LIVE RPSC-AE (DLB) Full Length Test Series

Civil Engineering

Full Length Paper - 5

Answer Key & Detailed Solution

Test Id - 505 **Date:- 09/04/2023**

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

34. (a)

35. (a)

36. (b)

37. (a)

38. (c)

39. (a)

40. (a)

41. (b)

From continuity equation, we get,

$$Q_0 = Q_1 + Q_2$$

$$\Rightarrow \quad Q_0 = 0.25\, Q_0 + Q_2$$

$$\Rightarrow \quad Q_2 = 0.75\, Q_0$$

Since, the impact losses are neglected, the velocity will remain unchanged in the direction of Q_1 and Q_2.

i.e., $V_0 = V_1 = V_2$

Applying impulse momentum equation, we get,

$$\rho Q_0 V_0 \sin\theta = \rho Q_2 V_2 - \rho Q_1 V_1$$

$$\Rightarrow \quad Q_0 \sin\theta = 0.75 Q_0 - 0.25 Q_0$$

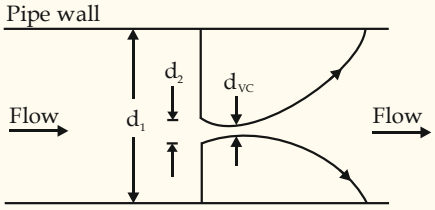
$$\Rightarrow \quad \sin\theta = 1/2$$

$$\Rightarrow \quad \theta = 30°$$

42. (b)

Orifice:

- The orifice is a small opening of any cross-section on the side or at the bottom of a tank, through which a fluid is flowing.
- It is used for measuring the rate of flow of fluid by measuring the pressure decrease across the opening.



d_1= Pipe diameter

d_2= Orifice diameter

d_{VC}=Vena contracta diameter

- According to the classification of the shape of the orifice, **if the head of the liquid from the center of the orifice is less than five times the depth of orifice, then it is known as the large orifice** and if the head of the liquid is more than five times the depth of orifice, it is known as a small orifice.
- Generally, the orifice diameter is kept half of the diameter of the pipe.
- It is economical and less space is required for fitting.
- The value of the coefficient of discharge (C_d) varies between 0.60-0.65.
- The head loss is more in the orifice meter as compared to the venturimeter.

43. (d)

As we know that,

Specific weight of liquid i.e. γ_{liquid} is

$$\gamma_{liquid} = G_s \gamma_{water}$$

Where,

G_s = Specific gravity of liquid = 0.85

γ_{water} = Unit weight / Specific weight of water = 10000 N/m^3

Hence,

$$\gamma_{liquid} = 0.85 \times 10000$$

$$\gamma_{liquid} = 8500\ \text{N/m}^3$$

$$\gamma_{liquid} = 8.5\ \text{kN/m}^3$$

44. (d)

Difference in mercury level between top and bottom = 700 - 500 = 200 mm

For calculating height of mountain,

Pressure difference due to air = Pressure difference due to mercury

$$\because \quad \rho_{air}\, g \times h = \rho_{mercury} \times g \times h_{mercury}$$

$$1.23 \times 9.81 \times h = 13.6 \times 1000 \times 9.81 \times 200 \times 10^{-3}$$

$$\text{Height of mountain (h)} = \frac{13.6 \times 10^3 \times 200 \times 10^{-3}}{1.23}$$

$$= 2211.38\ \text{m}$$

45. (a)

For Froude number from 2.5 to 4.5, the jump will be oscillating jump.

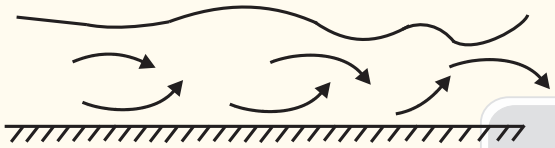
Depending on the values of Froude number F_r of incoming flow, there are 5 distinct type of hydraulic jump.

Note: Froude number of incoming flow (F_r) should be always greater than 1 for hydraulic jump to occur.

1. Undular jump
2. Weak jump
3. Oscillating jump
4. Steady jump
5. Strong or choppy jump

1. **Undular jump**

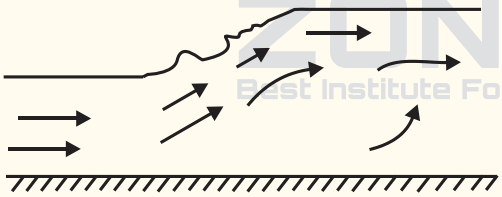
- $1.0 < F_r < 1.7$
- Water surface is undulating with a very small ripples on the surface.



(Undular Jump)

2. **Weak jump**

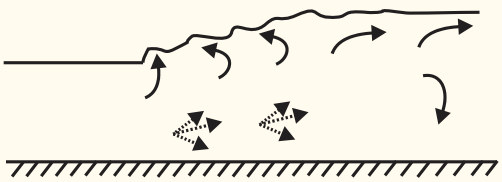
- $1.7 < F_r \leq 2.5$
- A series of small rollers forms on the jump surface, but the downstream water surface remains smooth.



(Weak Jump)

3. **Oscillating jump**

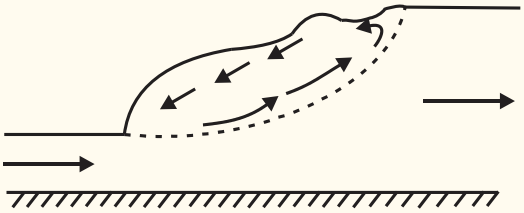
- $2.5 < F_r \leq 4.5$
- The entering jet of water oscillates in a random manner between bed and surface. These oscillations are very common in canals and can travel considerable distances and damaging earthen banks.



(Oscillating Jump)

4. **Steady jump**

- $4.5 < F_r \leq 9.0$
- The jump is well established, the roller and jump action is fully developed to cause appreciable energy loss (downstream surface smooth).
- It is always preferred to have steady jump.



(Steady Jump)

5. **Strong or Choppy jump**

- $F_r > 9.0$
- During this jump, water surface is very rough and choppy, which continues downstream for a long distance.
- Energy dissipation is very efficient.

(Strong or Choppy Jump)

46. (d)

Euler's equation for non-viscous flow,

$$\frac{dp}{\rho} + V\frac{\partial V}{\partial S}ds + gdz = 0$$

To get Bernoulli's equation we have to integrate Euler's equation by assuming flow is possible (i.e. velocity potential exists) and density is constant

$$\therefore \quad \frac{1}{\rho}\int dp + \int v\frac{\partial v}{\partial s}ds + \int gdz + = C$$

$$\frac{P}{\rho g} + \frac{V^2}{2g} + z = C$$

47. (a)

Real weight = 450 N

Apparent weight = 250 N

As we know that

Buoyancy force,

F_B = Real weight – Apparent weight

$F_B = 450 - 250 = 200$ N

From Archimedes principle of buoyancy,

Upward Buoyant force = Weight of fluid displaced

$$200 = \rho V_{displaced} \times g$$

$$V_{displaced} = \frac{200}{1000 \times 9.81} = 0.0204\,m^3$$

As we know that when body is fully submerged in fluid, liquid displaced by the body is equal to the volume of body.

$$V_{displaced} = V_{stone} = 0.0204\,m^3$$

48. (b)

$$h_f = \frac{FLV^2}{2gD}$$

$\because$ $F = 4f$

where F = friction factor

f = coefficient of friction

$$h_f = \frac{(4f)LV^2}{2gD} = \frac{2fLV^2}{gD}$$

49. **(c)**

Difference between English and Flemish Bond

ENGLISH BOND	FLEMISH BOND
Bond pattern with alternate header and stretcher course	Bond pattern with each course having alternate header and stretcher.
Less pleasing apperance	Apperance is more attractive and pleasing
Expensive	Economical
No strict supervision and skill is demanded.	Requires good workmanship and careful supervision.

