LIVE RPSC-AE (DLB) Full Length Test Series

Civil Engineering

Full Length Paper - 6

Answer Key & Detailed Solution

Test Id - 506 **Date:- 16/04/2023**

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

36. (c)

37. (a)

38. (b)

39. (a)

40. (c)

41. (b)

IS sieve (1)	Mass retained (gm) (2)	% Mass retained (3)	Cumulative % Mass retained (4)	% Finer i.e. (100 - 4) (5)
600 μ	1200	40	40	60
425 μ	1500	50	90	10
212 μ	300	10	100	0

Uniformity coefficient $(C_u) = \frac{D_{60}}{D_{10}}$

Here,

D_{60} = Grain diameter corresponding to 60% finer in weight.

D_{10} = Grain diameter corresponding to 10% of sample finer in weight

Assuming sieve size to be grain size

$$C_u = \frac{600}{425} = 1.41$$

42. (d)

Dupuit's theory assumptions hold that groundwater flows horizontally in an unconfined aquifer and that ground water discharge is proportional to saturated aquifer thickness.

43. (c)

By Mohr coulomb's criteria,

Shear at failure $(\tau_f) = C + \sigma\tan\phi$

From Test-1

$110 = C + 150\tan\phi$ ....(1)

From test-2

$120 = C + 250\tan\phi$ ....(2)

On solving equation (1) and equation (2), we get

$C = 95\ kN/m^2$

$\tan\phi = 0.1$

44. (a)

Flocculated structure is formed when clay particles settle on sea bed, since sea bed is polar in nature.

45. (b)

$$m_v = \frac{a_v}{1+e_0} = \frac{\frac{\Delta e}{\Delta\sigma}}{1+e_0} = \frac{(1.1-0.9)}{125\times2.1}$$

$= 7.619 \times 10^{-4}\ m^2/kN$

46. (b)

- Plate load test was conducted on a clay strata.
- Bearing capacity for the plate is 180 kPa.
- Ultimate bearing capacity in case of clay is independent of width of footing, hence ultimate bearing capacity for footing will be 180 kPa.

47. (a)

Triaxial test:

- Stress distribution on failure plane is fairly uniform.
- Drainage condition can be controlled completely.
- Pore water pressure can be measured.
- Volume changes can also be measured.
- There is no rotation of principal stresses during test and stresses can be determine at any stage.

48. (b)

Given,

Volume of air = V_A = 0.2 cc

Volume of water = V_W = 0.3 cc

Volume of solids = V_S = 0.5 cc

Weight of water = W_W = 0.3 g

Weight of solids = W_S = 1.0 g

$\because$ Volume of voids = $V_V = V_A + V_W$ = 0.5 cc

Now,

Void ratio i.e. $e = \frac{V_V}{V_S} = \frac{0.5}{0.5} = 1$

Water content i.e. $w = \frac{W_W}{W_S} = \frac{0.3}{1} = 0.3$ or 30%

Degree of saturation i.e. S

$$S = \frac{V_W}{V_V} = \frac{0.3}{0.5} = 0.6 \text{ or } 60\%$$

Saturated unit weight i.e. $\gamma_{sat} = \frac{(G+e)}{1+e} \times \gamma_W$

Where, G = Specific gravity of solids

As we know that,

$$Se = wG$$

On putting values of S, e and w in above equation, we get G = 2

$$\because \quad \gamma_{sat} = \frac{(2+1)}{1+1} \times 1 = 1.5 g/cc$$

Hence, statements 1, 3 and 4 are correct

49. (b)

Rigid Footing	
Cohesionless soil	**Cohesive soil**
Contact pressure is maximum at centre and zero at edges	Contact pressure is minimum at centre and maximum at edges
Uniform settlement	Uniform settlement

Flexible Footing	
Cohesionless soil	**Cohesive soil**
Contact pressure is uniform	Contact pressure is uniform
Settlement is minimum at centre and maximum at edges	Settlement is maximum at centre and minimum at edges

50. (b)

Wt. of soil = 260 gm

Wt. of pycnometer = 400 gm = w_1

Wt. of pycnometer + soil

= 400 + 260 = 660 gm = w_2

Wt. of pycnometer + soil + water

= 1415 gm. = w_3

Wt. of pycnometer + water

= 1275 gm. = w_4

Hence,

$$w = \left[\left(\frac{w_2 - w_1}{w_3 - w_4}\right)\left(\frac{G-1}{G}\right) - 1\right] \times 100$$

$$w = \left[\left(\frac{660-400}{1415-1275}\right)\left(\frac{2.75-1}{2.75}\right) - 1\right] \times 100$$

$$w = \left[\left(\frac{260}{140}\right) \times \frac{1.75}{2.75} - 1\right] \times 100$$

$$w = [1.1818 - 1] \times 100$$

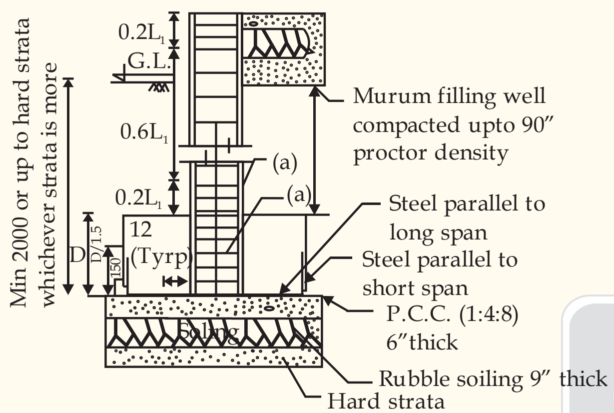
$$w = 18.2\%$$

51. (b)

Stone	Type	Uses
1. Granite	Igneous (Silicious)	Ornamental columns , sea walls,bridge piers, building blocks, railway ballast, in making of artificial stone.
2. Basalt or trap	Igneous (Siliceous)	Paving sets, road material, **aggregate in concrete**
3. Slate	Metamorphic rock formed from or mud stone	Making electrical switch board, as DPC, use in cisterns & urinal partition
4. Gneiss	Metamorphic rock	Street Paving
5. Sand stone	Sedimentary rock (silicious variety)	Coarse grained for ruffle work for slabs & tiles & fine grained for ashlar work, moulding etc.
6. Marble	Metamorphic rock (from limestone or dolomite)	Carving & decoration work, steps, wall liniques, table slabs, etc.
7. Laterite	Sedimentary (argillaceous)	As building stone, as road material

52. (a)

- **Soling**: Soling in the construction field is the bottom most layer of any component of structure.
- Soling may consist of bricks, stone cutting or such other building material having good crushing strength.
- It is done before laying the foundation, to provide better strength to the foundation.
- It is one of the most common techniques used for soil stabilization. It helps in enhancing the bearing capacity of soil.

