saturation headway: The constant headway achieved once a stable moving queue is established is called saturation headway.

Discharge headway: Discharge headway is the headway between successive vehicles negotiating an intersection during green time of signal operation.

98. (d)



99. (b)

The flakiness index for aggregates that are used in the pavement surface dressing should not exceed 25%, and in any case combined flakiness and elongation index should never exceed 30%.

100. (d)

Sandstone made of sand grains that have been cemented together, so the texture of Sand stone is Clastic.

- **Clastic texture :** Rocks in which grains or clasts do not interlock but rather are piled together and cemented when clasts or grains are microscopic.
  Ex. sand stone, Mudstone, etc.
- **Conglomerate texture :** When grain size > 2 mm., clasts are easily visible by naked eye.
  Ex. Granite, Quartzite etc.
- **Porphyritic texture :** When rock has well formed crystals visible to the naked eyes.
  Ex. Andesite, Rhyolite.
- **Vesicular texture :** When rock has cavities at its surface & inside.
  Ex. Basalt rock.

101. (b)

Fat lime is white in color, which has high calcium oxide content. This lime can set and become hard only in the presence of carbon dioxide. It is also called high-calcium lime, pure lime, rich lime or white lime.

102. **(c)**

Rough tooled ashlar masonry : In this type of ashlar masonry the sides of the stones are rough tooled and dressed with chisels. Thickness of joints is uniform, which does not exceed 6mm.

Rock or quarry faced ashlar masonry : This type of ashlar masonry is similar to rough tooled type except that there is chisel-drafted margin left rough on the face which is known as quarry faced.

Chamfered ashlar masonry : It is similar to quarry faced except that the edges are bevelled or chamfered for depth of 2.5 cm or more.

Block-in course masonry : It is the name given to a class of ashlar masonry which occupies an intermediate place between rubble and ashlars. The stones are all squared and properly dressed. It resembles to coursed rubble masonry or rough tooled ashlar masonry.

103. (b)

IS:3101: Aluminium collapsible tubes-specification

IS:3102: Classification of Burnt clay solid bricks

IS:3495-1 to 4: Methods of tests of burnt clay building bricks

Part 1 : Determination of compressive strength

Part 2 : Determination of water absorption

Part 3 : Determination of Efflorescence

Part 4 : Determination of warpage

IS : 3496 : Specification for Dobby Lage and pags

104. (b)

For compacting plain concrete surfaces of thickness less than 20 cm, screed vibrator should be used.

- **Screed vibrator** is directly placed on the concrete mass for compaction of shallow elements such as road surfaces, concrete floors.
- **Internal vibrator** (needle vibrator) is commonly used vibrator for concrets having depths not more than 600 mm.
- **Form vibrator** is used in congested reinforcement sections where needle vibrator can't be used i.e. columns, thin walls or in costing of precast units.

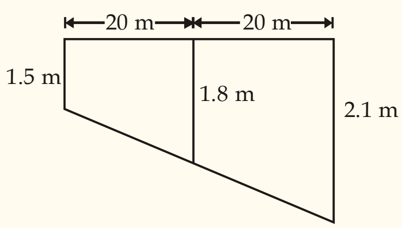
105. (b)

The sieves that are to be used for the sieve analysis of the aggregate (coarse, fine or all-in-aggregate) for concrete as per IS:2386 (Part-I) - 1963 are, 80 mm, 40 mm, 20 mm, 10 mm, 4.75 mm, 2.36 mm, 1.18 m, 600 μm, 300 μm and 150 μm.

The fineness modulus can be regarded as a weighted average size of a sieve on which material is retained and the sieves being counted from the first sieve.

Fineness modulus of 3.3 indicates size between 3^{th} and 4^{th} sieve i.e., between 600 μm and 1.18 mm.