Note : For walls having a thickness greater than 1.5 brick thick, an English bond is found to be stronger than a Flemish bond.

50. **(d)**

Sieve test: Cement passage through IS sieve no. 9 (90 micron)

Type of cement	Percentage of residual by weight	Specific surface area (m^2/kg) not less than
Ordinary Portland Cement (OPC)	10%	225
Portland Pozzolana Cement	5%	300
Rapid Hardening Cement	5%	325

Soundness test:

- This test is done by Le-chatelier's method.
- For OPC, soundness values should not exceed 10 mm.

Initial setting time test:

- This test is done by Vicat's apparatus.
- Initial setting time for OPC $\not<30$ minutes.

Compressive stress for OPC:

3 days $\not<16$ MPa, 7 days $\not<22$ MPa, 28 days $\not<33$ MPa

51. (c)

According to IS 2386, the formula of bulking of sand is

$$= \left(\frac{A-B}{B}\right) \times 100$$

Where,

A = Bulking sand

B = Dry sand

As per the question concrete mix ratio by 1 : 2 : 4

So, Cement = X, Sand = 2X, Aggregate = 4X

Bulking of sand = 15 %

$$\text{Hence, } 15 = \left(\frac{A-B}{B}\right) \times 100 = \left(\frac{2X-B}{B}\right) \times 100$$

$\because$ $B = 1.739$

Hence, ratio of dry sand to cement

$$= \frac{B}{\text{Cement}} = \frac{1.739X}{X} = 1.739$$

52. (b)

- Utility of rectangular rooms is better than a square room of the same floor area.
- Therefore, the length and breadth ratio should be 1.2: 1 to 1.5: 1, because if it is less than 1.2 then it becomes more squarish and if it is more than 1.5 then it creates a tunneling effect.

53. (c)

Methods for Preservation

Following are the six methods adopted for preservation of timber:

1. Brushing
2. Charring
3. Dipping and steeping
4. Hot and cold open tank treatment
5. Injecting under pressure
6. Spraying

The correct sequence of these methods in the increasing order of their effectiveness is-

- Brushing
- Spraying
- Dipping and steeping
- Hot and cold open tank treatment
- Injecting under pressure

Note:

Charring is very old method of preservation of wood and as such, no preservatives are used in this method.

54. **(b)**

Workability of concrete for different purposes			
S.No.	Type of member	Min. Slump	Max. Slump
1	Pavements	25	50
2	Mass concrete structures, Un-reinforced footings	25	75
3	Heavy Reinforced in slabs, beams, foundation, footings & walls	50	100
4	Pumped concrete, slip formwork	75	100
5	Trench fill, in situ piling	100	150
6	Tremie concrete	150	200

55. **(c)**

Crazing:

- Crazing also called pattern cracking or map cracking, is the formation of closely spaced shallow cracks or hairline cracks in an uneven manner.
- Crazing occurs due to rapid hardening of the top surface of concrete due to high temperatures or if the mix contains excess water content or due to insufficient curing.
- Pattern cracking can be avoided by proper curing, by dampening the sub-grade to resist absorption of water from concrete, by providing protection to the surface from rapid temperature changes.

Cracking :

- Complete or incomplete separation of either concrete or masonry into two or more parts produced by breaking or fracturing.
- Acceptable limits for the surface width of cracks is 0.1 to 0.3 mm.

Blistering :

- It begins when either bleeds water or bubbles of entrapped air move through the concrete and are unable to escape the surface.
- Usually, the surface was sealed too early during finishing, resulting in the hidden voids of air and bleed water underneath the mortar skin.

Laitance :

- Laitance is the weak, milky, or powdery layer of cement dust, lime, and sand fines that appear on the surface of the concrete. These fines rise to the surface of the concrete that was over-watered or allowed to dry prematurely in the absence of curing membranes or other good curing practices.

Grinning :

- Grinning is the term given to the appearance of a plastered wall when the positions of the mortar joints are clearly visible through the plaster. It is caused by the difference in suction between the masonry units and the mortar

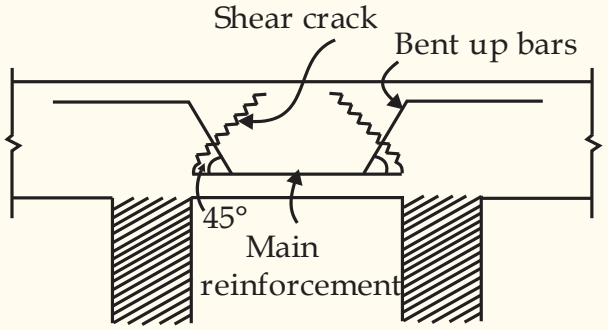
56. **(a)**

Minimum pH value of water for concrete = 6.0

As per IS code provision no. 5.4.2, the pH value of water shall not less than 6.0.

57. (d)

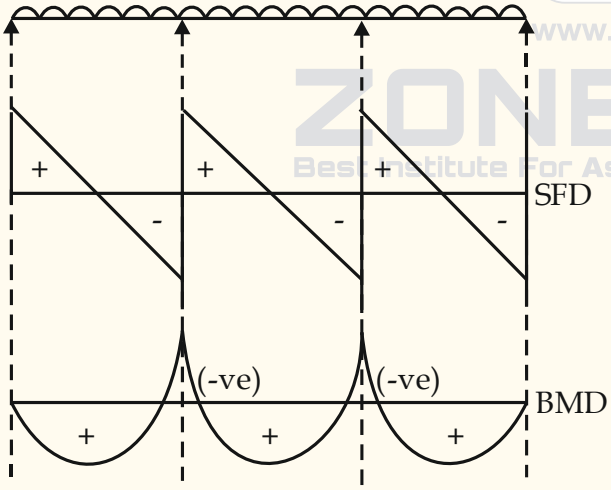
Bent up bars:



- Bent up bars are the main longitudinal reinforcement bent up at a certain location whenever not needed in upward side.
- Bent up bars intercept the crack caused due to shear, hence they help resisting the shear force and used as shear reinforcement with vertical stirrups.
- These bars helps in resisting negative tension bending moment at continuous supports of a beam. Because at supports these bars lie in upward side of neutral axis where negative bending moment develop due to continuous support condition.