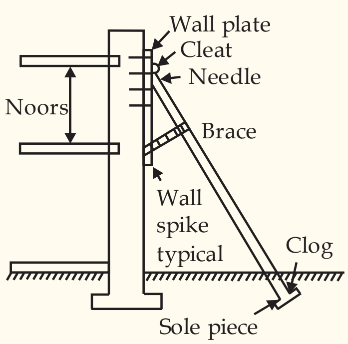


Typical detail of column and column links
Soling

Note:

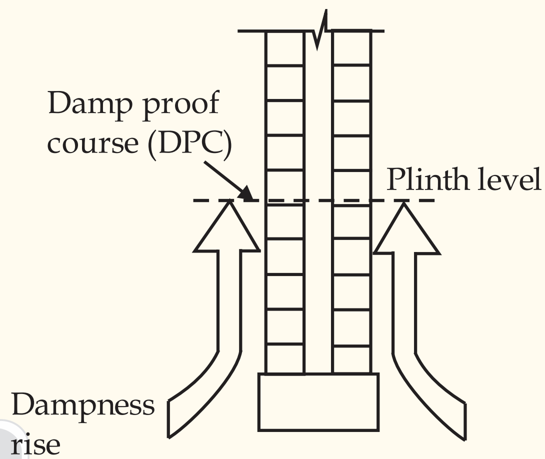
- Shoring is the technique of using a temporary support, usually form prop, to make a structure stable and safe.
- Shoring is often used to provide lateral support:

1. To walls undergoing repair or reinforcement.
2. During excavations
3. When an adjacent structure is to be pulled down.
4. When opening in a wall are made or enlarged.



A single raking timber shore

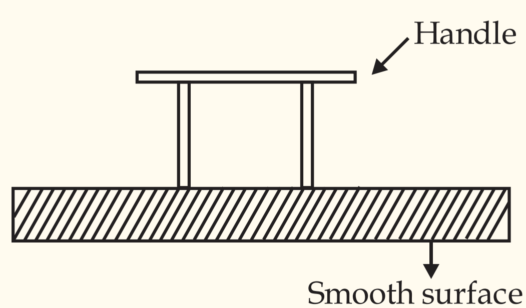
- **Damp Proof Course (D.P.C)** is a horizontal barrier in a wall designed to resist moisture rising through the structure by capillary action-a phenomenon known as rising damp.
- It is used to stop dampness in buildings.
- To avoid water from reaching to the walls DPC is laid at plinth level (the joint level of the wall and the foundations).



53. (b)

Screeding: Striking off the excess concrete to bring the top surface upto proper grade is called screeding. **It removes humps and hollow of uniform concrete surface.**

Floating: It is removal of all irregularities on the surface of concrete which are left after screeding. It is done by wooden float.



Wooden float

Trowelling: Final operation of finishing be done after all excess water has evaporated by steel float to give a very smooth finish.

Finishing: Process of levelling and smoothing the top surface of freshly placed concrete to achieve the desired appearance.

54. (b)

Quantity of water for different test are :

Type of Test	Water content used
Initial and Final setting time test	0.85P
Soundness test	0.78P
Compressive strength test	$(P/4+3)\%$ of combined weight of sand and cement
Tensile strength test	$(P/5+2.5)\%$ of combined weight of sand and cement

Where P is standard consistency of given cement sample

55. (a)

Dry Rot : Certain type of fungi feed on wood & during feeding they attack & convert it into dry powder form is known as Dry rot.

- This occurs due to lack of ventilation.

Wet Rot : Some variety of fungi Causes chemical decomposition of timber & convert timber into a grayish brown powder.

- Caused due to alternate dry & wet condition
- Improper seasoned wood exposed to air & wind.

56. (b)

Dormer window : A window set vertically in a structure projecting through a sloping roof. The purpose of Dormer window is to provide usable space in the loft and to provide an opening on the roof.

57. (b)

- **Aluminium :** If aluminium is in excess it causes shrinkage and warping of the brick during burning beams tool hard when burn.
- **Silica :** If silica is in excess it destroy the cohesion between particles and make brick brittle.
- **Lime :** If lime is in excess it causes brick to melt during burning & result in loss of the shapes.
- **Iron oxide :** If iron oxide is in excess it gives dark blue colour to brick
- **Magnesia :** If magnesia is in excess it leads to decay of brick

58. (b)

Field Irrigation Requirement (FIR):- It is defined as the amount of water required to meet the 'net irrigation requirements' plus the amount of water lost as surface runoff and through deep percolation.

$$FIR = \frac{NIR}{\eta_a}$$

Net Irrigation Requirement (NIR) : It is defined as the amount of irrigation water required to be delivered at the field to meet the evapotranspiration needs of a crop as well as the other needs such as leaching, presowing requirement and nursery water requirement.

$$NIR = CIR + LR + PSR + NWR$$

where,

LR = Leaching requirement

PSR = Presowing requirement

NWR = Nursery water requirement

CIR = Consumptive irrigation requirement

Consumptive Irrigation Requirement (CIR) : It is defined as the amount of irrigation water that is required to meet the evapotranspiration needs of a crop during its full growth.

$$CIR = C_u - R_e$$

C_u = Evapotranspiration or consumptive use of water

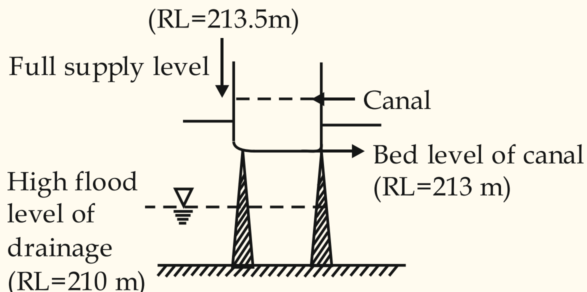
R_e = Effecfive rainfall during the growth of the crop

Gross Irrigation Requirement (GIR):- It is defined as the amount of water required to meet the field irrigation requirement plus the amount of irrigation lost in conveyance through the canal system by evaporation and by seepage.

$$GIR = \frac{FIR}{\eta_c}$$

$\therefore$ GIR > FIR > NIR > CIR

59. (a)



Aqueduct

Here the bed level of canal is above the top flood level of the drainage so the correct option will be **Aqueduct**.