106. (c)



$$D_{avg} = \frac{2.1+1.8+1.5}{3} = 1.8$$

$$d_{avg} = \frac{0.3+0+0.3}{3} = 0.2$$

$$\eta_d = 1 - \frac{d}{D} = 1 - \frac{0.2}{1.8} = 0.8889$$

107. (a)

According to Lacey, the ratio of bed width to depth affects the silt-bearing capacity of the channel or in other words, the shape of the channel for a given discharge is a function of the silt grade. Channel in finer material being narrower and deeper.

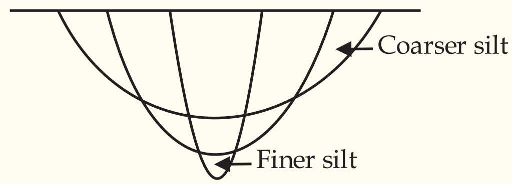


Figure : Lacey's theory - channel section according to silt grade

Note :

There is only one section of a channel and only one slope at which the canal carrying a given discharge will carry a particular grade of silt. For constant silt grades, the ratio of the bed width to depth steadily diminishes with a reduction in discharge.

108. (a)

Duty on capacity: Duty on capacity is also known as full supply coefficient.

It is defined as the area estimated to be irrigated during base period divided by the design full supply discharge of the channel as its head during maximum demand.

Capacity factor: The capacity factor for a canal is the ratio of the mean supply discharge in a canal during a period to its designed full capacity.

Capacity factor	Season
0.9-0.95	Kharif
0.6-0.70	Rabi

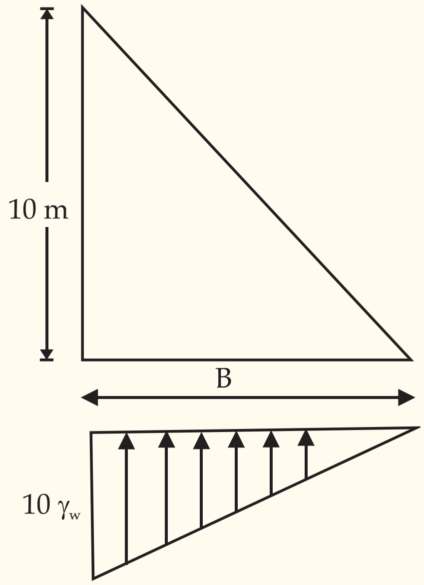
Nominal duty:

- It is the ratio of area actually irrigated by the cultivators to the mean supply discharge over the crop period.
- It is scheduled as per irrigation department.

Root zone depth

- It is the depth of soil from which the plants draw water and nutrients.
- Plants extract most of their moisture requirement in the upper half of their root zone where 60-75% of cluster root lie.

109. (c)



$\mu = 0.45$

$\gamma_{conc.} = 24\ kN/m^3$

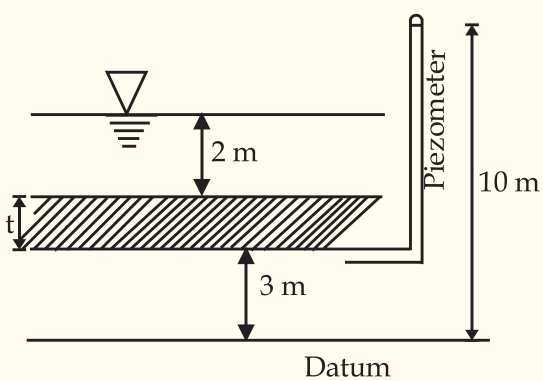
$G_{conc.} = 2.4$

$$B_{min.sliding} = \frac{H}{\mu(G-1)}$$

$$B_{min.sliding} = \frac{10}{0.45(2.4-1)}$$

$$= 15.873\ m$$

110. (a)