Note:

- In continuous beam, under uniformly distributed loading.



- At support B.M. is (-ve) means tension is above the neutral axis hence, bent up bars at support resist the (-ve) bending moment.
- Bent up bars are bent up at 45° to horizontal so that they can resist maximum shear force because shear cracks propagate at 45° to horizontal and reinforcement being perpendicular to shear cracks it will be more effective to control shear cracks.

58. (c)

In slabs,

Spacing $\propto$ (diameter)^2

$$\frac{S_1}{S_2} = \left(\frac{\phi_1}{\phi_2}\right)^2$$

$$S_1 = 100 \text{ mm},\ \phi_1 = 10 \text{ mm},\ \phi_2 = 12 \text{ mm}$$

$$\frac{S_2}{100} = \left(\frac{12}{10}\right)^2$$

$$\Rightarrow \quad S_2 = 144 \text{ mm} = 14.4 \text{ cm}$$

59. (b)

Probable variation of modulus of elasticity should be within $\pm 20\%$ of estimated value.

$$\text{Variation} = \frac{20}{100} \times 30 = \pm 6 \text{ GPa}$$

Hence, actual values could be between $30 - 6 = 24$ GPa and $30 + 6 = 36$ GPa.

60. (a)

As per clause 8.2.4.2, IS 456 : 2000 maximum cement content in concrete excluding fly ash and ground granulated blast furnace slag should not exceed 450 kg/m^3.

61. (d)

Development length in compression for HYST bars can be given as,

$$L_d = \frac{(0.87 \times f_y)\phi}{4 \times 1.6 \times 1.25 \times \tau_{bd}}$$

$$L_d = \frac{0.87 \times 415 \times 20}{4 \times 1.6 \times 1.25 \times 1.4}$$

$$L_d = 644.73 \simeq 645 \text{ mm}$$

62. (c)

According to IS 456 : 2000 Clause 26.2.5.1 (a) Lap splices shall not be used for bars larger than 36 mm without additional precautions.

But according to **3rd amendment of IS 456 : 2000 in 2007, the value was changed from 36 mm to 32 mm.**

So, 36 mm is an old provision and **32 mm** is a new provision.

63. (b)

As we know that

$$x_u = \left(\frac{mC}{mC+t}\right)d$$

Where,

$d = 300\,mm$

$x_u = 120\,mm$

$C = 5\,N/mm^2$ (compressive stress)

$m = 18$

Hence,

$$120 = \left(\frac{18\times5}{18\times5+t}\right)300$$

$$t = 135\,N/mm^2$$

64. (b)

Blaney - Criddle method:

- **It is used to determine evapotranspiration losses i.e. consumptive use of the crop.**
- It is one of the oldest methods to measure evapotranspiration (Consumptive use of water).

The monthly consumptive use of water for a crop is given as;

$$C_u = K\Sigma f$$

where,

K is the crop factor that depends on the type of crop and season

f = Monthly consumptive use factor

$$f = \frac{p}{40}(1.8t + 32)$$

t = Mean temperature of the month in °C

p = % day time hour of the year occuring that period. It is calculated using sunshine tables.

Consumptive Irrigation requirement (CIR),

CIR = C_u - Total effective rainfall

65. (c)

As one moves from head of the canal to the field, the duty of the water increases.

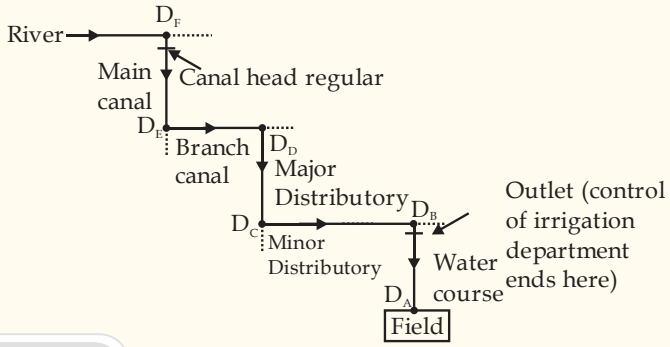
Duty : It is the number of hectares of land irrigated for full growth of a given crop by a supply of 1 cumec of water continuously during the entire base period of that crop.

Duty of water changes from place to place, it will be maximum at the head of the main canal.

Duty is the area that can be irrigated by the discharge of 1 cumec of water.

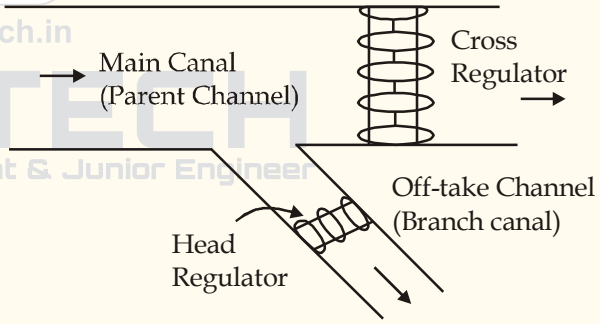
At the head of the canal, there are numerous losses to occur later which requires more amount of water to irrigate a particular field. However, if considered on the field, all losses have already occured and a lesser amount of water is required to irrigate the same considered area.

Duty of various places:



Hence, $D_A > D_B > D_C > D_D > D_E > D_F$.

66. (d)



Cross Regulator : It is a structure constructed across the parent channel for raising water level in it to fed the off-take channels.

It also absorbs the fluctuations in the canal system and facilitate the road or highway through it.

Head Regulator : It is a structure constructed across the off-take channels to regulate and control supplies from main (or parent) channel.

It also controls silt entering into the off-take channel and used for measurement of discharge.

67. (a)

Given -

Area of land i.e. A = 1200 hect.

Base period i.e. B = 140 days

Delta i.e. $\Delta = 134 \text{ cm} = 1.34 \text{ m}$

So, Duty i.e. $D = 8.64 \frac{B}{\Delta}$

$= 8.64 \times \frac{140}{1.34}$

$= 902.69$ hect./cumec.

$\therefore$ Dischrage required to irrigate 1200 hectare of land growing rice $= \frac{1200}{902.69} = 1.329$ cumec

This canal water (i.e. 1.329 cumec) is used to irrigate wheat of a base period i.e. B' = 120 days and Δ' = 52 cm or 0.52 m

So, duty i.e. $D' = 8.64 \times \frac{120}{0.52}$

$= 1993.85$ hect./cumes

Hence, the area that can be irrigated with discharge 1.329 cumec,

$= 1993.85 \times 1.329 = 2650$ hect.

68. (a)

Bligh's theory -

According to Bligh's Theory, the percolating water follows the outline of the base of the foundation of the hydraulic structure. In other words, water creeps along the bottom contour of the structure. The length of the path thus traversed by water is called the length of the creep. Further, it is assumed in this theory, that the loss of head is proportional to the length of the creep. If H_L is the total head loss between the upstream and the downstream, and L is the length of creep, then the loss of head per unit of creep length (i.e. H_L/L) is called the hydraulic gradient. Further, Bligh makes no distinction between horizontal and vertical creep.