60. (c)

Silt factor i.e. $f = 1.76\sqrt{m}$

So, $f \propto \sqrt{m}$ or $m^{1/2}$

61. (b)

Canal drop : It is an irrigation structure constructed across a canal to lower down its bed level to maintain the designed slope where change of ground level takes place.

Canal escape : It is a side channel constructed to remove surplus water from an irrigation channel (main canal, branch canal or distributory etc.) into a natural drain.

Canal cross regulator : Cross regulator is provided to control the supplies passing down the parent channel.

A cross regulator is provided on the parent channel at the d/s of the offtake to head up the parent channel to draw the required supply.

Canal outlet : It is a small structure built at the head of the water course so as to connect it with a minor or a distributory channel. It controls the discharge of water in water course.

62. (c)

Average depth of Rainfall over the catchment

$$= \frac{\Sigma P_i A_i}{\Sigma A_i} = \frac{6\times100+8\times200+10\times200}{100+200+200} = 8.4 \text{ cm}$$

63. (a)

Waterlogging is the saturation of soil with water. Soil may be regarded as waterlogged when it is nearly saturated with water much of the time. It can happen when the water table rises to the extent that the soil pores in the crop root zone. The result is a restriction in the normal supply of air in the soil, a decline in the levels of oxygen, and an increase in the levels of carbon dioxide and ethylene.

Effects of Waterlogging:

- Creation of Anaerobic condition in the crop root-zone.
- Growth of water loving wild plants.
- Falling of soil temperature
- Accumulation of harmful salts

64. (a)

For sample number-3:

DO after 5 days = 0 mg/l

Hence this data is to be neglected as nothing can be determined from this test.

Sample 1:

$$\text{BOD} = (DO_i - DO_f) \times \text{dilution factor}$$

$$= (9.2 - 6.9) \times \frac{300}{5} = 138 \text{ mg}/l$$

Sample 2:

$$\text{BOD} = (9.1 - 4.4) \times \frac{300}{10} = 141 \text{ mg}/l$$

$$\text{Average BOD} = \frac{138+141}{2} = 139.5 \text{ mg}/l$$

Note: Sample-3 data is excluded.

As $DO_f = 0$ for sample 3

Hence, BOD cannot be determined for this sample.

65. (b)

As per IS-10500:2012, Table 2

Permissible limit in absence of alternate source.

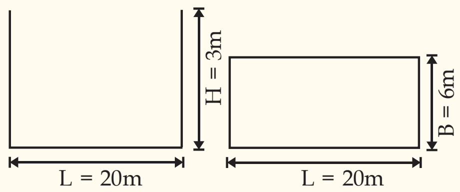
Chloride [as Cl^-]	Sulphate as $[SO_4]^{-2}$
1000 mg/l	400 mg/l

66. (c)

- Bleaching powder or chlorinated lime or calcium oxychlorite, having molecular formula as $CaOCl_2$
- This component is a white amorphous powder with pungent smell or chlorine.
- When freshly made, it contain **30% of available chlorine**.
- It is however, an unstable compound, and an exposure to air, light and moisture, it rapidly looses its chlorine content.

67. (b)

Given, Flow rate i.e. $Q = 0.6\ m^3/s$



Settling Basin

Surface overflow rate $(V_0) = \frac{Q}{B.L.} = \frac{0.6}{20\times6}$

$= 5 \times 10^{-3}$ m/sec

Settling velocity of particle $(V_s) = 0.004$ m/sec

$\%\ removal = \frac{V_s}{V_0} \times 100 = \frac{0.004}{0.005} \times 100 = 80\%$

68. (c)

- They have good insulation properties hence the temperature of water passing through such pipes is not effected by outside temperature.
- They possess high Hazen Williams constant and it results into adaptation of smaller size of PVC pipes compared to other conventional materials.
- They possess high coefficient of expansion as compared to cast-iron or galvanised-iron pipes.
- They have no problem of incrustation.

69. (b)

As per IS 1742 : 1983 (Reaffirmed 2007) clause 4.6.1.2, the sewer shall be designed for discharging **three times** the dry-weather flow flowing half-full with a minimum self-cleansing velocity of **0.75 m/s**.

70. (c)

Maximum water demand per day

$= [100 \times 200 \times 1.5]\ lt = 30000\ lt$

Average filtration rate $= 100\ lt/hr/m^2$

$= (100 \times 24) lt/day/m^2$

$\therefore$ Area of rapid sand filter required

$= \left[\frac{30000}{24\times100}\right] m^2 = 12.50\ m^2$

71. (b)

BOD = It is amount of oxygen required for biological decomposition of dissolved organic matter to occur at standard condition, time and temperature i.e. it indicates the amount of biodegradable matter of effluent

COD = It is used to measure the amount of oxygen required to chemical decomposition of total organic compound of water i.e. it indicates all oxidizable material but no information on their biodegradability

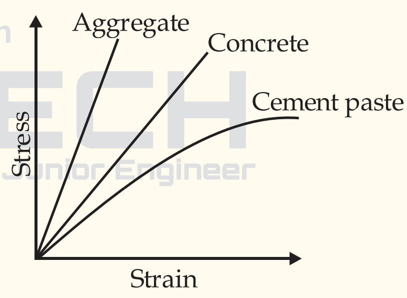
The ratio of COD/BOD helps to quality the biodegrability of effluent.

$\frac{COD}{BOD} < 2 \Rightarrow$ Readily biodegradable effluent

$\frac{COD}{BOD} = 2 - 4 \Rightarrow$ Moderate bidegradable effluent

$\frac{COD}{BOD} > 4 \Rightarrow$ Hardly biodegradable effluent

72. (b)



Stress strain for cement-paste:

The stress-strain curve for hardened cement paste is almost linear as shown in the figure.

Stress strain for aggregate:

The aggregate is more rigid than the cement paste and will therefore deform less (i.e. have a lower strain) under the same applied stress.

Stress strain for concrete:

The stress strain curve of concrete lies between those of the aggregate and the cement paste. However this relationship is non-linear over the most of the range.