$G_S = 2.3$

Piezometric head = 10 m

Datum head = 3 m

Piezometric head = Pressure head + Datum head

$\Rightarrow$ Pressure head = 10 - 3 = 7 m

At critical condition,

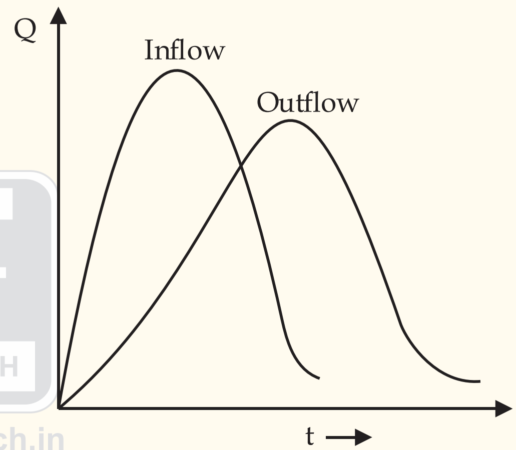
Uplift = Downward pressure

$$7 \times \gamma_w = (\gamma_w \times 2) + (\gamma_{floor} \times t)$$

$$\frac{5\gamma_w}{\gamma_{floor}} = t = \frac{5}{G} = \frac{5}{2.3}$$

$$\therefore t = 2.17\ m$$

111. (b)

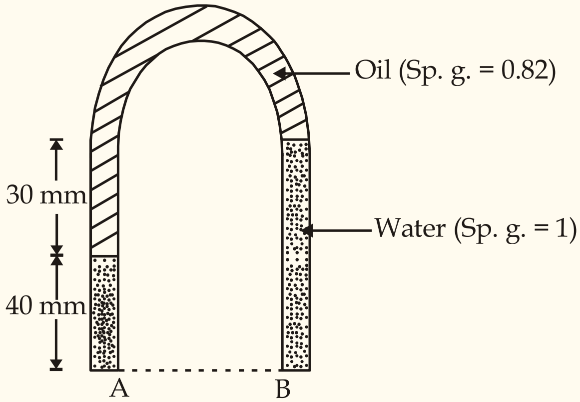


The outflow hydrograph will have attenuated peak with increased time-base.

112. (d)

- The best method of the reclaimation of the acidic soil is use limestone as a soil amendment.
- Different liming material to reclaimation of acid soil:
  - (a) Oxides - CaO
  - (b) Hydroxides - $Ca(OH)_2$
  - (c) Carbonate - $CaCO_3$
  - (d) Silicates of calcium $CaSiO_3$
- Leaching, provision of good drainage and use of gypsum as a soil amendment are generally adopted for the reclaimation of alkaline soil.

113. (d)



Starting from point A

$$P_A = (40 \times 10^{-3} \times g \times 10^3) + (30 \times 10^{-3} \times g \times 0.82 \times 10^3) - (70 \times 10^{-3} \times g \times 10^3) + P_B$$

$$\therefore P_A - P_B = -52.97 \text{ N/m}^2 \ (g = 9.81 \text{ m/sec}^2)$$

114. (b)

Cavitation is the formation of vapour bubbles in a flowing liquid in the region where the pressure falls below the vapour pressure and sudden collapsing of these vapour bubbles in a region of high pressure causes pitting

$$\because \quad \frac{p}{\gamma} + z + \frac{v^2}{2g} = C$$

If we reduce the velocity head then pressure head will increase, now chances of the pressure head falling below vapour pressure head will be less hence cavitation and pitting can be prevented.

115. (c)

Given

$$L_1 = 32000 \text{ m}$$
$$D_1 = ?$$
$$L_2 = 1000 \text{ m}$$
$$D_2 = 0.2 \text{ m}$$

Head Loss will be same

$$\frac{L_1}{D_1^5} = \frac{L_2}{D_2^5}$$

$$D_1^5 = \frac{L_1 D_2^5}{L_2}$$

$$D_1^5 = \frac{32000 \times 0.2^5}{1000} = D_1 = 0.4 \text{ m}$$

116. (c)

Reynolds number (R_e)=1000VD/μ

Where,

V = 0.1 m/s

D = A/T = 50/5 = 10 m

μ = 0.625 N-s/m2

So, R_e = 1000(0.1) (10)/ 0.625

R_e = 1600

Hence the flow is Transition flow (500 - 2000).