Limitations of Bligh's Creep Theory :

- **This theory made no distinction between horizontal and vertical creep.**
- Did not explain the idea of exit gradient - safety against undermining cannot simply be obtained by considering a flat average gradient but by keeping this gradient will be low critical.
- No distinction between outer and inner faces of sheet piles or the intermediate sheet piles, whereas from investigation it is clear, that the outer faces of the end sheet piles are much more effective than inner ones.
- Losses of head does not take place in the same proportions as the creep length. Also the uplift pressure distribution is not linear but follow a sine curve.
- In case of two piles the width between should be greater than twice the head or the piles are not effective

69. (c)

The result from Thiessen polygon method is more accurate than arithmetic mean method. But there is no any close relationship between values obtained by Thiessen polygon method and Arithmetic mean method.

$\therefore$ There is no any relation between P_A and P_T.

70. (c)

Percentage change in Braking Distance

$$= \left(\frac{L_{B_1} - L_{B_2}}{L_{B_1}} \right) \times 100$$

$$\%\Delta L_B = \frac{\frac{V^2}{254\left[f_r + 0.01G\right]} - \frac{V^2}{254\left[f_r + 0.02G\right]}}{\frac{V^2}{254\left[f_r + 0.01G\right]}}$$

$$\%\Delta L_B = \frac{f_r + 0.02G - f_r - 0.01G}{\left(f_r + 0.01G\right)\left(f_r + 0.02G\right)} \times (f_r + 0.01G)$$

$$\%\Delta L_B = \left(\frac{0.01G}{f_r + 0.02G} \times 100 \right)$$

$$\%\Delta L_B = \left(\frac{0.01G}{f_r + 0.02G} \times 100 \right)$$

71. (c)

Index Plan:

It shows the general topography of the area like the position or alignment of roads, markets, hospitals, parks, number of roads/ bridges to be constructed, etc.

Layout Plan:

- The layout plan is a plan of a layout that includes the site plan, parks, gardens, community drainage, etc.
- It is a plan used for the construction of commercial buildings.

Key Plan:

- Key plans are floor plans showing the primary architectural elements of each building by floor level.
- They graphically represent walls, doors, windows, room numbers, and other features.

Service Plan:

It includes different types of services such as details of plumbing service, water supply, sewage disposal system, electrical services, mechanical services, fire services, etc.

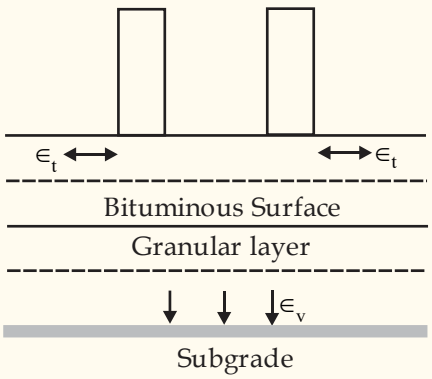
Site Plan:

- Site plans are used to locate the position of buildings in relation to setting out points, means of access, and the general layout of the site.
- These plans may also contain information on services, drainage networks, etc.

72. (b)

As per IRC: 37-2012, clause 6.3.2, the model considers the vertical strain in subgrade as the only variable for rutting, which is a measure of bearing capacity of the subgrade. Rutting in granular layer also is lower when the vertical subgrade elastic strains are given by equation:

$$N = 1.41 \times 10^{-8}\left[\frac{1}{\epsilon_V}\right]^{4.5337}$$



where, N = No. of cumulative standard axle

ϵ_v = Vertical strain in the subgrade

$\therefore$ As evident from expression, vertical compressive strain on top of subgrade is the only variable considered for rutting in flexible pavements.

73. (d)

Origin and Destination studies are carried out in numerous methods:

Roadside Interview method:

- In this method data is collected quickly in a short duration.
- Skilled team is required which can be trained quickly.
- The main drawback of this method is that vehicles are stopped for interviews. It causes delays in vehicular movement.
- It may cause congestion unless there is enough space.

License Plate Method:

- It is quite easy as far as fieldwork is concerned.
- The field organisation can be trained quickly.
- It involvees a lot of office work in tracing trips through various stations.
- It is advantageous when the area under consideration is small like a **large intersection** or small business center.

Return Post Card Method:

- It is suitable when traffic is heavy.
- It does not require skilled personnel.
- It may not give the true picture.

Tag on car method:

- It is useful where the traffic is heavy and moves continuously.
- It gives only information about entry, exit, and time taken.

74. (a)

Given that:

Design speed (v) = 20 m/sec

Acceleration (a) = 0.25 m/sec^2

$$\frac{\text{Centrifugal force}}{\text{Weight of vehicle}} = \frac{1}{4}$$

$$\frac{\text{Centrifugal force}}{\text{Weight of vehicle}} = \frac{mv^2}{R\times mg} = \frac{1}{4}$$

$$\frac{V^2}{gR} = \frac{1}{4}$$

$$R = \frac{4V^2}{g} = \frac{4\times(20)^2}{10}$$

$$R = 160\ m$$

75. (d)

Asphalt:

- Asphalt is a native mixture of hydrocarbons- a product of decomposition of animal and vegetable substance.
- It is black or brownish black in colour.
- At temperature between 50-100°C it is liquid state whereas at temperature less than this it remain in solid state.

1. **Refined Asphalt**: It is obtained by heating pitch to drive off the water and to draw off the mineral matter by segregating the impurities:
   Composition
   Bitumen → 52%
   Inorganic matter → 38%
   Organic matter → 10%
2. **Natural Asphalt**: It is also known as native asphalt when obtained from lakes it is termed as lake asphalt. It is used for making pavements, for water proofing of structure, stopping vibrations in machine foundations, tunnels and subways in manufacture of marine glue, and in lining trenches.
3. **Rock Asphalt**: It is a natural occuring rock formation, usually limestone or sandstone intimately impregnated throughout its mass with 6-14% bitumen.
4. **Mastic Asphalt**: It is manufactured by adding pulverized natural rock gradually to molten refined bitumen, agitating the mixture for about 5 hours (200-250°C) and placing it into moulds for cooling. The mass consolidates into hard elastic blocks which can be remelted when used for pavement. It is tough, durable, non absorbent, damp proof, noninflammable, and noiseless.
5. **Liquid Asphalt**: It is viscous residue obtained by the distillation of asphaltic base crude oil to 425°C.
6. **Cut-back Asphalt**: It is derived by distillation as asphalt in a volatile solvent.
7. **Artificial Asphalt**: It is pitch residue obtained by evaporation of the volatile constituent of coal tar. It is formed of an admixture of coal tar, pitch, ground iron slag, sawdust, chalk, etc.
   Composition:
   Bitumen → 12%
   Minerals and sand → 87%
   Organic matter → 1%
8. **Asphaltic cement**: It is prepared by oxidising asphalt at a high temperature and is used for flooring and water proofing.

76. (b)

Pier: It is a vertical load-bearing member such as an intermediate support for adjacent ends of two bridge spans.

