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Detailed Solutions

ESE-2019 Mains Test Series

Civil Engineering Test No : 9

Section A : Water Resource Engineering + Building Materials + Railway & Airport

Q.1 (a) Solution:

Water requirements per hectare:

(i) 1 to 15 days i.e. 15 days @ 0.2 cm/day

$$= \frac{15 \times 0.2}{100} \times 10^4 = 300 \text{ m}^3$$

(ii) 16 to 40 days i.e. 25 days @ 0.3 cm/day

$$= \frac{25 \times 0.3}{100} \times 10^4 = 750 \text{ m}^3$$

(iii) 41 to 50 days i.e. 10 days @ 0.5 cm/day

$$= \frac{10 \times 0.5}{100} \times 10^4 = 500 \text{ m}^3$$

(iv) 51 to 55 days i.e. 5 days @ 0.1 cm/day

$$= \frac{5 \times 0.1}{100} \times 10^4 = 50 \text{ m}^3$$

$$\text{Pre-sowing requirement} = \frac{5}{100} \times 10^4 = 500 \text{ m}^3$$

$\therefore$ Total water requirement per hectare = 2100 m^3

Effective rainfall /hectare from 36th to 45th day (i.e. 10 days)

$$= \frac{3.5}{100} \times 10^4 = 350 \text{ m}^3$$

Net water quantity to be delivered per hectare = 2100 – 350 = 1750 m^3

$\therefore$ Net quantity for water to be delivered for 50 hectares = 50 × 1750 = 87500 m^3

Q.1 (b) Solution :

(i) Lime putty: It is obtained by adding hydrated lime to water, stirring to the consistency of a thick cream and allowing it to stand and mature for a period of about 16 hours in the case of non-hydraulic lime before using. The putty so obtained should be protected from drying out.

(ii) Revibration: The delayed vibration of concrete, already placed and compacted is known as revibration. When successive top layers are vibrated, some vibration is transferred to bottom layers. It is beneficial since the quality of concrete improves as the entrapped air and water escape and also the rearrangement of particles takes place.

(iii) Mobility and Placeability: The term mobility is used to indicate the consistency of mortar. The placeability is the case with which the mortar mix can be applied with a minimum cost in a thin and uniform layer on the surface. Depending on its composition, a mortar may have a consistency ranging from the stiff to fluid. Mortars for masonry, finishes and other works are made sufficiently mobile. The mobility of mortar mix determines its placeability.

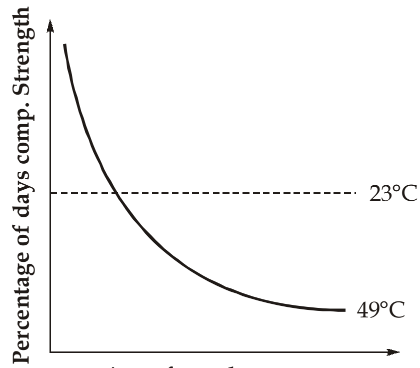
Q.1 (c) Solution:

(i) The advantages of accelerated curing are as follows:

1. The moulds can be removed within a shorter time.
2. Due to shorter period, production gets increased and cost gets reduced.

Method of steam curing

The concrete members are heated by steam at 93°C either at low pressure or high pressure. In low pressure steam curing, about 70 percent of the 28 days compressive strength of concrete can be obtained in about 16-24 hrs. High pressure steam curing is usually used in precast concrete members and gives 28 days compressive strength at 24 hours. The effect of curing temperature on compressive strength of concrete is shown below:

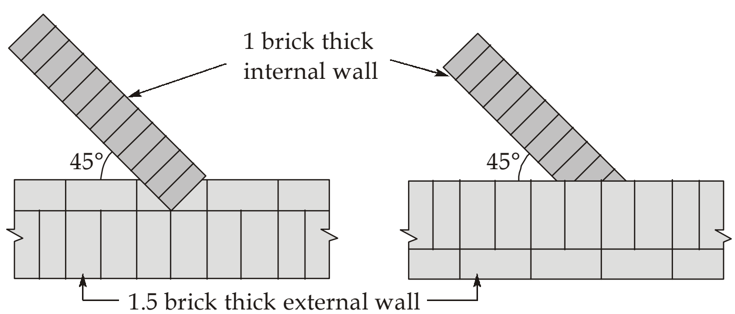


It also results in increased resistance to sulphate action and resistance against freezing and thawing.

