LIVE RPSC-AE (DLB) Full Length Test Series

Civil Engineering

Full Length Paper - 7

Answer Key & Detailed Solution

Test Id - 507 **Date:- 23/04/2023**

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

39. (c)

40. (a)

41. (d)

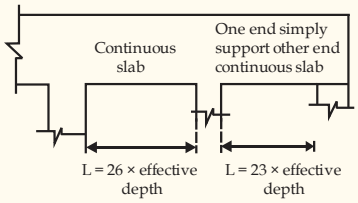
- Span/effective depth ratio for continuous slab = 26

  $\Rightarrow$ Intermediate span = 26 × Effective depth = 26 × d
- Span/effective depth ratio for one end is simply supported & other is continuous = 23

$\Rightarrow$ End span = 23 × Effective depth = 23 × d

$\therefore$ So, ratio of end span to intermediate span

$$= \frac{23\times d}{26\times d} = 0.89 \approx 0.9$$

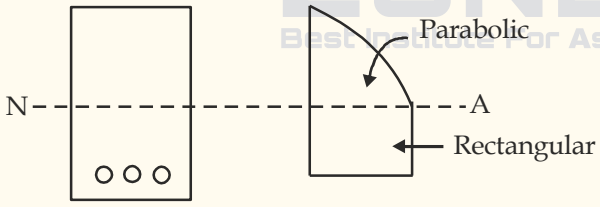


42. (b)

As per IS 456 : 2000 clause 26.5.1.2, Maximum area of compression reinforcement in RCC beam shall not exceed 0.04 bD (D = overall depth)

43. (b)

Shear stress distribution in RCC beam :



44. (d)

Grade	M15	M20	M25	M30	M35	M40
Bond stress	1	1.2	1.4	1.5	1.7	1.9

1. These are for plain mild steel bar.
2. For deformed bar, these values are increased by 60%.

i.e. $\tau_{bd,deformed} = 1.6 \times \tau_{bd,plain}$

$\tau_{bd,\ deformed} = 1.6 \times 1.2 = 1.92$ MPa

45. (b)

- While calculating the upward soil pressure the self weight of the footing is not considered.
- While calculating the area of footing required self weight of footing is considered.
- If self weight not given, it is assumed to be 10% of the service load on the footing.
- Area of footing required is found out on the basis of service load.

  For example

  P = Service load on footing (kN)

  Q = Allowable bearing pressure of soil (kN/m^2)

  Then area of footing required

$$= \frac{\text{Service load} + \text{Self weight of footing}}{\text{Allowable bearing pressure of soil}}$$

46. (b)

Statement-1:

Modular ratio, $m = \frac{280}{3\sigma_{cbc}}$

σ_{cbc} = permissible compressive stress due to bending

It clearly show that modular ratio (m) is independent of type of steel.

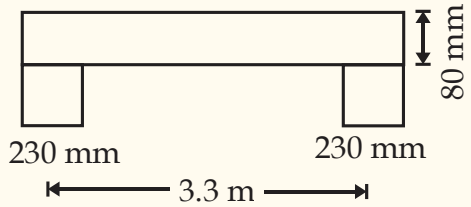
Statement-2:

Upper limit of nominal shear $\tau_{c\,max}$ depends upon the grade of concrete. Upper limit is to avoid the failure of concrete in diagonal compression.

Statement-3:

For a slab to be designed as two-way slab, it must be supported on all four edges and $\frac{L}{B} \le 2$.

47. (d)



Here support width = 230 mm

Effective depth of slab = 80 mm

Clear span = 3.3 - 0.23 = 3.07 m

$$\text{Effective span} = \text{Min. of} \begin{cases} \text{Clear span} + d \\ \text{Clear span} + w = \text{c/c spacing} \end{cases}$$

$$l_{eff} = \text{Min. of} \begin{cases} 3.07 + 0.80 = 3.15\,\text{m} \\ 3.3\,\text{m} \end{cases}$$

$\therefore l_{eff} = 3.15$ m

48. (c)

$$\frac{dQ}{Q} = 3\%$$

For suppressed rectangular weir

$$\frac{dQ}{Q} = \frac{3}{2}\frac{dH}{H}$$

$$\frac{dH}{H} = \left(\frac{dQ}{Q} \times \frac{2}{3}\right)$$

$$\frac{dH}{H} = \left(3 \times \frac{2}{3}\right)$$

$$\frac{dH}{H} = 2\%$$

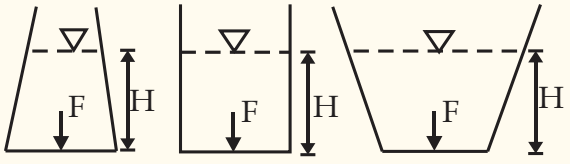
$\therefore$ Measured head was 2% excess

49. **(c)**

D'Alembert proved that for incompressible and inviscid potential flow the drag force is zero on a body moving with constant velocity relative to the fluid.

Magnus effect: The magnus effect is an observable phenomenon in a real fluid flow, in which local circulation can be produced through surface drag by rotating the cylinder itself. The sudden deviation of a ball which has been chopped (as in volley ball or table tennis) or sliced (as in lawn tennis) by player; from its normal trajectory is simple illustration of the Magnus effect.

Hydrostatic Paradox:



The hydrostatic force 'F' is the same on the bottom of all three containers if the bottom cross-section area and the fluid are the same even though the weight of liquid above are quite different.

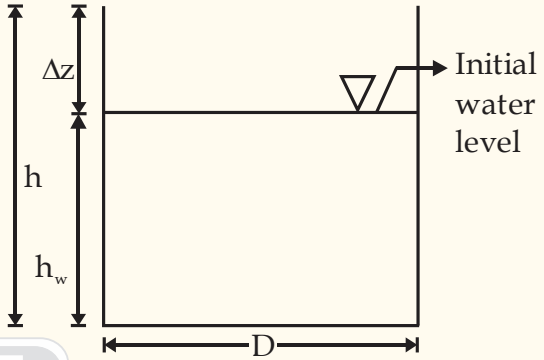
This is called hydrostatic paradox.

For the same force it is shows that the pressure at a certain horizontal level in a static fluid is proportional to the vertical distance to the surface of fluid.

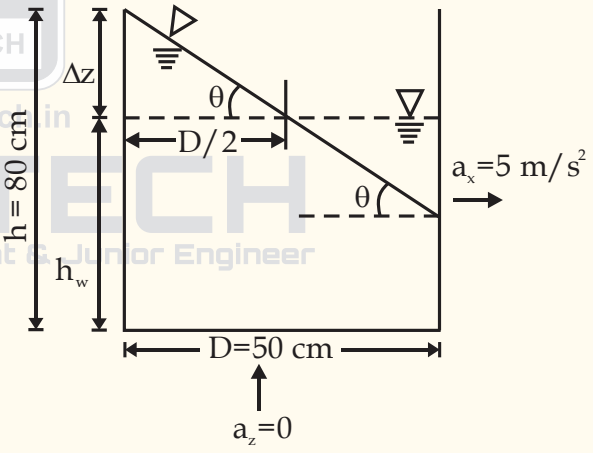
Archimedes effect: Archimedes principle states that the upward buoyant force that is exerted on a body immersed in a fluid, whether partially or fully submerged, is equal to the weight of the fluid that the body displaces and acts in the upward direction at the center of mass of the displaced fluid.