73. (d)
If the sides of slab simply supported on edges (edges can be lifted) then factor multiplied with moment as follows

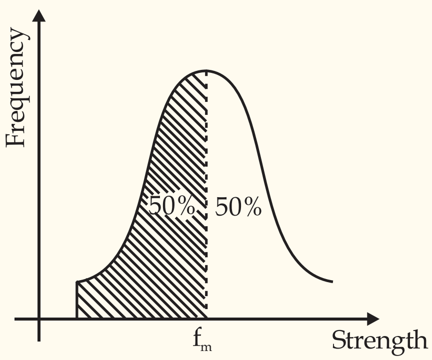
$$M_x = \left(\frac{r^4}{1+r^4}\right)\frac{wL_x^2}{8}$$

$$M_y = \left(\frac{r^4}{1+r^4}\right)\frac{wL_y^2}{8}$$

Where, $r = \frac{l_y}{l_x} = 1 \qquad [\because l_y = l_x]$

Hence, multiplied factor $= \frac{r^4}{1+r^4} = \frac{1^4}{1+1^4} = 0.5$

74. (c)



According to question, f_{ck} is defined as the strength below which 50% of test results are expected to fall according to curve.

Hence, $f_{ck} = f_{mean}$

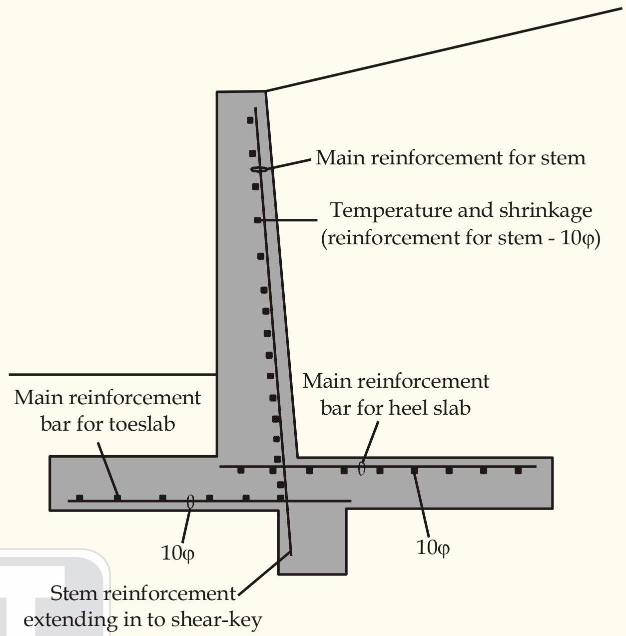
75. (a)
Depth of beam = 85 × 6 = 510 mm = 0.51 m
So, volume of beam = 0.51 × 6 × 0.23 = 0.7038 m^3
Weight of beam = Volume × Unit weight
= 0.7038 × 25 = 17.595 kN
Factored weight of beam = 1.5 × 17.595 = 26.39 kN

76. (c)
Diameter of lateral ties in column

$$\phi_{tie} = \text{greater of} \begin{cases} \dfrac{\phi_{\text{Largest longitudinal bar}}}{4} \\ 6\text{mm} \end{cases}$$

(Clause 26.5.3.2 (c)-2, IS-456)

77. (a)
In heel slab of cantilever retaining wall, main reinforcement is provided at top face of slab.



78. (c)
Effective width of Flange i.e. b_f is

$$b_f = \frac{l_o}{6} + b_w + 6d_f$$

Where,

l_o = Distance between points of zero moments (points of contraflexure) which may be taken as 0.7 times the effective span for continuous beams and for beams in frames.

b_w = Breadth of web

d_f = Thickness of flange

Hence,

$$b_f = \frac{3600}{6} + 300 + 6 \times 100 = 1500$$

or b_f = C/C distance between beams
= 3000 mm

Take least value of above two,

$\therefore \quad b_f = 1500\,\text{mm}$

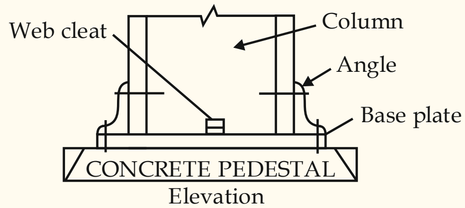
79. (c)

Explanation:

Column Base: It is used to transfer a load of steel columns to the concrete without any failure in the concrete.

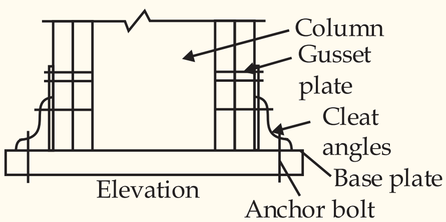
Types of column base:

1. **Slab base**: Slab base is generally used for axial loading.



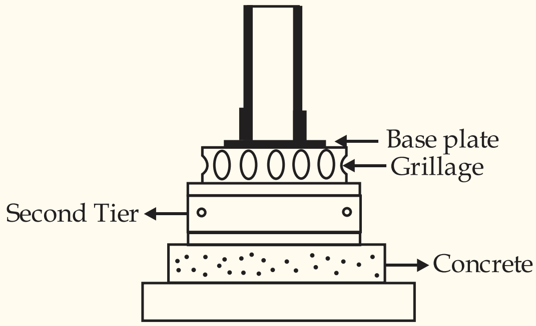
Slab Base

2. **Gusseted base**: Gusseted base is used for axial load and moment i.e. for eccentrically loaded steel column.



Gusseted Column Base

3. **Grillage foundation**: Grillage foundation is used when soil is very weak and load is to be transferred at shallow depth, it is also used for heavy-load steel columns to be rested on weak soil.



Grillage Foundation

80. (a)

The span of the bridge for which the total cost of the bridge is minimum is called economic span.

Let, the ratio of cost of one span 'S' to cost of one pier 'P' be R (i.e. $R = S/P$).

Then,

The overall cost of the considered bridge be

$C = nS + (n - 1) \times P$

Putting $S = RP$

$C = n(RP) + (n - 1)P$

where,

n = Number of spans

$(n - 1)$ = Number of piers

For C to be minimum,

$dC/dn = 0,$

$\Rightarrow PR + (-1) \times P = 0$

$\Rightarrow R = 1$

Hence,

S = P i.e. economical span is one for which the cost of one span is equal to one pier.

In other words, Economical span is defined as that span for which the total cost of the substructure is equal to the total cost of superstructure.

81. (d)

For double angles placed back to back on the same side of gusset plate,

Allowable working stress = $0.8\ \sigma_{ac}$

For compression member consisting of angle sections.