77. (d)

Expressway	Plain Terrain	
	Ruling	Minimum
NH and SH	100 kmph	80 kmph
MDR	80 kmph	65 kmph
ODR	65 kmph	50 kmph
VR	50 kmph	40 kmph

78. (a)

Given -

SSD = 18m

Length of vehicle, L = 6m

V = 10m/s

So, maximum capacity i.e. $C = \frac{1000\times V}{S}$

S = Space headway = SSD + L = 18 + 6 = 24 m

$\therefore\ C = \frac{1000\times(10\times 3.6)}{24}$ = 1500 veh/hour

79. (c)

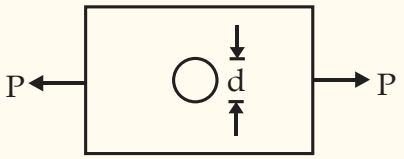


Figure 1

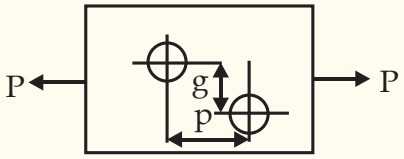


Figure 2

Tensile strength of plate in arrangement (2) will be greater than in arrangement (1),
As per IS code 800:2007 clause 6.3,

$$\left(0.9A_{net}\frac{f_{up}}{\gamma_{m1}}\right)_2 > \left(0.9A_{net}\frac{f_{up}}{\gamma_{m1}}\right)_1$$

$$(A_{net})_2 > (A_{net})_1$$

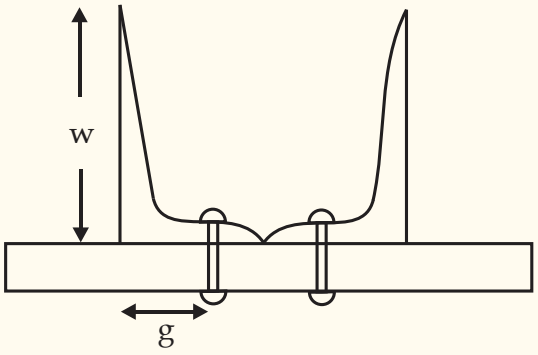
$$\left[\left(B - 2d + \frac{p^2}{4g}\right)t\right]_2 > [(B - d)t]_1$$

$$B - 2d + \frac{p^2}{4g} > B - d$$

$$\frac{p^2}{4g} > d$$

$$p^2 > 4gd$$

80. (b)



In compression member the outstanding width is taken as 'w' i.e. nominal width of section.

Note:

- In Tension member,
  b_s = Shear lag width which is measured as from the edge to the first row of rivets.
  i.e. $\boxed{b_s = w+g-t}$
- But in compression member, it is nominal width 'w' of the section.

81. (b)

For normal loading condition,
The effective length of a simply supported beam with ends restrained against torsion and also the ends of compression flange partially restrained against lateral bending = 0.85 × Length of span.

Conditions of Restraints at supports			Loading condition	
SI. No.	**Torsional Restraint**	**Warping Restraint**	**Normal**	**Desta-bilizing**
1.	Fully restrained	Both flanges full restrained	0.70L	0.85L
2.	Fully restrained	Compression flanges fully restrained	0.75L	0.90L
3.	Fully restrained	Both flanges partially restrained	0.80L	0.95L
4.	Fully restrained	Compression flange partially restrained	0.85L	1.00L
5.	Fully restrained	Warping not restrained in both flanges	1.00L	1.20L
6.	Partially restrained by bottom flange support connection	Warping not restrained in both flanges	1.0L + 2D	1.2L + 2D
7.	Partially restrained by bottom flange bearing support	Warping not restrained in both flanges	1.2L + 2D	1.4L + 2D

82. (a)
Previously as per IS 1893 (Part I)-1970, based on the levels of intensities sustained during damaging past earthquakes, the zone map subdivided India into 5 zone.
But now as per BIS [IS 1893 (Part-I): 2002], the country has group into four seismic zones viz zone II, III, IV, and V.

83. (b)
Unequal angles with long legs back to back, has slightly improved axial capacity compared to equal sections and does not have a weak axis for buckling, hence it is best preferred section among the double angles sections and it has a larger values of radius of gyration.

84. (d)

$$Q = 0.8\ m^3/d$$

Detention time,

$$D_t = \frac{V}{Q} = \frac{4\times2\times2\ m^3}{0.8\ m^3/day} = 20\ days$$

$$L_t = \frac{L_0}{1+k_e t} = \frac{54}{1+0.1\times20} = 18\ mg/l$$

85. (b)
The biological conversion of organic matter occurs in three steps:

The first step (hydrolysis) involves the transformation of higher molecular-mass compounds into compounds suitable for use as a source of energy and cell carbon.

The second step (acidogenesis) involves the bacterial conversion of the compounds resulting from the first step into identifiable lower-molecular-mass intermediate compounds. Lower chain volatile fatty acids produced during acidogenesis are utilized by a group of bacteria (acetogens) to produce acetate.

The third step (methanogenesis) involves the bacterial conversion of the intermediate compounds into simpler end products, such as methane and carbon dioxide.

86. (c)
The anaerobic sludge digester is a better method for handling the sludge because it produces a large amount of energy in the form of methane. It also **reduces the nuisance of digested sludge and reduces the vectors such as rodents, flies, etc. attraction towards sludge.**

$\therefore$ **Statement I is true and Statement II is false.**

Other points about gas production in anaerobic sludge digester:

1. Out of total volatile solids, 65% are induced to gasses and 35% formed in digested sludge.
2. The total volume of gasses formed during digestion is either 0.6 m^3/kg of volatile solids or 0.9 m^3/kg of volatile solids reduce to gasses.
3. Out of the total gasses formed 70% is methane (CH_4) and 30% is carbon dioxide (CO_2).

87. (a)

5% + 95% → 100%
Solid waste Water Wet sludge

5 kg solid waste make = 100 kg wet sludge

1 kg solid waste make = $\frac{100}{5} = 20$ kg wet sludge

210 kg solid waste make = 20 × 210 = 4200 kg wet sludge.

Density of wet sludge = 1.05 × 1000 = 1050 kg/m^3

So, volume of wet sludge = $\frac{4200}{1050} = 4\ m^3$

88. (d)
When alum is added in water, it reacts with alkalnity present in water and leads to formation of sticky gelatinous precipitate of $Al(OH)_3$ which attracts fine suspended impurities in water over its surface and gets easily settled in the process.

$Al_2(SO_4)_3.18H_2O + 3Ca(HCO_3)_2 \rightarrow 2Al(OH)_3 \downarrow + 3CaSO_4 + 6CO_2$

This carbon dioxide formed reacts and leads to formation of carbonic acid which **reduces pH of water**

89. (d)

Measuring Compound	Indicator
Iron	1, 10 phenanthroline
Alkalinity	Methyl orange and phenolpthalein
Hardness	Erichrome black T
Chlorides	Potassium Chromate

90. (d)

BOD = $(Do_i - Do_f) \times$ Dilution ratio

Dilution to 1% = Dilution ratio = 100/1

Hence, BOD of given sewage sample is (10–2)×100 = 800 mg/ltr.