50. **(b)**

At Rest



At Motion



Data given:

Diameter of cylindrical container, $D = 0.5$ m.

Height of cylindrical container, $h = 0.8\,\text{m} = 80\,\text{cm}$.

Maximum acceleration of the vehicle, $a_x = 5\,\text{m/s}^2$

As we know that,

$$\tan\theta = \left(\frac{a_x}{a_z + g}\right) \quad \ldots(1)$$

Where, $g =$ Acceleration due to gravity

But $a_z = 0$, as there is no acceleration in vertical direction.

So, $\tan\theta = \frac{a_x}{g} = \frac{5}{9.81} = 0.5097$

For no spill,

$$\frac{\Delta z}{D/2} = \tan\theta$$

$$\Delta z = \frac{D}{2}\tan\theta = \frac{0.5}{2} \times 0.5097$$

$$\Delta z = 0.127 \text{ m} = 12.7 \text{ cm}$$

If no water is to spill, the initial level of water $= (80 - 12.7) =$ **67.3 cm**

51. (d)

As we know that,

$$\frac{dy}{dx} = \frac{(dE/dx)}{1 - F_r^2}$$

Given, dy/dx is positive, so, sign of dE/dx depends on term $(1 - F_r^2)$

If $y > y_c$ i.e. flow is sub-critical $\Rightarrow F_r < 1 \Rightarrow (1 - F_r^2) > 0 \Rightarrow dE/dx > 0$

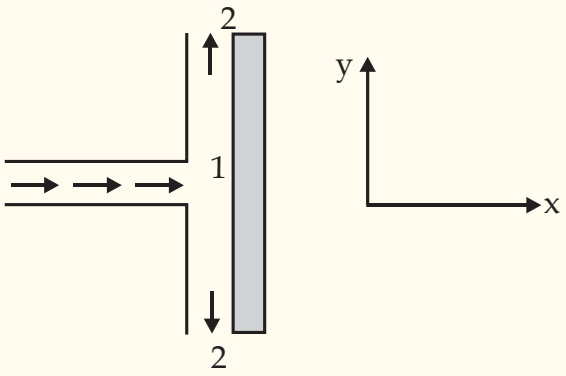
If $y < y_c$ i.e. flow is super-critical $\Rightarrow F_r > 1 \Rightarrow (1 - F_r^2) < 0 \Rightarrow dE/dx < 0$

Hence, dE/dx is positive if $y/y_c > 1$

52. (c)

- Reynolds number, $Re = \frac{\text{Inertia force}}{\text{Viscous force}}$
- Froude number, $F_r = \sqrt{\frac{\text{Inertia force}}{\text{Gravity force}}}$
- Euler number, $F_e = \sqrt{\frac{\text{Inertia force}}{\text{Pressure force}}}$
- **Weber number, $W_e = \sqrt{\frac{\text{Inertia force}}{\text{Surface tension force}}}$**
- Mach number, $M = \sqrt{\frac{\text{Inertia force}}{\text{Elastic force}}}$

53. **(c)**



Velocity of jet, $V = 10 \text{ m/s}$
Cross sectional area, $a = 10 \text{ mm}^2$
Discharge, $Q = a \times V$
$= 10 \times 10^{-6} \times 10 = 10^{-4} \text{ m}^3/\text{s}$
Force on the plate in *x*-direction
= Change in momentum in *x*-direction
$= \rho Q(V_1 - V_2)$
$= 1000 \times 10^{-4} (10 - 0) = 1\text{N}$

54. **(d)**

For a flow to exist, continuity equation should be satisfied.

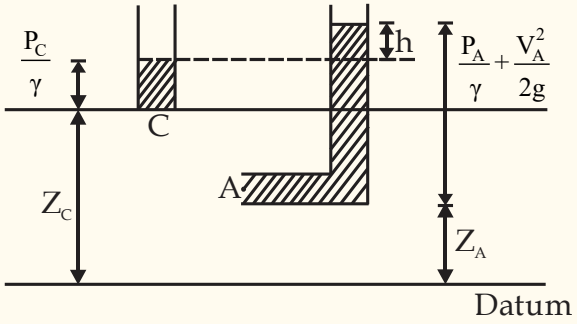
$$\Rightarrow \frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0$$

$$\Rightarrow \frac{1}{T_1} - \frac{1}{T_2} = 0$$

$$\Rightarrow T_1 = T_2$$

55. **(c)**

Pitot tube: It is used to measure **velocity of fluid.** Difference in the readings of pitot tube and piezometer (h), indicates the velocity head. This is with the assumption that piezometric head at A and C is same.



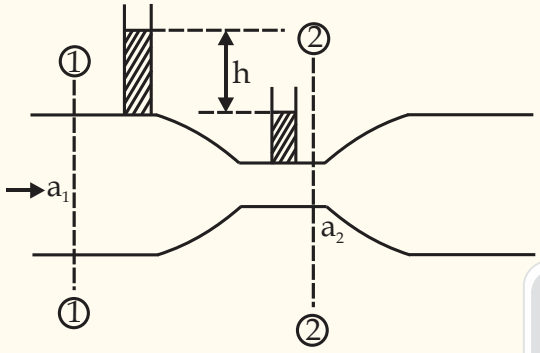
i.e., $$\frac{P_A}{\gamma} + Z_A = \frac{P_C}{\gamma} + Z_C$$

$$\left(\frac{P_A}{\gamma} + Z_A + \frac{V_A^2}{2g}\right) - \left(\frac{P_C}{\gamma} + Z_C\right) = h$$

$$\frac{V_A^2}{2g} = h$$

$$V_A = \sqrt{2gh}$$

Manometer: Measuring **pressure** in a pipe.
Venturimeter: Measuring **discharge** in a pipe.



$$Q = C_d \times \frac{a_1 a_2}{\sqrt{a_1^2 - a_2^2}} \sqrt{2gh}$$

Anemometer: Used to measure **air velocity**.

56. (d)
As per IS 2212 clause 6.6.2.4, the suitability of various walls under different conditions of exposure are given below

Construction	Sheltered exposure	Moderate exposure	Severe exposure
Unrendered 1/2-brick thick wall	Not recommended	Not recommended	Not recommended
Unrendered 1/2-brick thick solid wall	Recommended	Not recommended	Not recommended
Unrendered 1.5-brick thick solid wall	Recommended	Recommended	Not recommended
Rendered solid wall	Recommended	Recommended	Not recommended
Cavity wall or rendered one - brick thick solid wall	Recommended	Recommended	**Recommended**

57. **(c)**
Diorite rock is an example of intrusive igneous rock

Intrusive igneous rocks:
- Igneous rocks made from cooling of solidification of magma.
- When magma is cooling below earth surface, (cooling rate is slow) then intrusive rock is formed.
  Ex. **Diorite**, Granite, Pegmatite, Peridotite, etc.

Extrusive igneous rocks
- When magma is reached earth surface, then it is called lava.
- When lava is cooling and they cool quickly to form small crystals, then extrusive igneous rock is formed.
  Eg. Basalt, Dacite, Pumice, Rhyolite, etc.

58. **(a)**
- **Flash set** is the stiffening of cement paste without strength development with high heat evolution **(premature hardening)**.
- Tri calcium aluminate (C_3A) reacts immediately with water and is responsible for flash set.
- Plasticity can be regained with addition of water.
- Gypsum is added to cement to reduce flash setting.
- After flash set mixing is not allowed because no gain in strength development after mixing.