Sections	Type	Allowable compressive stress
1. Single or double angle	Continuous	σ_{ac}
2. Single angle connected with one rivet	Discontinuous	$0.8\sigma_{ac}$
3. Single angle connected with more than one rivet or with weld	Discontinuous	σ_{ac}
4. Double angles placed back to back on opposite sides of gusset plate	Discontinuous	σ_{ac}
5. Double angles placed back to back on same side of gusset plate	**Discontinuous**	$0.8\sigma_{ac}$

82. (b)

Given:-

$L = 60$ mm, $t = 6$ mm, $P_{PFW} = 15$ kN, $\tau_S = 200$ MPa

As we know that,

$P_{PFW} = 0.707 \times t \times L \times \tau_S$, (where PFW = Parallel fillet weld)

$$\Rightarrow \quad \frac{15\times10^3}{0.707\times6\times60} = \tau_S$$

$$\therefore \quad \tau_S = 58.9344 \text{ MPa}$$

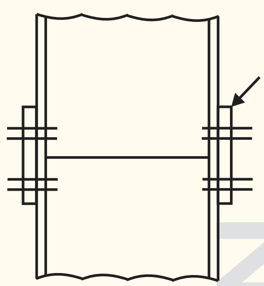
Given the shear strength of the material = 200 MPa

$$\therefore \text{Factor of safety} = \frac{200}{58.9344} = 3.4$$

83. (d)

The splice system shown in figure below is used to connect two column section having same cross section i.e. the flange of the upper storey column have full bearing over there of the lower storey column.

In this case no bearing plate and no filler plate is used, only splice plate is used.

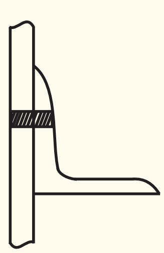


Note:

1. If the depth of upper column is smaller than the lower column means the flange of the above storey column rest over the web of lower storey column then both filler plate and bearing plate is used.
2. If the lower storey is much deeper than the upper storey column section, stiffener can be welded.

84. (b)

For a single angle connected by one leg only,



$$A_{net} = A_1 + kA_2$$

where,

A_1 = Effective net cross-sectional area of connected leg.

A_2 = Gross cross-sectional area of outstanding leg

$$k = \frac{3A_1}{3A_1 + A_2}$$

Here, $A_1 = a$, $A_2 = b$

$$\therefore \quad k = \frac{3a}{3a+b} = \frac{1}{1+0.33\frac{b}{a}}$$

Hence, $\quad A_{net} = a + k \times b$

$$\therefore \quad A_{net} = a + \frac{b}{1+0.33\frac{b}{a}}$$

85. (c)

As per IS 800 : 2007

Stiffener	Purpose
Intermediate transverse web stiffener	To improve the buckling strength of a slender web due to shear
Load carrying stiffener	To prevent local buckling of web due to concentrated loading.
Bearing stiffener	To prevent local crushing of web due to concentrated loading.
Torsional stiffener	To provide torsional restraint of beams and girder at supports
Diagonal stiffener	To provide local reinforcement to web under shear and bearing
Tension stiffener	To transmit tensile force applied to a web through flange

86. (a)

Joint efficiency (η): It is the ratio of the strength of the joint per pitch length to the original strength of plate per pitch length.

$$\eta = \frac{\text{Strength of joint per pitch length}}{\text{Original strength of plate per pitch length}}$$

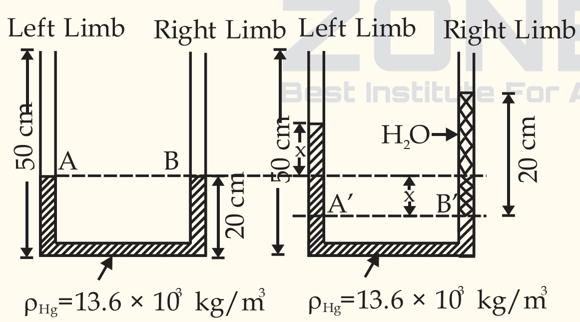
$$\eta = \frac{2556}{4260} = 60\%$$

87. (a)

- Purlin are design as a flexural member.
- It is used for supporting roofing material.
- Slope in purlin should not exceed by 30°.
- Live load on purlin is not more than 0.75 kN/m^2 and not less than 0.4 kN/m^2.
- Depth of purlin angle section should not be less than span/45
- Width of purlin angle section should not be less than span/60
- Maximum bending moment in purlin $= \frac{WL}{10}$

88. (b)

After addition of water in right limb, rise in left limb will be equal to fall in right limb due to conservation of volume.



Now equating pressure at section A' - B'

$$P_{A'} = P_{B'}$$

$$(13.6 \times 10^3)g \times (2x) = (10^3)\ g(20)$$

$$x = \frac{1.0}{3.6} = 0.735\ \text{cm}$$

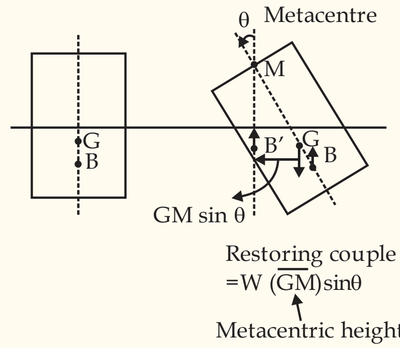
So, the new height (in cm) of mercury in the left limb will be

= Initial height of mercury in left limb + x

$= 20 + 0.74 = 20.74$ cm

89. (d)

The stability of a floating body is determined from the position of metacenter (M). If the point M is above G (Centre of gravity), the floating body will be in stable equilibrium.



Case (a): If M below G

BM < BG: Unstable equilibrium

Case (b): If M above G

BM > BG: Stable equilibrium

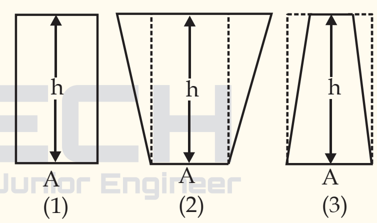
Case (c): If M at G

BM = BG; Neutral equilibrium

90. (d)

Bucket → Identical height

→ Identical base area



All three buckets have the same base area and of identical heights

$\Rightarrow \quad W_2 > W_1 > W_3$

Force on the base in each case will be $= \gamma_w hA$

Where, h & A for all three buckets are same

Hence, $\quad F_1 = F_2 = F_3$

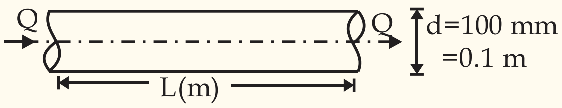
91. (c)

Bernoulli's equation is applicable for:

1. Flow along a stream line
2. When the effect of viscosity is negligible i.e., inviscid flow
3. Incompressible flow condition
4. Steady flow condition

Note: Even if flow is rotational, Bernoulli's equation can be applied between two points on the same stream line.