91. (b)

Method	Decomposition	Contact Mechanism
Trickling filter	Aerobic	Attached
Rotating biological /contractor	Aerobic	Attached
Activated sludge process	Aerobic	Suspended
Oxidation pond	Aerobic	Suspended
Septic tank	Anaerobic	Suspended
Sludge digestion tank	Anaerobic	Suspended

92. (b)

Porosity gives a measure of the water storage capability of soil but not all the water present in the soil pores is available for extraction by pumping for the use of humans or draining by gravity. The pores in the soil hold back sufficient quantity of water on acccount of forces like surface tension and molecular attraction. Hence the actual amount of water that can be extracted from the unit volume of aquifer by pumping or under the action of gravity is called as specific yield. The fraction of water held back in the aquifer is known as specific retention. Thus it can be said that porosity is the sum of specific yield and specific retention. Specific yield of soils differ from each other in the sense that some soil types have strong molecular attraction with the water held in their pores while others have less. It is found experimentally that cohesionless soils have high specific yield than cohesive soils because the former has significantly less molecular attraction then the latter. Coarse-grained soils or rocks such as coarse sandstone can have specific yields that are closer to their actual porosity in the range 20 to 35%. The case of fine grained materials is quite opposite to that range.

Porosity and specific yield of soil formation:

Formation	Porosity(%)	Specific yield(%)
Clay	45-55	1-10
Sand	35-40	10-30
Gravel	30-40	15-30
Sandstone	10-30	5-15
Shale	1-10	0.5-5
Limestone	1-10	0.5-5

93. (b)

$$OCR = \frac{\text{Maximum effective stress in past}}{\text{Maximum effective stress in present}}$$

Maximum effective stress in present

$= 10\,\gamma_{sat} - 10\,\gamma_w$

$= 10 \times 16 - 10 \times 10 = 60\ kN/m^2$

$\therefore\ OCR = \frac{90}{60} = 1.5$

94. (a)

$$S_n = \frac{C}{\gamma H_C} = \frac{C}{\gamma F_C H} \qquad \left\{\because F_C = \frac{H_C}{H}\right\}$$

95. (b)

The maximum height of unsupported cut

$$= \frac{4c}{\gamma\sqrt{K_A}}$$

For $\phi_u = 0;\ K_A = \left[\frac{1-\sin 0°}{1+\sin 0°}\right] = 1.0$

$\therefore$ Maximum height of unsupported cut

$$= \frac{4 \times 120}{20} = 24\ m$$

Actual height of cut = 4m

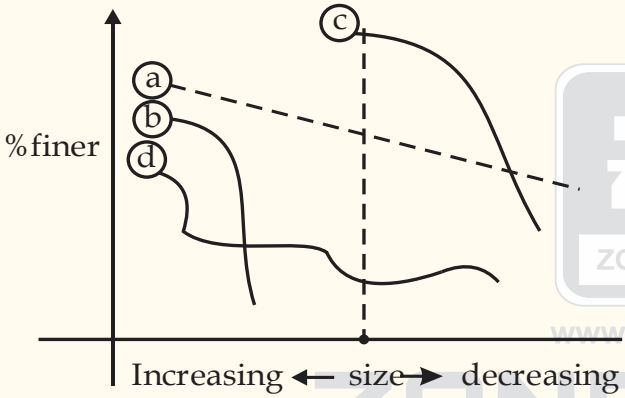
$\therefore$ Factor of safety $= \frac{24}{4} = 6$

96. (d)

Horizontal line represents gap graded soil i.e. all the size of soils between 20 mm and 4.75 mm are missing.

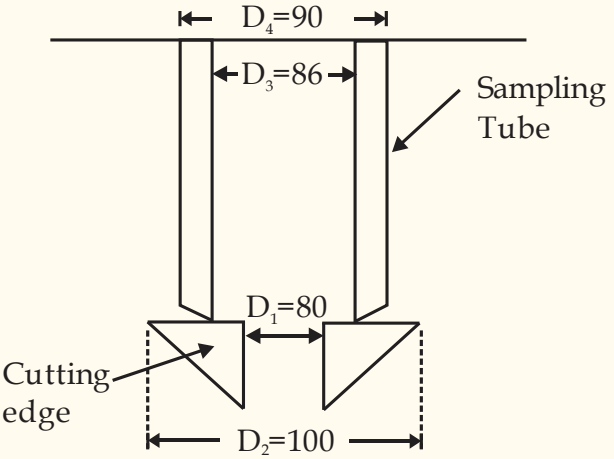
Note:

- **Gap grading is represented by horizontal line which means that some of the soil particle sizes are missing as shown in curve (d).**
- Well graded soil are represented by inclined line which means that soil of all sizes are present as shown in curve (a).
- Poorly/uniformly graded soil are represented by vertical line which means that soil of predominantly of one size is only present as shown in curve (b) and (c).
- Note that position of the curve indicates type of soil whereas shape of the curve indicates gradation.



97. (c)

Outside clearance



$$\text{Outside clearance} = \left[\frac{D_2 - D_4}{D_4}\right] \times 100$$

$$\text{Outside clearance} = \left[\frac{100 - 90}{90}\right] \times 100$$

$$= 11.11\%$$

98. (c)

Bertram introduced the ratios D_{15},F / D_{85},B ≈ 6 and D_{15},F / D_{15},B $\approx$ 9 as empirical filter designs taking into consideration the grain size distribution. The first criterion was given to ensure that the soil particles do not pass through the voids of the filter (retention or stability criterion) and the second to avoid clogging of the filter, i.e. the filter voids should not be filled with too many fine particles (permeability criterion).

Terzaghi & Peck specified more precisely;

- $$\frac{D_{15}\,(\text{Filter})}{D_{85}\,(\text{Base material})} \le 4$$
- $$\frac{D_{15}\,(\text{Filter})}{D_{15}\,(\text{base material})} \ge 4$$

99. (b)

Given,

D_f = 2 m,

B = 1 m

L = 2 m

q_u = unconfined compressive strength = 100 kN/m^2

According to Skempton, the net ultimate bearing capacity is given by

$$q_{nu} = CN_C$$

$$\& \; C = \frac{q_u}{2}$$

Where,

N_C = Bearing capacity factor =

$$= 5\left(1 + 0.2\frac{B}{L}\right)\left(1 + 0.2\frac{D_f}{B}\right)$$

$$\left\{\text{For Rectangular / Raft if } \frac{D_f}{B} \le 2.5\right\}$$

C = Unit cohesion

Hence,

$C = \frac{100}{2} = 50 kN/m^2$

For $\frac{D_f}{B} < 2.5$

$N_C = 5 \times \left(1 + 0.2 \times \frac{1}{2}\right)\left(1 + 0.2 \times \frac{2}{1}\right) = 7.7$

So, $q_{nu} = 50 \times 7.7 = 385 \text{ kN/m}^2$

100. (a)

IS code specification for permissible settlement:

(i) Total Permissible settlement

For isolated footing on clay = 65 mm
For isolated footing on sand = 40 mm
For raft footing on clay = 65-100 mm
For raft footing on sand = 40-65 mm

(ii) Permissible Differential settlement

For isolated footing on clay = 40 mm
For isolated footing on sand = 25 mm

101. (a)

Bridge footing is completely submerged in water, so, ultimate bearing capacity would be based on buoyant unit weight or submerged unit weight.