Note: False set is stiffening of paste without heat evolution. Remixing of paste without addition of water restores plasticity of the paste. Hence mixing is allowed.

59. **(c)**
- **Bleeding** in fresh concrete refers to the process where free water in the mix is pushed upward to the surface due to the settlement of heavier solid particles. So bleeding is related to watergain.
- **Segregation** denotes the separation of the constituent of homogeneous mixture of concrete.
- **Mobility** is the property of fresh concrete to flow into formwork around the steel reinforcement without the occurence of segregation or bleeding. It is ability of the concrete to be moulded.
- **Consistency** is the relative mobility or ability of freshly mixed concrete to flow. So it is related to firmness of concrete.

60. (d)

Defects due to	Defects
1. Insects	Tunnels inside 2 mm diameter pin holes, etc.
2. Natural forces	Knots, shakes, foxiness, druxiness, burls (rind galls), coarse grain, etc
3. Fungi	Brown rot, dry rot, white rot, wet rot.
4. Conversion	**Chip mark, diagonal grain, torn grain, wane , etc.**

61. (b)

Hydraulicity is the property of binder to harden in contact with water. As the percentage of clay increases in lime its slaking is suppressed and hydraulicity increases.

Note:

- At an about of 30% clay, hydraulic lime resembles cement.
- Hydraulic lime/water lime has ability to set under water in thick damp condition with no air circulation. This is why hydraulic lime is useful in foundation and under water work.

62. (a)

Compaction is a technique that eliminates the entrapped air bubbles from the concrete, so that concrete becomes highly dense.

It can be achieved by different methods depending on the area of application, which is briefed below:

1. **Manual or Hand compaction:**
- It is carried out by roding, ramming, or tamping the concrete with either a bamboo or steel rod.
- It is effective with higher slump concrete.
- It is used only for small construction works and unimportant or temporary construction works.

2. **Compaction by pressure and jolting**
- In this method, the stiff concrete is vibrated, pressed, and also given jolts.
- This compaction method is used for **compacting hollow blocks, cavity blocks, concrete blocks.**

3. **Compaction by spinning**
- In this method, the fresh concrete is well compacted by centrifugal force which is generated while spinning process.
- This method is used for compacting concrete pipes such as RCC Hume pipes.

4. **Compaction by vibration**
- In this method, concrete is compacted by using a different types of vibrators such as internal vibrators-Needle vibrators or Immersion vibrators, external vibrators, table vibrators, platform vibrators, etc.
- This is suitable for RCC beam, column and slab.

63. (d)

Pozzolanas: Mineral additives also called supplementary cementing materials or pozzolana are fine grained siliceous inorganic materials which as such, do not possess cementing properties in themselves, but react chemically with calcium hydroxide $Ca(OH)_2$ released from the hydration of portland cement at normal temperature to form compounds of low solubility having cementing properties. The action is termed as pozzolanic action.

Advantages

1. Improved workability with lesser amount of water.
2. Lower heat of hydration & thermal shrinkage.
3. Improved resistance to attack from salts & sulphates from soils & sea water.
4. Reduced susceptibility to dissolution & leaching of calcium hydroxide.
5. Reduced permeability.
6. Lower cost.

Undesirable side effects of pozzolanas

- Reduction in the rate of development of strength.
- Reduction in durability.

64. (a)

Set back distance i.e. M is

$$M = \frac{S^2}{8R} \text{ [Approx formula]}$$

Given,

Stopping sight distance (S) = 80 m

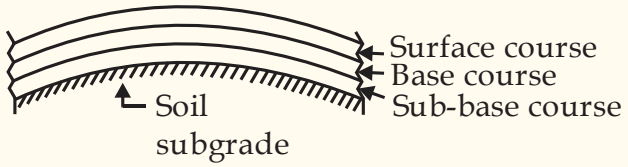
Set back distance (M) = 10 m

So, $$R = \frac{S^2}{8M} = \frac{80^2}{8 \times 10}$$

$$R = 80 \text{ m}$$

Note :
Set back distance is the distance required from the center line of a horizontal curve to an obstruction on the inner side of the curve to provide adequate sight distance at a horizontal curve.

65. (a)



Flexible Pavement

Soil subgrade:
- It is the top natural soil.
- It's function is to receive stress from layers above.

Sub-base course:
- It is provided beneath sub-base course.
- It's primary function is to provide structural support, improved drainage, reduce intrusion of fines.

Base course:
- It is provided immediately below the surface course.
- It provides load distribution and contributes to sub-surface drainage.

Surface course:
- It is directly in contact with traffic load.
- It is superior in quality.
- It's function is to provide friction, smoothness and drainage.

66. (a)
Median barriers separate opposite traffic streams, hence, head on collision is eliminated

67. (b)
When linear moment of tyre is more than circumferential movement then it is called **skid** but if circumferential movement is greater than linear movement then it is called slip.

68. (a)
Tentative capacity values of urban roads suggested by IRC are:
1. One way two lane road with no frontage access, no standing vehicles and very little cross traffic - **2400 PCU per hour**.
2. One way two lane road with frontage access, but no standing vehicle and high capacity intersections - 1500 PCU per hour.
3. One way two lane road with free frontage access, parked vehicles and heavy cross traffic - **1200 PCU per hour**.

69. (a)

Properties of Bitumen		**Lab Test**
Resistance to flow	:	Viscosity test
Hardness	:	Penetration test
Safety	:	Flash and fire point test
Ability to deform under load without breaking	:	Ductility test

70. (d)
Beam Bridge:
1. These bridges are provided upto 100 m lengths. This doesn't mean beam bridges aren't used to cross great distances. For long spans they are provided as continuous spans.
2. When a bridge is made up of beams spanning between only two supports, it is called a simply supported beam bridge. If two or more beams are joined rigidly together over supports, the bridge becomes continuous.

Cantilever Bridge:
1. These bridges can be provided for lengths approximately upto 500 m.

Truss Bridge:
1. These bridges can be provided for lengths approximately upto 700 m.
2. Truss bridges are provided because they use a relatively small amount of material to carry relatively large loads.

Suspension Bridge:
1. These bridges are long span bridges which means they can be provided up to 3 km or more.

71. (d)

$$\text{Settlement (s)} = \frac{C_C.H}{1+e_0}\log\left(\frac{\sigma_2}{\sigma_1}\right)$$

Now, from given data

$$20 = \frac{C_C.H}{1+e_0}\log\left(\frac{50}{25}\right) \quad ....(1)$$

$$\Delta H = \frac{C_C.H}{1+e_0}\log\left(\frac{100}{50}\right) \quad ....(2)$$

From equation (1) and (2),

$$\frac{\Delta H}{20}=\frac{\log\left(\frac{100}{50}\right)}{\log\left(\frac{50}{25}\right)}=\frac{\log(2)}{\log(2)}$$

$\Delta H=20mm$

72. (a)

Ultimate bearing capacity: Maximum gross pressure that can be apply at the base of foundation without shear failure or it may also be defined as minimum gross pressure at which soil fails in shear.

Net safe bearing capacity: Net ultimate bearing capacity divided by factor of safety

Safe bearing capacity: Maximum gross pressure which soil can carry safely at the base of foundation without risk of shear failure

Allowable bearing pressure: Maximum net pressure that can be applied on the soil safely without the possibility of shear failure or settlement failure.