92. (c)



Head loss due to frictions,

$$h_L = \frac{fLQ^2}{12.1d^5}$$

Here, $f =$ friction factor

$$= \frac{64}{Re} = \frac{64}{800} = 0.08$$

$\therefore$ Head loss per metre length,

$$\frac{h_L}{L} = \frac{fQ^2}{12.1d^5} = \frac{0.08 \times (0.01)^3}{12.1 \times (0.1)^5}$$

$$\frac{h_L}{L} = \frac{0.8}{12.1} = 0.06611 \text{ meter/meter}$$

$$\frac{h_L}{L} = 66.11 \text{ meter/km}$$

93. (a)

The general equation for determining critical depth on the discharge rate and channel geometry is:

$$\frac{Q^2}{g} = \frac{A^3}{T}$$

Where,
g = Acceleration due to gravity,
A = Cross-sectional area,
T = Top width of water surface

Hence, it may be noted that the critical flow condition is governed solely by the **channel geometry and discharge**. Other channel properties such as bed slope and roughness do not influence the critical flow condition for any given discharge.

94. (d)

Mass density of water $= 1000 \text{ kg/m}^3$

As per given unit $= \frac{Kg\,sec^2}{m^4}$

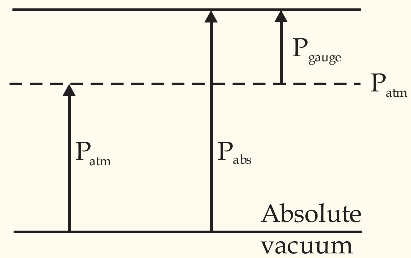
$$= \frac{Kg}{m^3 \times \frac{m}{sec^2}}$$

$$= \frac{Kg/m^3}{g}$$

For water $= \frac{1000\,kg/m^3}{9.81\,m/sec^2}$

$$= 101.9 \frac{Kg \times sec^2}{m^4}$$

95. (a)



$$P_{gauge} = P_{abs} - P_{atm}$$

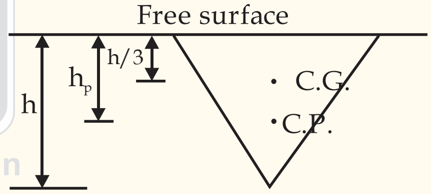
$$\therefore \quad P_{atm} = P_{abs} - P_{gauge}$$

96. (a)

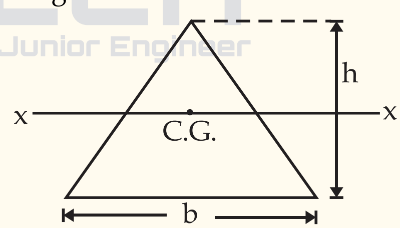
Centre of pressure $h_p = \bar{h} + \frac{I_{C.G.}\sin^2\theta}{A.\bar{h}}$

Here, $\theta = 90°$

$$\bar{h} = \frac{h}{3}$$



For triangle



For given figure

$$I_{C.G.} = \frac{bh^3}{36}$$

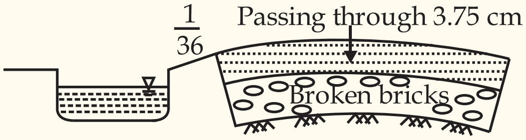
Hence, Centre of pressure $h_p = \frac{h}{3} + \frac{\frac{bh^3}{36} \times \sin^2 90°}{\frac{bh}{2} \times \frac{h}{3}}$

$$h_p = \frac{h}{3} + \frac{h}{6} = \frac{h}{2}$$

$$\therefore \quad \boxed{h_p = \frac{h}{2}}$$

97. (c)

Macadam Construction: This was the first method of scientific construction where the top layer was provided with higher strength compared to the bottom. A curved surface for the pavement with a slope of 1 in 36 along with side drains was recommended.



Macadam Model

98. (c)

Three road plans developed for the planning and construction of the road network are:

1st 20-year road plan	2nd 20-year road plan	3rd 20-year road plan
Nagpur Plan	Bombay Plan	**Lucknow Plan**
1943-1963	1961-1981	1981-2001
Total road length-5,32,700 km	Total road length-10,57,330 km	
Density-16 km road length/100 km^2 area	Density-32 km road length/100 km^2 area	Density-82 km road length/100 km^2 area
Pattern-star and grid		**Square and block pattern**
	1600 km Expressways have been considered	2000 km Expressways have been considered
Development allowance -15%	Development allowance-5%	
Roads are divided into 5 categories: NH, SH, MDR, ODR, VR	Every town with a population above 2000 in plains and 1000 in semi hilly areas and 500 in hilly areas should be connected by a metalled road.	Roads divided into 3 categories: Primary, Secondary, and Tertiary roads system.

99. (b)

$$w_s = \frac{V}{9.5\sqrt{R}} = \frac{80}{9.5\sqrt{225}} = .561\text{m}$$

100. (c)

- Present serviceability index is the measure of ability of a pavement to serve traffic.
- It is used for functional evaluation of pavement surface condition.
- It depends on
  - Longitudinal surface irregularities
  - Degree of cracking
  - Depth of rutting

Comparison between flexible pavement and rigid pavement:

Flexible Pavement	Rigid Pavement
It is less suitable for stage construction	It is more suitable for stage construction
Temperature variations do not produce stresses	Temperature changes induce heavy stresses
It transfers the load by grain-to-grain contact	It distributes the load over wide area because of its high rigidity.

101. (b)

The legal axle load used for the design of pavements is 8.2 tonnes; usually they are expressed in msa (million standard axles).

102. (b)

The specifications for the highway are prepared by MORTH, which is the Ministry of Road Transport and Highway. The Ministry of Road Transport and Highways is a ministry of the Government of India, is the apex body for formulation and administration of the rules, regulations and laws relating to road transport, and transport research, in order to increase the mobility and efficiency of the road transport system in India. Road transport is a critical infrastructure for economic development of the country. It influences the pace, structure and pattern of development. In India, roads are used to transport over 60% of the total goods and 85% of the passenger traffic. Hence, development of this sector is of paramount importance for the India and accounts for a significant part in the budget

103. (a)

Radius beyond which no superelevation required $= R_0$

$$\because \quad R_0 = \frac{V^2}{225(e)_{min}}$$

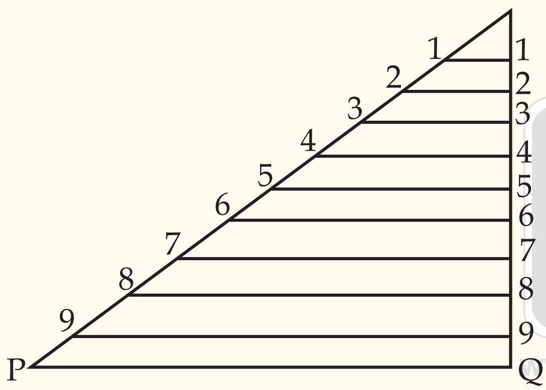
$$= \frac{V^2}{225 \times \text{camber of road}}$$

$$= \frac{(80)^2}{225 \times \frac{3}{100}}$$

$$= 948.15 \text{ m} \approx 950 \text{ m}$$

104. (a)

Diagonal scale: On diagonal scale, it is possible to measure three dimensions such as meters, centimeters and decimeters.