(ii) Squint Junction:

A squint junction is formed when an internal wall meets an external continuous wall at an angle other than 90°. Usually, the angle of squint is kept at 45°, though squint junctions are not very common in brickwork.

1. Squint junction in English bond:



Squint junction in English bond

The above figure shows a squint junction between a 1½ brick thick external wall and a 1-brick thick internal wall, both being constructed in English bond. The header course of the cross-wall is taken inside the main wall, thus getting the required bond. Alternate courses of both the walls remains unbonded.

Q.1 (d) Solution:

(a) Corrections to runway take-off length

(i) Correction for elevation $= \frac{7}{100} \times 2500 \times \frac{150}{300} = 87$ m

$\therefore$ Corrected length $= 2500 + 87 = 2587$ m

(ii) Correction for temperature

Rise of temperature = 24 – 14.025 = 9.975°C

$$\text{Correction} = \frac{2587}{100} \times 9.975°C = 258 \text{ m}$$

$\therefore$ Corrected length = 2587 + 258 = 2845 m

(iii) Check for total correction for elevation plus temperature

$$\text{Total correction in percent} = \frac{2845 - 2500}{2500} \times 100 = 13.8 \text{ percent}$$

According to ICAO the total correction for (i) and (ii) should not exceed 35 percent.

(iv) $$\text{Correction for gradient} = \frac{20}{100} \times 2845 \times 0.5 = 284 \text{ m}$$

Corrected length = 2845 + 284 = 3130 m (say)

(b) Correction to runway landing length

(i) $$\text{Correction for elevation} = \frac{7}{100} \times 3000 \times \frac{150}{300} = 105 \text{ m}$$

Correction runway landing length = 3000 + 105 = 3105 m

No corrections are needed to landing length for temperature and gradient.

$\therefore$ Actual runway length to be provided would be greater of (a) and (b) above = 3130 m.

Q.1 (e) Solution:

(i) Artificial harbours : The harbours where natural formations such as creeks and basins are not available to afford protection from storms or waves by natural configuration of land, have to be created artificially by the use of engineering skills are called artificial harbours.

(ii) Groynes : The structure built to protect beach or retard erosion of an existing or restored beach by trapping of littoral drift are called groynes. They also protect the toes of sea walls or bulk head.

(iii) Littoral drift : The exposed coasts are subjected to erosion at certain sections and siltation at some other sections due to wind and waves striking the shore. These waves tend to stir up and move the lighter particles of sand in suspension. The process of movement and deposition of sand near the fore shore is known as littoral drift.

(iv) Wharves : The landing platforms or places in the form of walls built near the shore for vessels to berth are known as wharves.

Q.2 (a) Solution:

(i)

Following methods of river training are commonly used:

1. **Embankments:** The floods may be prevented from submerging the country by constructing earth embankments. They are designed and constructed in the same way as an earth dam. The embankments are generally constructed parallel to the river channel.
2. **Guide banks or Bell's bunds:** Rivers in flood plains submerge very large areas during flood periods. Naturally when some structure is to be constructed across such a river, it is very expensive to construct the work spanning whole width of the river. To economise this, some training work may be constructed to confine the flow of water within a reasonable waterway.

   Guide banks are meant for guiding and confining the flow in a reasonable waterway at the site of the structure.
3. **Spurs or Groynes:** They are the structures constructed transverse to the river flow. They extend from the bank into the river.

   Groynes serve following purposes:

   (i) They protect the river banks by keeping the flow away from it.

   (ii) They create still pond along a bank with the aim of silting up the area in the vicinity.They train the river to flow along a course by attracting, deflecting or repelling the flow.

   (iii)They contract the wide river channel for improving the navigation depth. Groynes can be classified according to the method of construction as (a) Permeable, and (b) Impermeable.