73. (a)

In undrained triaxial test on saturated clay, the volume change due to confining pressure is zero.

$$\Rightarrow \quad \varepsilon_3=0$$

$$\frac{\sigma_3}{E}-\frac{\mu\sigma_1}{E}-\frac{\mu\sigma_3}{E}=0 \qquad [\sigma_2=\sigma_3]$$

$$\mu=\frac{\sigma_3}{\sigma_1+\sigma_3}$$

74. (d)

From Coulomb's theory, Karl Culmann (1866) devised his own **Culmann's Graphical Method** for calculating earth pressure. According to Coulomb's wedge theory, Culmann's method allows us to graphically calculate the magnitude of the earth pressure and locate the most dangerous rupture surface.

75. (d)

Soil is plastic in the range of 26-48%.

Hence plastic limit = 26% and liquid limit = 48%. Because liquid limit is in the range of 35% to 50%. Hence **intermediate compressible soil**.

76. (d)

Face failure or slope failure can occur when the slope angle β is very high and the soil close to the toe is quite strong or the soil in the upper part of slope is relatively weak.

Base failure can occur when the soil below the toe is relatively weak and soft and the slope is flat.

Toe failure occurs in steep slopes when the soil mass above the base and below the base is homogeneous.

77. (b)

For strip footing on sand $(c=0)$

$$q_u=\underset{I}{\gamma D_f N_q}+\underset{II}{0.5B\gamma N\gamma}$$

In flooding condition water level rises to base of footing hence unit weight of soil i.e. γ (present in II term) will change and unit weight of soil i.e. γ (present in I term) will be unaffected.

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

$$\because \quad \gamma'\simeq\frac{1}{2}\gamma_{sat}$$

Hence II term reduced and I term will be same thereby percentage reduction will not be 50%.

According to option approach answer should be 25%

Note:

If water table rises to ground level then both γ will reduce to γ' hence percentage reduction would be approximately 50%.

78. (d)

Laterite soils are mostly the end products of weathering.

- **They are formed by the decomposition of rocks, removal of bases and silica, and accumulation of iron oxide and aluminium oxide.**
- Heavy rainfall promotes leaching (nutrients gets washed away by water) of soil whereby lime and silica are leached away, and some soil rich in oxides of iron and aluminium compounds is left behind.

The chemical composition of Laterite-Lateritic soils

- Laterite soils are rich in bauxite or ferric oxides.
- They are very poor in lime, magnesia, potash and nitrogen.

The economic value of Laterite-Lateritic soils

- Laterite and lateritic soils provide valuable building material.
- These soils can be easily cut into cakes but hardens like iron when exposed to air.

79. (c)

The shrinkage limit method is used to determine the specific gravity of solid particles. Based on Shrinkage Ratio (SR) and Shrinkage Limit (SL), the specific gravity of soil solids can be calculated using the following formula:

$$G = \frac{1}{\frac{1}{SR} - \frac{SL}{100}}$$

Note:

1. Oven dry method, Calcium carbide method, Alcohol method, Sand bath method, Torsion balance method etc. are used to determine the water content of soil.
2. Pycnometer is also used for determining the specific gravity of soil if we know the water content and also used for determining the water content if we know the specific gravity of soil.

80. (c)

The average flow velocity or discharge velocity,

$$v = ki = 30 \times \left(\frac{45-20}{1500}\right) = 0.5 \text{ m/day}$$

Seepage velocity,

$$v_s = \frac{v}{n} = \frac{0.5}{0.25} = 2 \text{m/day}$$

$$\therefore \text{Travel time} = \frac{1500}{2} = 750 \text{ days}$$

81. (d)

$$\text{Scale} = \frac{1}{4000} = \frac{\text{Distance on map}}{\text{Distance on ground}}$$

$$\text{Distance on ground} = 4000 \times 10 = 40000 \text{ cm}$$

$$= \frac{40000}{100 \times 1000} = 0.4 \text{ km}$$

82. (b)

There are five fundamental lines in a theodolite:

1. **Vertical axis (Azimuth axis)**: It is the axis about which the instrument rotates in the horizontal plane.
2. **Horizontal axis (Trunnion axis)**: It is the axis about which the instrument rotates in the vertical plane.
3. **Line of Collimation (Line of sight)**: It is the line that passes through the intersection of horizontal and vertical crosshairs and the optical center of the object glass.
4. **Bubble Line (Level tube axis or Altitude level axis)**: It is a straight line tangential to the longitudinal curve of the level tube at its center. It is horizontal when the bubble is in the center.
5. **Plate level axis**: It is perpendicular to the vertical axis when the bubble is at the center.

83. (c)

If a quantity of a given weight is divided by a factor, the weight of the result is obtained by multiplying its given weight by the square of that factor.

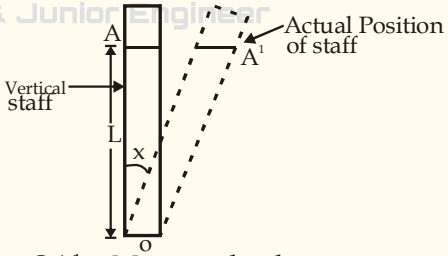
If measurement x_1 taken with weight w_1 is divide by a constant k then

Weight of result = $k^2 \times w_1$

Here, weight of angle α is 2

So, weight of angle $\frac{\alpha}{4}$ is = $(4)^2 \times 2$

84. (c)



OA^1 = Measured value
= L sec x
OA = True value = L
Error = M.V. – T.V.
= L (sec x – 1)

85. (b)

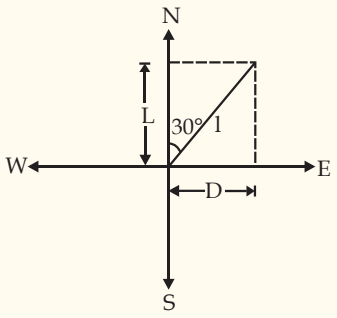
Topographical survey : It is conducted to obtain information about natural as well as man made physical features of earth's surface such as mountain ranges, road network, railway line etc.

Cadastral survey : It is done to establish the boundary line of property for legal purposes. It

is also known as public land survey.

City Survey : These surveys are conducted within the limits of a city for urban planning. These are required for the purpose of layout of streets, buildings, sewers, pipes, etc.

86. (d)



The departure of the line,

$$D = l \sin\theta$$

$$D = 10 \sin 30°$$

$$D = \frac{10}{2} = 5 \text{ m}$$

87. (b)

A **directional theodolite** has only one vertical axis, and a single horizontal clamp-and-tangent screw which controls the rotation about the vertical axis.

Theodolite is a surveying instrument used in measuring horizontal and vertical angles.

The various types of Theodolite are specified below:

Transit theodolite: A theodolite is named a transit theodolite once its telescope will be transited i.e. rotated through a whole revolution regarding its horizontal axis within the vertical plane.

Non-Transit Theodolite: In this kind, the telescope cannot be transited.

Total station: The total station accommodates the functions of a theodolite for measuring angles, an EDM for measuring gaps, digital data, and information documentation.

Directional Theodolite: Angles are obtained by deducting the first direction reading from the second direction reading. This reads directions rather than angles. The common usage of direction theodolite is in triangulation.

Repeating theodolite: Repeating theodolites are theodolites that measure angles on a graduated scale. The average of the angle measured is then derived. This is done by dividing the total of these readings by the number of readings that were taken. It is used in locations where the base is not steady.