102. (c)

Balancing Backsights and Foresights:

When the difference in elevation between any two points is determined from a single set-up by backsighting on one point and foresighting on the other, the error due to non-parallelism of line of collimation and axis of the bubble tube (when the bubble is in the centre of the run) and also the error due to curvature and refraction may be eliminated if the lengths of two sights can be made equal.

103. (d)

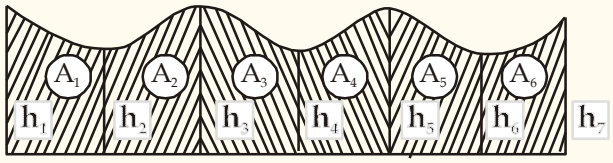
The method which gives more accurate results in the measurement of areas is simpson's one third rule

Note:

Simpson's one third rule :

"The area is equal to the sum of the two end ordinates plus four times the sum of even intermediate ordinates plus twice the sum of the odd intermediate ordinates, the whole multiplied by one-third the common interval between them."

Simpson's rule



$$A = \frac{d}{3}\left[(h_1 + h_n) + 4(h_2 + h_4 + h_6 + ...) + 2(h_3 + h_5 + h_7 + ...)\right]$$

Where, $h_1, h_2, h_3, \ldots\ldots, h_n$ are height of ordinates at a common interval d.

Other points related to Simpson's rule:

- The boundary between the extremities is assumed to be parabolic.
- This rule is applicable only when number of divisions of the area is even i.e. the total number of ordinates is odd.
- The formula is only useful if the ordinates are odd.
- The Area enclosed in a parabolic segment is 2/3 rectangular area.
- If the first offset or last offset is zero, it should not be ignored.

104. (d)

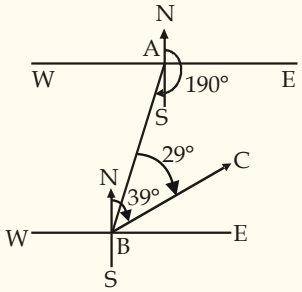
Alidade : An alidade is a straight-edge ruler provided with sighting device. It is used for sighting the object and drawing the line.

Arrow : An arrow is inserted into the ground after every chain length measured on the ground.

Bubble tube : These vials are incompletely filled with a liquid usually a colored spirit or alcohol, leaving a bubble in the tube.

Stadia hair : Stadia hair are crosshairs on the reticle of a theodolite or other surveying instrument that allow stadia metric range finding.

105. (a)



The included ∠ABC is

= 39° – 10° = 29°

106. (a)

"Check levelling"

Check levelling can be conducted regarding the activities of the running levels to check the lists of levels and these levels or series have been previously determined. After the work of every day in agriculture, the level line has been kept and the individual returns to the beginning part and detect the work process regarding this type of levelling.

"Reciprocal levelling"

"Reciprocal levelling" helps an individual to make differentiation among the elevation of the two points. It can be said that through this levelling the two types of observation can be differentiated minutely and accurately. This process is only applicable when there is no possibility to fix the level among the two points in the midway.

"Barometric levelling"

Through "Barometric levelling", the altitudes of the various points agave been detected. This detection can be conducted through the use of a barometer. Through this levelling, the pressure of the atmosphere can be measured.

"Hypsometry"

Hypsometry levelling is another process of levelling in that the heights of hills or the mountains can be measured through the detection of the temperature and most importantly, this temperature has been taken to the level at which the water boils.

107. (a)

Third-Order or Tertiary Triangulation:

The third-order triangle consists of a number of points that are fixed within the framework of the second triangle and form the instant control for detailed engineering and other survey's.

The sizes of triangles are small and can be used with devices with medium accuracy.

The specifications for a third-order triangulation are as follows :

Average triangle closure	: 6 sec
Maximum triangle closure	: 12 sec
Length of baseline	: 0.5 to 3 km
Length of sides of triangles	: 1.5 to 10 km
Actual error of base	: 1 in 75,000
Probable error of base	: 1 in 250,000

Probable error of computed distance : 1 in 5,000 to 1 in 20,000

Probable error in astronomic azimuth : 5 sec

108. (b)

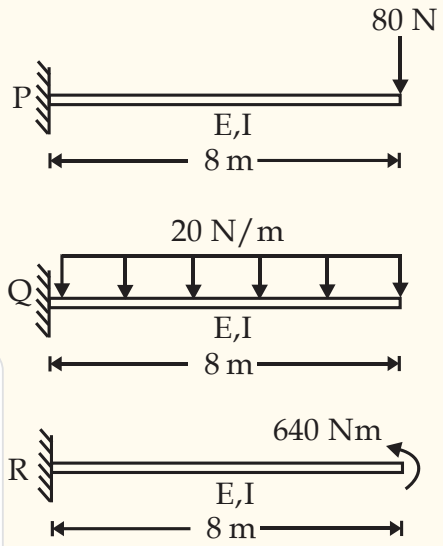
$$\text{Sensitivity} = \frac{S}{nD} \times 206265''$$

$$= \frac{0.05}{10 \times 100} \times 206265''$$

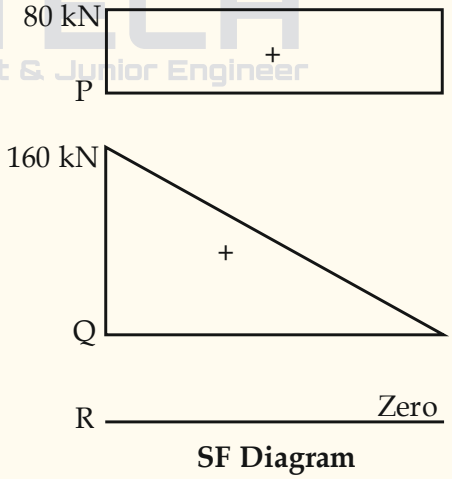
$$= 10.3''$$

109. (c)

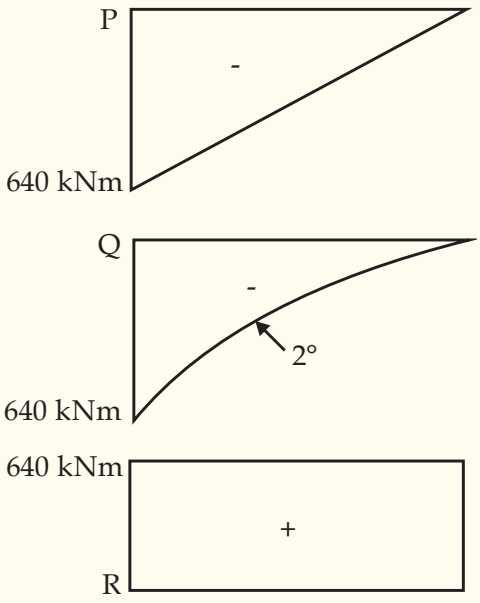
Loading Diagrams:



Shear Force Diagrams:



SF Diagram



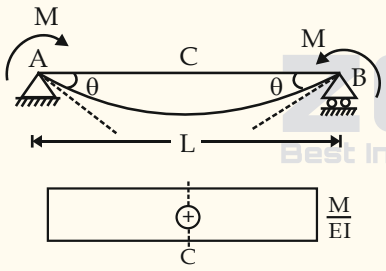
BM Diagram

Hence,

$$S_P < S_Q > S_R$$
$$M_P = M_Q = M_R$$

So, option (c) is correct.