1-1 represent 1/10 PQ;
2-2 represent 2/10 PQ

105. (b)

Given,
Focal length of objective (f) = 20 cm = 200 mm
Stadia interval (i) = 4 mm = 0.4 cm
Staff intercept (S) = 1 m
Additive constant (C) = zero
So, Horizontal distance i.e. D = KS + C

Where, $K = \frac{f}{i} = \frac{20\text{cm}}{0.4\text{cm}} = 50$

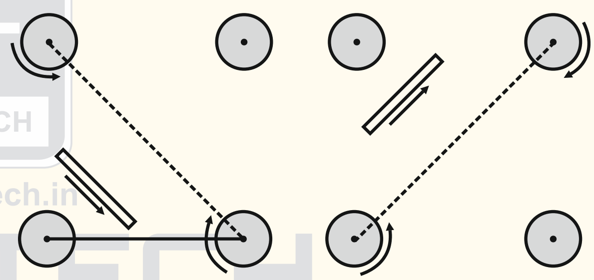
Hence, D = KS + C = 50 × 1 + 0 = 50 m

106. (c)

When the theodolite has a four-screw levelling head, the following procedure is adopted.

1. After setting up and centring the theodolite, bring the plate level parallel to any one pair of diagonally opposite foot screws. Operate these foot screws to centre the bubble (shown in figure below)
2. Swing the instrument to bring the plate level parallel to the other pair of foot screws. Centre the bubble.
3. Swing it back to the previous position. Check whether the bubble traverses. If it does not, centre it with the foot screws to which the level is parallel.
4. Swing it back, check the position of the bubble, and repeat the procedure.
5. Once the bubble traverses in the two orthogonal positions, swing it through 180°. The bubble should traverse in this position or in any other position.

If two plate levels are provided, the procedure is the same. Bring one plate level parallel to a pair of opposite foot screws. The other pair will be parallel to the remaining pair of foot screws. There is no need to swing the instrument. Bring the bubble to the central position alternately and check in the other positions.



Four-foot-screw levelling head

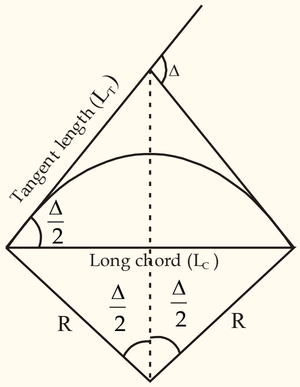
107. (a)

Chaining is the process of measuring the length of series of a straight lines with tape or chain and then locating the details on the ground relative to these lines.

Ranging is the process of locating a number of points on the long survey line.

- A building is an obstacle to both chaining and ranging.
- A river is an obstacle to chaining but not ranging.
- A hill is an obstacle to ranging but not chaining

108. (c)



Tangent length i.e. L_T is

$$L_T = R\tan\frac{\Delta}{2} \qquad \text{... (i)}$$

Length of long chord i.e. L_C is

$$L_C = 2R\sin\frac{\Delta}{2} \qquad \text{... (ii)}$$

As mentioned in question, equating equation (i) with equation (ii)

$$2R\sin\frac{\Delta}{2} = R\tan\frac{\Delta}{2}$$

$$\sin\frac{\Delta}{2} = \frac{1}{2}\tan\frac{\Delta}{2}$$

$$\cos\frac{\Delta}{2} = \frac{1}{2}$$

$$\frac{\Delta}{2} = 60°$$

Hence, $\Delta = 120°$

109. (d)

Actual extension

$$\Delta_1 = \frac{4PL}{\pi d_1 d_2 E}$$

Extension based on average diameter

$$\Delta_2 = \frac{4PL}{\pi\left(\frac{d_1+d_2}{2}\right)^2 E}$$

Assuming $\Delta_1 > \Delta_2$

$$\text{So, } \Delta_1 = \frac{4PL}{\pi d_1 d_2 E} > \Delta_2 = \frac{4PL}{\pi\left(\frac{d_1+d_2}{2}\right)^2 E}$$

$$\Rightarrow \left(\frac{d_1+d_2}{2}\right)^2 > d_1 d_2$$

$$\Rightarrow \frac{d_1^2+d_2^2+2d_1d_2}{4} - d_1d_2 = 0$$

$\Rightarrow (d_1 - d_2)^2 > 0$ which is true.

110. (a)

$$\frac{I_{NA}}{Z} = \frac{I_{NA}}{I_{NA}/Y_{max}} = Y_{max}$$

For a solid circular cross-section,

$$Y_{max} = d/2$$

Hence,

$$\frac{I_{NA}}{Z} = Y_{max} = d/2$$

111. (a)

Elastic critical stress,

$$\sigma = \frac{\pi^2 E}{\lambda^2}$$

$$\because \ \sigma \propto \frac{1}{\lambda^2}$$

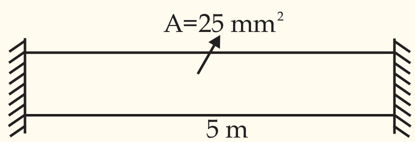
Where, λ = slenderness ratio

$$\lambda = \frac{\text{Effective length}}{\text{Radius of gyration}}$$

Effective length - Effective length is the length of the equivalent pinned-end member, or the distance between points of inflection in the deflection curve. It depends on the boundary condition at the end of member.

Hence, Elastic critical stress in compression is inversely proportional to the slenderness ratio, i.e., elastic critical stress in compression increases with decrease in slenderness ratio.