88. (b)

Using Rise and Fall method,

$$\Sigma F.S. > \Sigma B.S.$$

$$\therefore \quad \text{Fall} = \Sigma F.S. - \Sigma B.S.$$

Fall = R.L. of first station - RL of last station

= 5.645 - 3.085 = 2.56 m

R.L. (last station) = R.L. (first station) - Fall

= 100 - 2.56 = 97.44 m

89. (b)

Chlorination

$$Cl_2 + H_2O \underset{}{\overset{pH>5}{\rightleftharpoons}} \underset{\text{Hypochlorous acid}}{HOCl} + H$$

$$HOCl \underset{pH<7}{\overset{pH>8}{\rightleftharpoons}} H^+ + OCl^-$$

Unstable hence break down at higher pH

- At pH < 5, chlorine does not react with water and remains as free chlorine.
- ($HOCl + OCl^-$ 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.
- Moreover chlorine will immediately react with ammonia present in water to form chloramines.

$$NH_3 + HOCl \xrightarrow{pH>7.5} \underset{\text{Monochloramine}}{NH_2Cl} + H_2O$$

$$NH_2Cl + HOCl \xrightarrow{pH(5\text{-}6.5)} \underset{\text{Dichloramine}}{NHCl_2} + H_2O$$

$$NHCl_2 + HOCl \xrightarrow{pH<4.4} \underset{\text{Trichloramine}}{NCl_3} + H_2O$$

- Chloramines are combined form of chlorine. It is less effective than free chlorine (25 times lesser). But they are stable and remains in water for greater duration.
- In the usual chlorine treatment, in which pH is kept slightly less than 7, dichloramine is most predominant.

90. (a)

BOD of waste = 162×10^{-6} kg/L (1 mg = 10^{-6} kg)

Flow = 1000×1000 L/day (1 m^3 = 1000 L)

BOD of flow = $162 \times 10^{-6} \times 1000 \times 1000$

= 162 kg/day

$$\text{Population equivalent} = \frac{162 \times 1000\,\text{gm}}{80\,\text{gm}} = 2025$$

91. (b)

Sludge digestion:

Sludge digestion is a biological process in which organic solids are decomposed into stable substances. Digestion reduces the total mass of solids, destroys pathogens, and makes it easier to dewater or dry the sludge. Digested sludge is inoffensive, having the apperance and characteristics of rich potting soil. It includes aerobic suspended culture.

Stages in the sludge digestion process:

Three distinct stages have been found to occur in the biological action involved in the natural process of sludge digestion. The stages are

1. Acid fermentation
2. Acid regression
3. Alkaline fermentation

1. **Acid fermentation stage or acid production stage**:

In this first stage of sludge digestion, the fresh sewage-sludge begins to be acted upon by anaerobic and facultative bacteria called acid formers. These organisms solubilize the organic solids through hydrolysis. The soluble products are then fermented to volatile acids and organic alcohols of low molecular weight like propoinic acid, acetic acid, etc. Gase like methane, CO_2 and H_2S are also evolved. Intensive acid production makes the sludge highly acidic and lowers the pH value to less than 6. Highly purefaction odours are evolved during this stage which continues for about 15 days or so (at about 21°C). BOD of the sludge increases to some extent, during this stage.

2. **Acid regression stage**:

In this intermediate stage, the volatile organic acids and nitrogeneous compounds of the first stage are attacked by the bacteria, so as to form acid carbonates and ammonia compounds. Small amount of H_2S and CO_2 gases are also given off. The decomposed sludge has a very offensive odour and its pH value rises a little and to be about 6.8. The decomposed sludge also entraps the gases of decomposition becomes foamy and rises to the surface form scum. This sludge continues for a period of about 3 months or so. BOD of the sludge remains high even during this stage.

3. **Alkaline fermentation stage**:

In this final stage of sludge digestion more resistant materials like proteints and organic acids are attacked at broken up by anaerobic bacteria called methane formers into simple substances like ammonia, organic acids and gases. During this stage, the liquid separates out from the solids, and the digested sludge is formed. This sludge is granular and stable and does not give offensive odours. (It has a musty earthy odour). This digested sludge is collected at the bottom of the digested tank and is also called ripened stage. Digested sludge is alkaline in nature. The pH value during this stage rises to a little above 7, in the alkaline range. Large volumes of methane gas (having a considerable fuel value) along with small amount of CO_2 and nitrogen are evolved during this stage. This stage extends for a period of about one month or so. The BOD of the sludge also rapidly falls down during this stage. It is thus, seen that several months (about 4.5 months or so) are required for the complete process of digestion to take place under natural uncontrolled conditions at about 21°C. This period of digestion is however very much dependent upon the temperature of digestion and other factors.

92. (b)

- Alum is used as coagulant to form gelatinous white ppt. (floc) of aluminium hydroxide and its quantity is determined in the laboratory by jar test.
- The water of zero hardness can be obtained from the ion exchange method only. It is also called zeolite process of base exchange treatment. Lime soda process doesn't remove the complete hardness from the water.
- Winkler test is used to determine D.O. in water, it makes use of manganese salt iodide and hydroxide. In first step $Mn(OH)_2$ ppt. are formed. Then a strong acid is used to convert Iodide (I^-) to Iodine (I_2). The amount of dissolve oxygen is directly proportional to the titration of iodine with the sulphate solution.

- Oxidation pond employs algal bacterial symbiosis. On top, algae exist which produces oxygen by photosynthesis. This oxygen is used up by bacteria in breaking down of food.

93. (c)

Organic matter stabilized per day

$$= Q[S_i - S_O] \times \eta$$
$$= 500 \times 10^3 (2000 - 400) \times 0.8$$
$$= 640 \text{ kg}$$

$\because$ 1 kg BOD generates 0.35 m^3 methane

$\therefore$ 640 kg BOD generates $0.35 \times 640 = 224$ m^3

94. (b)

The flow meters are generally of two types based on their functionality:

1. Inferential meters
2. Displacement or Positive meters

1. **Inferential meters**: They measure the rate of flow i.e. **discharge across a cross-section of a given area**. They do not measure absolute velocity or volume.
   Examples are:
   Venturi tubes, Rotameter, Orifice plate, Flow nozzles, Mass flow meter, Swirl meters, etc.
2. **Displacement or Positive meters**: They measure the total amount of flow i.e. volume of flow.
   Examples are:
   Reciprocating piston, Rotating piston, etc.

95. (a)

Hardness in water is due to presence of multivalent metallic cations.

Versenate method is used to determine the total hardness of fresh water. The method uses a molecule called EDTA (ethylene diamine tetra acetic acid) which forms a complex with calcium and magnesium ions. A blue dye called Eriochrome Black T (EBT) is used as the indicator.

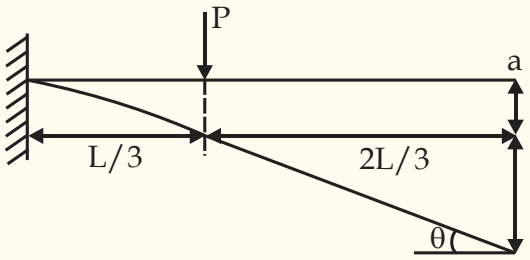
Clark's method is the water softening process. It removes the hardness of water by converting bicarbonates into carbonate.