117. (a)

Total acceleration = Convective acceleration + Local or Temporal acceleration

$$a = V\frac{dV}{dx} + \frac{dV}{dt}$$

$V\frac{dV}{dx}$ ↓ Convective acceleration; $\frac{dV}{dt}$ ↓ Local or Temporal acceleration

Velocity along the center line of a nozzle of length 'L' is given by

$$V = 3t\left(2 + \frac{x}{L}\right)$$

Hence, Convective acceleration i.e. a_c is

$$a_c = V\frac{dV}{dx}$$

$$a_c = 3t\left(2 + \frac{x}{L}\right)\left(\frac{3t}{L}\right)$$

Given, $x = 0.5$ m
$L = 1$m
$t = 4$ sec

$$\therefore \quad a_c = 3 \times 4\left(2 + \frac{0.5}{1}\right)\left(\frac{3 \times 4}{1}\right)$$

$$a_c = 360 \text{ m/sec}^2$$

118. (b)

Vortex flow:

The motion of a fluid in a curved path is known as vortex flow.

When a cylindrical vessel containing some liquid is rotated about its vertical axis, the vortex flow will be followed by liquid.

Vortex motion is of two types:

1. **Forced vortex**:
   - In the forced vortex, fluid moves on the curve under the influence of **external torque**.
   - Due to the external torque, a forced vortex is a **rotational flow**.

- As there is the continuous expenditure of energy, Bernoulli's equation is not valid for forced vortex.
- For forced vortex, **v** = **r**ω is applicable.

Examples:
  - The flow of water through a runner of the turbine.
  - Rotation of water in the washing machine.

2. **Free vortex**:

- When **no external torque** is required to rotate the fluid mass, that type of flow is called a free vortex.
- As there is no torque in the free vortex, so free vortex is an **irrotational flow**.
- For free vortex, a moment of momentum is constant i.e. **vr** = **constant**.

Examples:
  - The flow of liquid through a hole provided at the bottom of a container.
  - Draining the bathtub.

∵ Vortex flow is both rotational and irrotational flow depending on the torque applied.

119. (d)

Given, velocity field $\vec{V} = 2x^3\hat{i} + 6x^2y\hat{j}$,

For possible flow,

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0$$

$$u = 2x^3 \Rightarrow \frac{\partial u}{\partial x} = 6x^2$$

$$v = 6x^2y \Rightarrow \frac{\partial v}{\partial y} = 6x^2$$

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 6x^2 + 6x^2 = 12x^2 \neq 0$$

Flow is physically not possible.

120. (c)

1. When the water level on the downstream of the weir is above the crest level of weir then the weir is said to be submerged weir.
2. During floods often weirs constructed across river become submerged.
3. Submerged weir have larger discharging capacity as compare with freely discharging weirs.
4. The discharge over submerged weir may be obtained by dividing it into two part Q_1 and Q_2.

Where Q_1 and Q_2 are the discharge through the free and the drowned portion respectively then

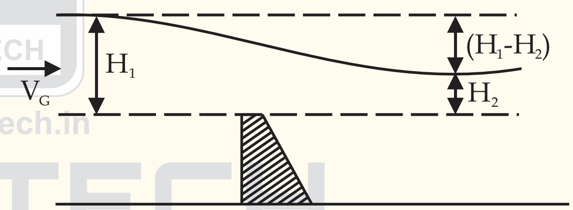
$$Q_1 = \frac{2}{3} C_{d_1} L\sqrt{2g}\left(H_1 - H_2\right)^{3/2}$$

$$Q_2 = C_{d_2}\left(L \times H_2\right)\sqrt{2g\left(H_1 - H_2\right)}$$

Where, H_1 and H_2 are respectively the heads on the upstream and downstream of weir.

L = Length of weir

C_{d_1} and C_{d_2} are coefficient of discharge of freely and drowned portion.



Submerged weir