110. (a)



As we know that,

$\theta_C - \theta_A$ = Area of M/EI diagram

$$\Rightarrow 0 - \theta_A = \frac{M}{EI} \times \frac{L}{2} = \frac{ML}{2EI}$$

$$\therefore \quad \theta_A = -\frac{ML}{2EI}$$

$$\therefore \quad \theta_A = \frac{ML}{2EI} \text{ (anticlockwise)}$$

$$\Rightarrow \frac{ML}{EI} = 2\theta$$

111. (a)

The deflection of the beam is inversely proportional to the moment of inertia of the beam section.

$$\text{Deflection, } \Delta \propto \frac{1}{I}$$

So deflection increases with decrease in moment of inertia.

112. (a)

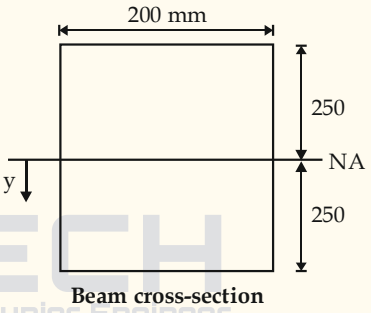
Part AC of the beam is rigid. Hence C will act as a fixed end. Thus the deflection at B will be given as

$$\delta_B = \frac{PL^3}{3EI}$$

But the bending moment does not depend on the rigidity or flexibility of the beam. Thus the bending moment at A will be given as

$$BM_A = P \times 2L = 2PL$$

113. (d)



Beam cross-section

Given -

M = 6 kNm,
b = 200 mm,
d = 500 mm

As we know that -

$$\sigma = \frac{M}{I}.y \qquad \text{... (i)}$$

Where,

σ = Bending stress
I = Moment of inertia about neutral axis
y = Distance from neutral axis

From equation (i) we can say that the bending stress at a distance of 250 mm from bottom fibre i.e. y = 0 is zero

$\because y = 0 \rightarrow \sigma = 0$

114. (d)

As we know that -

$$E = 2G(1 + \mu)$$

$\because$ For elastic isotropic material, μ varies between 0 to 0.5

For $\mu = 0$,

$$E = 2G(1 + 0)$$

$$\frac{G}{E} = \frac{1}{2}$$

For $\mu = 0.5$,

$$E = 2G(1 + 0.5)$$

$$\frac{G}{E} = \frac{1}{3}$$

Hence, For $0 < \mu < 0.5$,

$$\frac{1}{3} < \frac{G}{E} < \frac{1}{2}$$

115. (c)

The variation of bending moment due to UDL is parabolic.

NOTE :

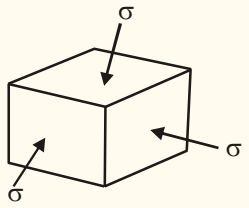
The degree of variation of bending moment is one degree higher than the variation in shear force and two degree higher than the variation in loading.

Table : Variation of SFD & BMD for different degree of loading conditions

Loading	SFD	BMD
n°	(n+1)°	(n+2)°
Point load	Const (0°)	linear (1°)
(const) UDL	1°	2°
(linear) UVL	2°	3°

- Point at which a concentrated force is acting, there will be a sudden change in SFD and slope of BMD.
- A point at which a couple is acting there will be a sudden change in BMD

116. (c)



$\because$ Cubes restrained from all directions so when T°C temperature is raised, then cube want to expand but a compressive stress is applied by supports to resist this expansion. By symmetry, this compressive stress (σ) will be same for all directions i.e.

Strain due to temperature rise = Strain due to 'σ'

$$\alpha T = \left(\frac{\sigma}{E} - \mu\frac{\sigma}{E} - \mu\frac{\sigma}{E}\right)$$

$$\alpha T\, E = \sigma(1 - 2\mu)$$

$$\text{Hence, } \sigma = \frac{\alpha TE}{1 - 2\mu}$$

117. (c)

Elastic recovery/strain: The strain recovered after the removal of the load is known as elastic strain.

Plastic strain: The permanent changes in dimension after the removal of load is known as plastic strain.

The load is removed when the stress was 200 MPa and the corresponding strain was 0.03

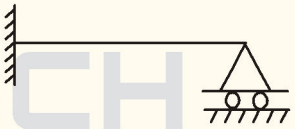
After the removal of load, the body recovered and the final strain found was 0.01.

Hence,

Elastic strain = 0.03 - 0.01 = 0.02 and

Plastic strain = 0.01 respectively.

118. (c)



Degree of static indeterminacy i.e. D_S is

$$D_S = R_e - 3$$

Where,

R_e = Total reactions at supports = 4

So, $D_S = 4 - 3 = 1$

Hence,

A propped cantilever with hinged prop is indeterminate externally to First degree

119. (d)

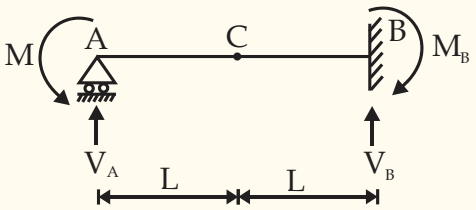
Castigliano's First Theorem: The first partial derivative of the total internal energy (strain energy) in a structure with respect to any particular deflection component at a point is equal to the force applied at that point and in the direction corresponding to that deflection component i.e.

$$\frac{\partial U}{\partial d_i} = R_i$$

Castigliano's Second Theorem: The first partial derivative of the total internal energy (strain energy) in a structure with respect to the force applied at any point is equal to the deflection at the point of application of that force in the direction of its line of action i.e.

$$\frac{\partial U}{\partial R_i} = d_i$$

120. (d)



Applying a moment M at A.
Let reaction at A and B is V_A and V_B respectively and carryover moment be M_B.

Taking $M_C = 0$ (from left)

$$V_A \times L - M = 0$$

$$\Rightarrow \quad V_A = \frac{M}{L}$$

$$\therefore \quad V_B = -\frac{M}{L}$$

Now, taking $M_C = 0$ from right,

$$-M_B + V_B \times L = 0$$

$$\Rightarrow \quad M_B = \left(\frac{-M}{L}\right) \times L$$

$$\Rightarrow \quad M_B = -M$$

$$\text{Carryover factor} = \frac{\text{Carryover moment}}{\text{Applied moment}}$$

$$= \frac{M}{M}$$

$$= 1$$