The Hoyer system is generally used for the production on large scale of pre-tensioned structural element of the structure.

Hehner's method is used to determine the temporary hardness of water. It is determined by finding the alkalinity of water before boiling and that left after boiling.

96. (b)

- When load P is acting at 1/3rd of the span, then deflection at free end is



Deflection at free end, $\Delta_a = \Delta_1 + \Delta_2$

$$\Delta_1 = \frac{P\left(\frac{L}{3}\right)^3}{3EI}$$

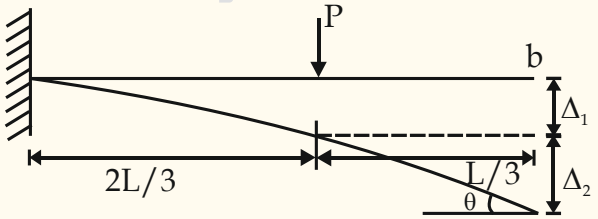
$$\Delta_2 = \frac{P\left(\frac{L}{3}\right)^2}{2EI} \times \left(\frac{2L}{3}\right)$$

Hence,

$$\Delta_a = \frac{P\left(\frac{L}{3}\right)^3}{3EI} + \frac{P\left(\frac{L}{3}\right)^2}{2EI} \times \left(\frac{2L}{3}\right)$$

$$\Delta_a = \frac{4}{81}\frac{PL^3}{EI}$$

- When load P is acting at 2/3rd of the span, then deflection at free end is:



Deflection at free end, $\Delta_b = \Delta_1 + \Delta_2$

$$\Delta_1 = \frac{P\left(\frac{2L}{3}\right)^3}{3EI}$$

$$\Delta_2 = \frac{P\left(\frac{2}{3}L\right)^2}{2EI} \times \left(\frac{L}{3}\right)$$

Hence,

$$\Delta_b = \frac{P\left(\frac{2L}{3}\right)^3}{3EI} + \frac{P\left(\frac{2}{3}L\right)^2}{2EI} \times \left(\frac{L}{3}\right)$$

$$\Delta_b = \frac{14}{81}\left(\frac{PL^3}{EI}\right)$$

- Ratio of the deflection of free end due to an isolated load at 1/3rd and 2/3rd of the span is

$$\frac{\Delta_a}{\Delta_b} = \left(\frac{4}{81}\right) \times \left(\frac{81}{14}\right) = \frac{2}{7}$$

97. (a)

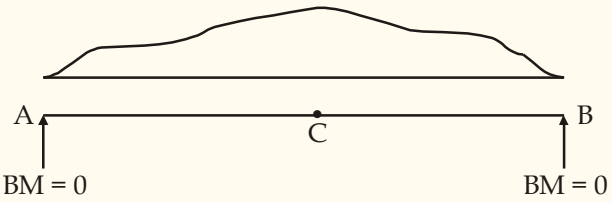
Algebraic sum of Area of Shear Force Diagram between two sections is equal to the difference between Bending Moment values at those sections.

Beacuse $\frac{d(M)}{dx} = SF$

$$\therefore \quad M = \int_{x_1}^{x_2} (SF).dx$$

In any beam bending moment will be same either calculated from left or right side.

Thus the

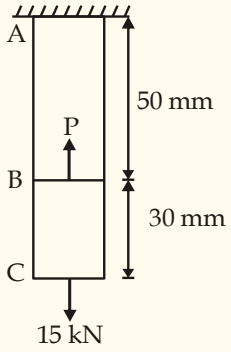


$$M_C - M_A = M_C - M_B$$

$$\int_A^C SF.dx = \int_B^C SF.dx$$

So, in Simply Supported Beams, algebraic sum of Area of Shear Force Diagram on left side of any section is same as that on the right side of that section.

98. (a)

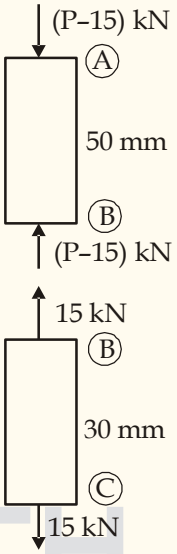


Steel Bar

Cross-sectional area i.e. A = 100 mm²

Modulus of elasticity i.e. E = 200 × 10³ MPa

Free Body Diagram of Steel Bar



If C point not move, then,

$$\Delta_{AB} + \Delta_{BC} = 0$$

$$-\frac{(P-15)\times 10^3 \times 50}{100 \times 200 \times 10^3} + \frac{15 \times 10^3 \times 30}{100 \times 200 \times 10^3} = 0$$

$$50P - 750 = 450$$

$$P = 24 \text{ kN}$$

99. (c)

Axial stiffness (K) is defined as force require for unit axial deformation

$$\because \quad \Delta = \frac{Pl}{AE}$$

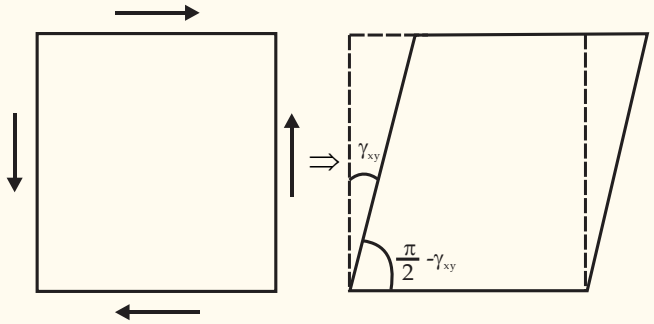
For $\Delta = 1, P = K$

So, $\quad 1 = \frac{Kl}{AE}$

$$\therefore \quad K = \frac{EA}{l}$$

100. (d)

According to the sign convention,



+ve shear stress **+ve shear strain**

In question since angle has been increase therefore shear strain should be negative.

$$\therefore \quad \gamma_{xy} = -0.0005 \text{ rad} = 0.001\ k$$

$$-0.0005 = 0.001\ k$$

$$\Rightarrow \quad k = -0.50$$

101. (b)

$\because$ Stress is internal force per unit area

$$\text{Stress}(\sigma) = \frac{\text{Internal force}(F_i)}{\text{Cross-section area}(A)}$$

For equilibrium condition -

Internal force (F_i) = External force (F_e)

So, $\sigma = \frac{F_e}{A}$

Stress developed is depends only on applied force (F_e) and cross-section area (A).

Note:

By Hooke's law-

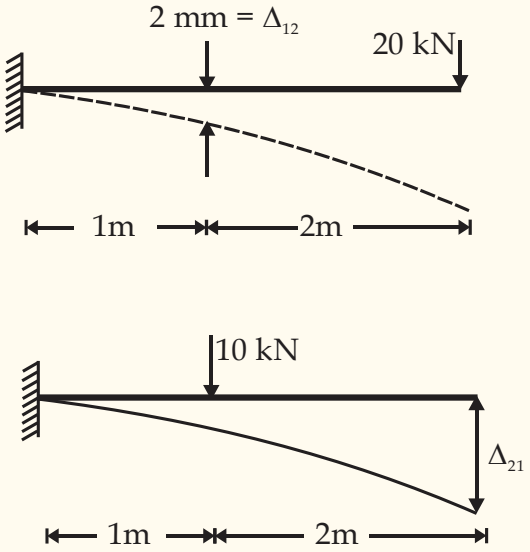
Stress (σ) $\propto$ strain (ε)

$\because$ To balance the mathematical relation between σ & ε, a constent E (elastic constant) introduced.