112. (b)



Change in temperature,

$\Delta t = 50°C$

$E_{st} = 0.2\ MN/mm^2 = 0.2 \times 10^6\ N/mm^2$

$\alpha_{steel} = 0.000012$ per °C $= 12 \times 10^{-6}$ per °C

Restricted deformation due to temperature change

$$= L\alpha\Delta t$$

This restricted deformation results in thermal stresses. Let it be σ

$$L\alpha\Delta t = \frac{\sigma L}{E}$$

$$\Rightarrow \quad L \times 12 \times 10^{-6} \times 50 = \frac{L \times \sigma}{0.2 \times 10^6}$$

$$\therefore \quad \sigma = 120 N/mm^2$$

113. (b)

Cast iron is a brittle material which has tensile strength < shear strength < compressive strength

- **In compression test-**

Failure in cast iron is due to shear failure, that is along an oblique plane.

- **In tensile test-**

Failure in cast iron is due to tensile failure, that is along the perpendicular cross-section.

114. (c)

For uniform strength of beam subjected to bending moment, M

Section modulus (z) is given as

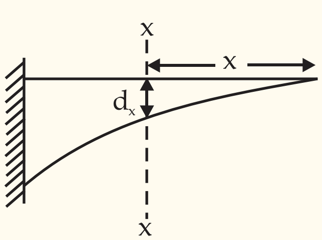
$$Z = \frac{1}{y} = \frac{\frac{bd_x^3}{12}}{\frac{d_x}{2}}$$

$$\Rightarrow \quad Z = \frac{bd_x^2}{6}$$

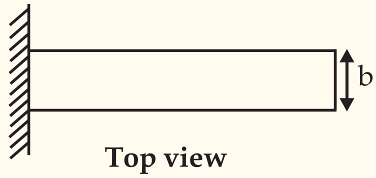
$$\sigma_{max} = \frac{M}{Z} = \frac{6M}{bd_x^2}$$

$$\Rightarrow \quad \boxed{d_x \propto \sqrt{M}}$$

(as width and strength is kept constant)



Side view



Top view

Note: Depth is constant and width varying, then

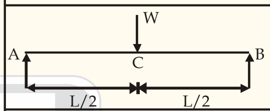
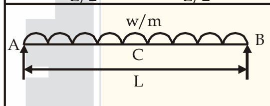
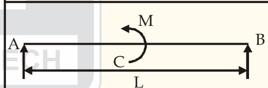
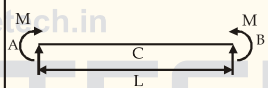
$$\sigma_{max} = \frac{M}{Z} = \frac{6M}{b_x d^2}$$

[$\because \sigma_{max}$ & d is kept constant]

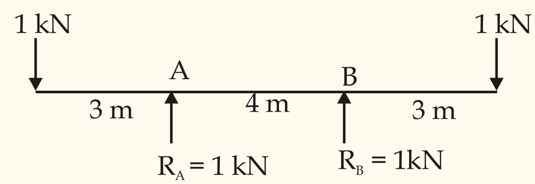
$$\boxed{b_x \propto M}$$

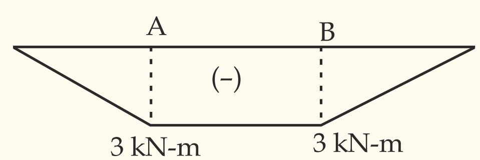
115. (c)

Deflection and slope of simply supported beams are given by:

Loading Condition	Deflection	Slope
	$y_C = \frac{WL^3}{48EI}$	$\theta_A = \theta_B = \frac{WL^2}{16EI}$
	$y_C = \frac{5}{384}\frac{wL^4}{EI}$	$\theta_A = \theta_B = \frac{wL^3}{24EI}$
	$y_C = 0$	$\theta_A = \theta_B = \frac{ML}{24EI}$
	$y_C = \frac{ML^2}{8EI}$	$\theta_A = \theta_B = \frac{ML}{2EI}$

116. (a)





BMD

As we know that -

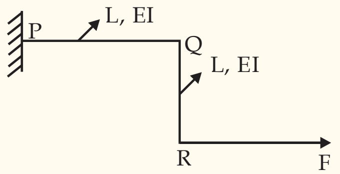
$$\frac{\sigma}{y} = \frac{M}{I}$$

$$\because \quad M_{max} = 3 \text{ kNm (Hogging)}$$

So, $\sigma_{max} = \frac{M}{I} \cdot y_{max}$

$$\sigma_{max} = \frac{3\times10^6}{3\times10^6} \times 70 = 70 \text{ MPa}$$

117. (b)



As we know that by Castigliano's theorem:

$$(\delta_H)_R = \frac{\partial U}{\partial F}$$

Where,

U = Total strain energy = $U_{PQ} + U_{QR}$

$$U = \frac{M^2L}{2EI} + \int_0^L \frac{(M_{x\text{-}x})^2 (dx)}{2EI}$$

$$U = \frac{(FL)^2 L}{2EI} + \int_O^L \left(\frac{(Fx)^2 (dx)}{2EI}\right)$$

$$U = \frac{F^2L^3}{2EI} + \frac{F^2L^3}{6EI} = \frac{2F^2L^3}{3EI}$$

Hence, $(\delta_H)_R = \frac{\partial U}{\partial F}$

$$(\delta_H)_R = \frac{4FL^3}{3EI}$$

118. (a)

In ILD we analyze effect of a force or moment on a fixed point by constantly varying point of application of load/moment.

119. (d)

Static indeterminacy of 2-D Rigid frame,

$D_S = 3m + r_e - 3j - r_r$

Where,

m = Number of members = 9

r_e = Total external reactions = 3

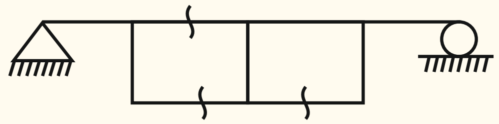
j = Number of joints = 8

r_r = Released reactions = 0

So, $D_S = 3 \times 9 + 3 - 3 \times 8 - 0$

$D_S = 6$

Alternative solution:



Static indeterminacy of 2-D Rigid frame,

$D_S = 3C - r$

Where,

C = Number of cut required to make open tree like structure = 3

R = Number of restraint required to make supports rigid = 3

So, $D_S = 3 \times 3 - 3$

$= 6$

120. (a)

Clapeyron's theorem of three moment's equation is derived using Mohr's first and second moment theorems. This theorem can be comfortably used for **simply supported and continuous beams** (even when there is support settlements). It is not applicable to fixed supports.

But in case of a fixed end of a continuous beam, to apply the Clapeyron's theorem of three moments we assume the following things:

1. Imaginary length (Zero length)
2. **Infinite stiffness**
3. Replacing fixed end with simply supported end.

∴ The answer is **Infinite stiffness**.