So, $\sigma = E\varepsilon$

$\because$ For same stress, strain will be different for different materials so, stress (σ) is independent of E but strain (ε) is dependent on E.

102. (a)



From Betti's law,

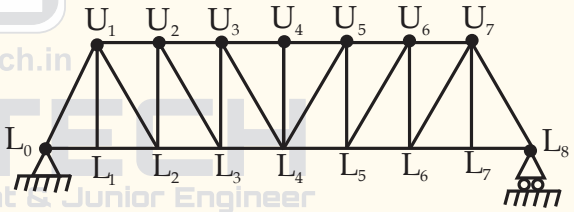
$$P_1 \times \Delta_{12} = P_2 \times \Delta_{21}$$

$$\Rightarrow \quad 10 \times 2 = 20 \times \Delta_{21}$$

$$\Rightarrow \quad \Delta_{21} = 1 \text{ mm}$$

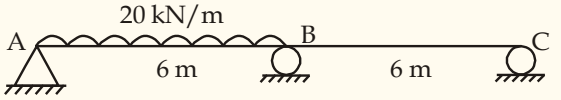
103. (a)

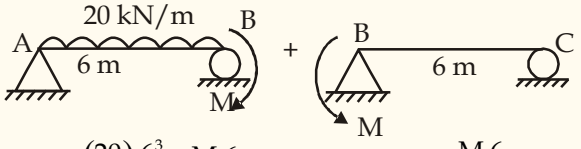
The figure shows Pratt truss



When the load is at L_1, the force in U_1L_2 will be compressive and when the load is at L_2 the force in U_1L_2 will be tensile. This will happen for all diagonal members in left half. Reverse will be the case for diagonal members of right half.

104. (b)





$$\theta_{B_1} = \frac{(20).6^3}{24EI} - \frac{M.6}{3EI} \qquad \theta_{B_2} = \frac{M.6}{3EI}$$

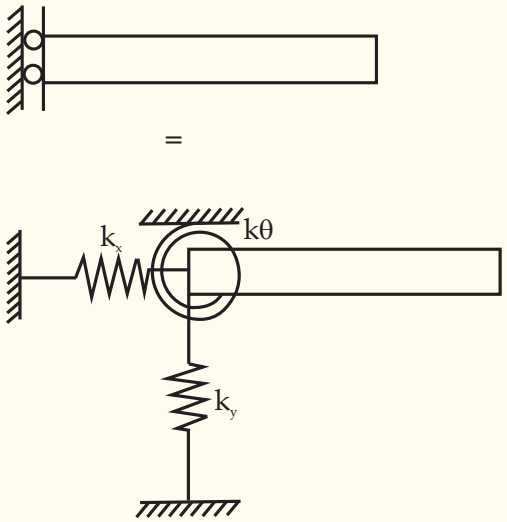
Compatibility equation:- $\theta_{B_1} = \theta_{B_2}$

$$\frac{(20).6^3}{24EI} - \frac{M.6}{3EI} = \frac{M.6}{3EI}$$

$\therefore$ M = 45 kN–m (Hogging)

105. (a)

Guided roller support has 2 reactions:



For given support, $k_x = \infty$, $k_y = 0$, $k_\theta = \infty$

106. (b)

Option 1:

m = 4, j = 4

For perfect truss m = 2j – 3

But here 2 × 4 – 3 = 5 ≠ 4 (5 > 4) this truss is **Deficient truss**

Option 2:

m = 4, j = 4

For perfect truss m = 2j – 3

2 × 3 – 3 = 3 = members of truss

So this is **Perfect truss**

Option 3:

m = 11, j = 6

For perfect truss m = 2j – 3

But here 2 × 6 – 3 = 9 ≠ 11 (9 < 11) this truss is **Redundant truss**

Option 4:

m = 6, j = 5

For perfect truss m = 2j – 3

But here 2 × 5 – 3 = 7 ≠ 6 (7 > 6) so this truss is **Deficient truss**

Note:

- Triangle is the smallest perfect truss
- Cantilever is the smallest perfect frame

107. (a)

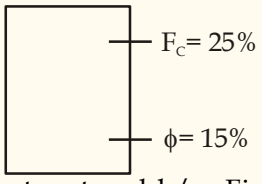
A flow duration curve is a plot of flow and percent of time that a particular discharge was equalled or exceeded. The area under the flow duration curve gives the average daily flow for a given period for which flow duration curve is plotted.

Application:

1. To find out the maximum and minimum flow for a hydroelectric power plant.
2. The shape of a flow-duration curve is used to evaluate the stream and catchment characteristics.
3. A very steep curve means high flow for very short period of time and it would cause flood. On the other hand, flat curve means low flow region and it can sustain the flow.

108. (c)

Root zone depth (D) = 80 cm



Depth of water stored b/w Field capacity (F_c) and Permanent wilting point (ϕ)

$$= \frac{\gamma_d}{\gamma_W} \times D \times (F_C - \phi)$$

$$= \frac{G}{\gamma_W} \times \gamma_W \times D \times (F_C - \phi)$$

= 1.5 × 80 × (0.25 – 0.15)

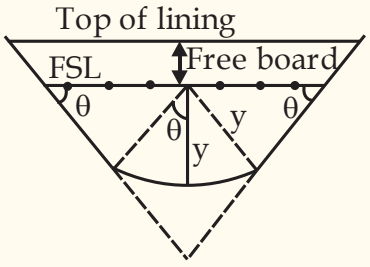
= 12 cm

109. (a)

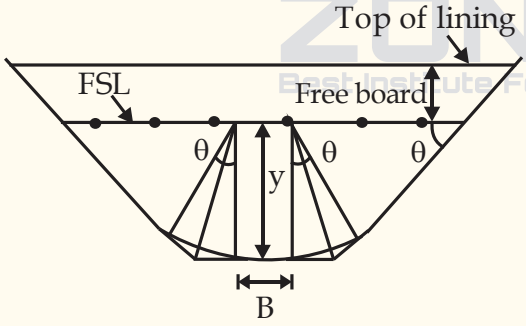
For lined canal, the free board is measured from the full supply level to the top of the lining.

For channel of different discharge carrying capacity the value recommened for freeboard are as follows:

S.No	Type of channel	Discharge (cumec)	Free board (m)
1.	Main and branch canal	> 10	0.75
2.	Branch canal and major distributaries	5 to 10	0.6
3.	Major distributaries	1 to 5	0.5
4.	Minor distributaries	< 1	0.3
5.	Water course	< 0.06	0.1 to 0.15



Triangular section



Trapezoidal section

110. (a)

Silt excluders:
- It is those silt control devices which excludes silt from water entering the canal.
- It is constructed on the river bed in front of the head regulators.
- A silt excluder consists of a number of rectangular tunnels resisting on the floor of the undersluice pocket.

Silt extractros or silt ejectors:
- It is those silt devices which remove the silt which has already entered the canal from head.
- It is provided in the canal a little distance d/s from the head regulators.

Under sluices or scouring sluices:
- It is the openings provided in the weir wall with their crest at a low level.
- It is located on the same sides as the off taking canal.

111. (a)

The maximum height of a masonary dam of a triangular section is

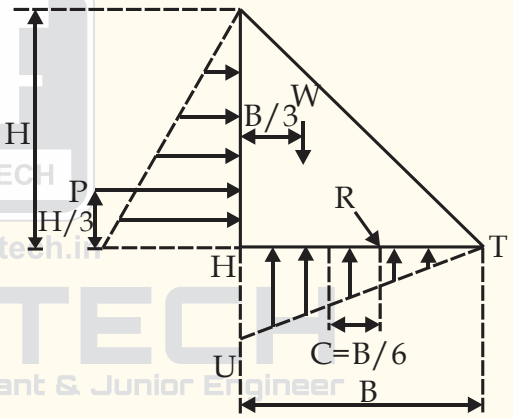
$$H = B\sqrt{S - C}$$

$$H = B\sqrt{S}$$

[When No uplift is considered i.e. $C = 0$]

Where, B = Base width

S = Specific gravity



[R=Resultant of all forces]

Note:

1. For no tension failure of gravity dam,

$$B \geq \frac{H}{\sqrt{S - C}}$$

2. For no sliding failure of gravity dam

$$B \geq \frac{H}{\mu(S - C)}$$

3. For maximum height of dam, without exceeding the allowable compressive stress.

$$H_{max} = \frac{f}{\gamma_w (S\text{-}C+1)}$$

where, $f = \frac{\sigma_y}{F.O.S}$

112. (c)

1. Width of waterway is obtained by Lacey's wetted perimeter, which is given by
$$P = 4.75\sqrt{Q}$$
2. Level and length of downstream floor is decided according to the characteristics of hydraulic jump.
3. Depth of sheet piles must be upto the level of scour depth below the river bed.
4. Barrage floor thickness should be sufficient to counteract the uplift pressure.

113. (d)

In a certain year;

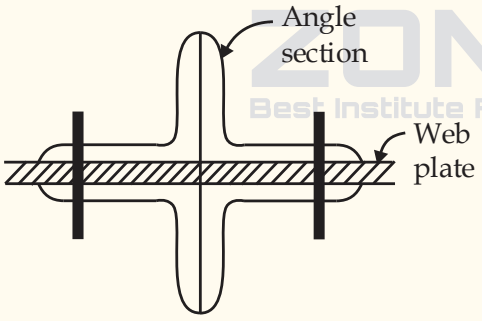
Intensity of irrigation in Kharif season i.e. IOI_{Kharif}
$= 100 - 60 = 40\%$

Intensity of irrigation in Rabi season i.e. IOI_{Rabi}
$= 100 - 46 = 54\%$

Intensity of irrigation i.e. IOI, for that year
$= IOI_{Kharif} + IOI_{Rabi}$
$= 40 + 54 = 94\%$

114. (c)

Tension member made of four angles with a plate as web,



As we can see from the figure above, one hole is made for each angles and two holes are made for web plate.

115. (b)

- End bearing stiffeners are provided to transfer the load from beam to the support.
- When thin webs are used, intermediate transverse stiffeners are provided to improve buckling strength of web.
- Many times longitudinal (horizontal) stiffeners are provided to increase the buckling strength of the web. If only one longitudinal stiffeners is provided, it will be at a depth of 0.2 d from the compression flange where 'd' is the depth of the web.
- If $\frac{d}{t_w} > 90$
vertical stiffener are provided to prevent buckling of web due to diagonal compression.
- If $\frac{d}{t_w} > 200$
Horizontal stiffeners are provided above neutral axis at a distance of 0.2d from the compression flange. They prevent buckling of web due to bending compressive stress.
- If $\frac{d}{t_w} > 250$
Additional horizontal stiffeners are provided at neutral axis, these are prevent buckling of web between vertical stiffeners due to shear force.
- If $\frac{d}{t_w} > 400$ then section is redesigned
At support, to prevent bending of flange plate and buckling of web plate due to support reaction, end bearing stiffeners are used.

The following points may be observed in design of plate girder according to IS 800 : 2007.

1. If $k = \frac{d}{t_w} \le 67$, the plate girder may be designed as ordinary beam, i.e. without any stiffener (except end bearing stiffener). But such sections will be uneconomical.
2. If $k = \frac{d}{t_w}$ is between 67 to 200, it may be possible to have the plate girder without intermediate stiffeners. However designer has to check for the shear buckling of web. For k values upto 100-110, intermediate transverse stiffeners may not be required. But for larger k values consideration of web buckling may force to go for transverse stiffener.
3. For k value upto 250, longitudinal stiffener is also required.
4. k value should not be taken more than 345 to avoid compression flange requirement.

116. (d)

Explanation:

Splices in tension member are provided to joint two sections subjected to tensile force.

Splices connection for tension member is usually bolted connection and it is designed for a force of at least 0.3 times the member design capacity in tension or the design action, whichever is more.

The splice section as well as splice connection are subjected to the tensile loads to be transmitted by the main tension member.

117. (c)

Gross diameter i.e. $d_g = 18.0 + 1.5$

$= 19.5 \text{ mm} = 1.95 \text{ cm}$

Sectional Area of plate,

$$A_{net} = B \times t - d_g \times t$$

$$A_{net} = 30 \times 1 - 1.95 \times 1$$

$$A_{net} = 28.05 \text{cm}^2$$

118. (c)

IS 875 (part 1)-1987: Indian Standard Codes provides design dead loads (Unit weight of building material and stored materials) for buildings and structures.

IS 875 (part 2)-1987: Indian Standard Codes provides **conservatively imposed loads for buildings and structures.**

IS 875 (part 3)-1987: Indian Standard Codes provides design wind loads for buildings and structures.

IS 875 (part 4)-1987: Indian Standard Codes provides design snow loads for buildings and structures.

IS 875 (part 5)-1987: Indian Standard Codes provides design special loads (load combination) for buildings and structures.

119. (c)

A beam is subjected to low shear force if the factored design shear force is less than or equal to 0.6 times design shear strength of the section. The design bending strength of such section is given by:

$M_d = \beta_b Z_p f_y / Y_{mo}$

where,

$\beta_b = 1.0$ (for plastic & compact section) or Z_e / Z_p (for semi-compact section)

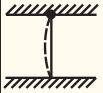
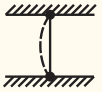
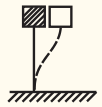
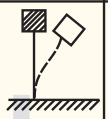
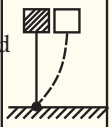
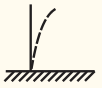
Z_e = Elastic section modulus of the cross section

Z_p = Plastic section modulus of the cross section

f_y = Yield stress of the material

$Y_{mo} = 1.1$, the partial safety factor

120. (a)

S.No.	Degree of end restraint of compression members	Figure	Theo. value of effective length	Reco. value of effective length
1.	Effectively held in position and restrained against rotation in both ends		0.50L	0.65L
2.	Effectively held in position at both ends, restrained against rotation at one end.		0.70L	0.80L
3.	Effectively held in position at both ends, but not restrained against rotation		1.0L	1.0L
4.	Effectively held in position and restrained against rotation at one end, and at the other restrained against rotation but not held in position.		**1.0L**	**1.20L**
5.	Effectively held in position and restrained against rotation at one end, and at the other partially restrained against rotation but not held in position.		-	1.5L
6.	Effectively held in position at one end, and at the other partially restrained against rotation but not held in position.		2.0L	2.0L
7.	Effectively held in position and restrained against rotation at one end but not held in position nor restrained against rotation at the other end		2.0L	2.0L