   Groynes can also classified according to the functions they serve as (a) Attracting type (b) Deflecting type and (c) Repelling type.
4. **Bed pitching and bank revetment:** Sometimes to protect the bed and bank against action of water, protection is provided by laying a closely packed stone blocks or boulders or even concrete blocks. This permanent revetment and pitching counteracts the general tendency of the water to notch away the material from bed and banks.

5. **Dredging of river:** To improve navigability of the river channel, the river section may need to be excavated. This excavation is carried out to increase the depth of flow. The process of underwater excavation is termed as dredging. The machinery used for the purpose is called as dredger.

(ii)

For spillway,

Design head, $H = 17$ m

Slope of downstream face, $\frac{dy}{dx} = 0.8\text{ H} : 1\ V = \frac{1}{0.8} = 1.25$

$\{\because\ x^n = kH^{n-1} \times y; \quad n = 1.85, k = 2\}$

Using downstream profile, $x^{1.85} = 2yH^{0.85}$

$\Rightarrow \quad y = \frac{x^{1.85}}{2 \times (17)^{0.85}} = \frac{x^{1.85}}{22.23}$

$\Rightarrow \quad \frac{dy}{dx} = \frac{1.85x^{0.85}}{22.23} = \frac{x^{0.85}}{12.02}$

For downstream face, $\frac{dy}{dx} = \frac{x^{0.85}}{12.02} = 1.25$

$\Rightarrow \quad x = 24.24$ m

For $x = 24.24$ m, $y = \frac{(24.24)^{1.85}}{22.23} = 16.38$ m

So end point co-ordinates are (24.24 m, 16.38 m)

Q.2 (b) Solution:

(i)

Functions of ballast in a railway track:

(a) To transfer and distribute the load from sleeper to a larger area of formation (embankment).

(b) To provide longitudinal and lateral stability to rails of track.

(c) To provide elasticity and resilience to track for better and comfortable ride.

(d) To keep track above soil and better drainage.

(e) To provide flexibility to maintain evenness and alignment of track.

Requirements of a good ballast material:

(a) It should be tough and wear resistant.

(b) It should be hard with high crushing resistant.

(c) It should be cubical having sharp edges.

(d) It should be nonporous and able to provide good drainage to track.

(e) It should be durable and weather resistant.

(f) It should be cheap, economical and easily available.

(g) It should resist attrition.

(ii)

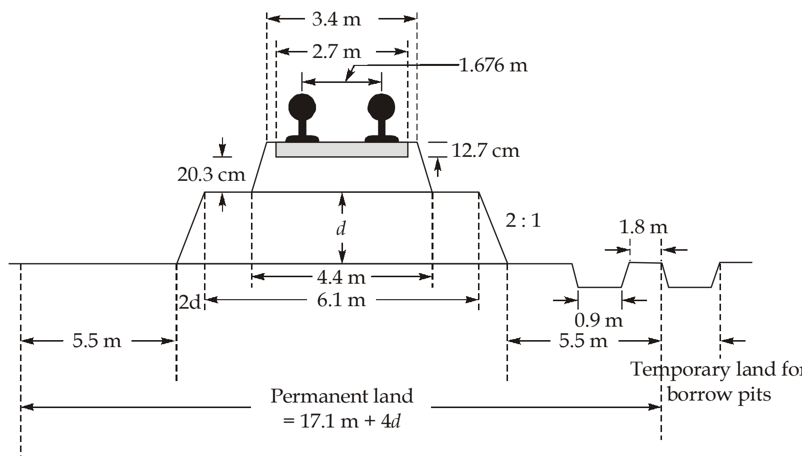


Fig. Cross-section of BG track on embankment (On a straight track)

Q.2 (c) Solution:

The defects occurring in the timber are grouped into the following division:

1. **Defects due to conversion:** During the process of converting timber into commercial form, the following defects may occur.
   - **(a) Chip mark:** The defect is indicated by marks or signs placed by chips on the finished surface of timber
   - **(b) Diagonal grain:** This defect is formed due to improper sawing of timber.
   - **(c) Torn grain:** This defect is caused when a small depression is formed on the finished surface of timber by falling of a tool.
   - **(d) Wane:** This defect is denoted by the presence of original rounded surface on the manufactured piece of timber. Fungi defect takes place when moisture > 20% and air is present in surrounding.

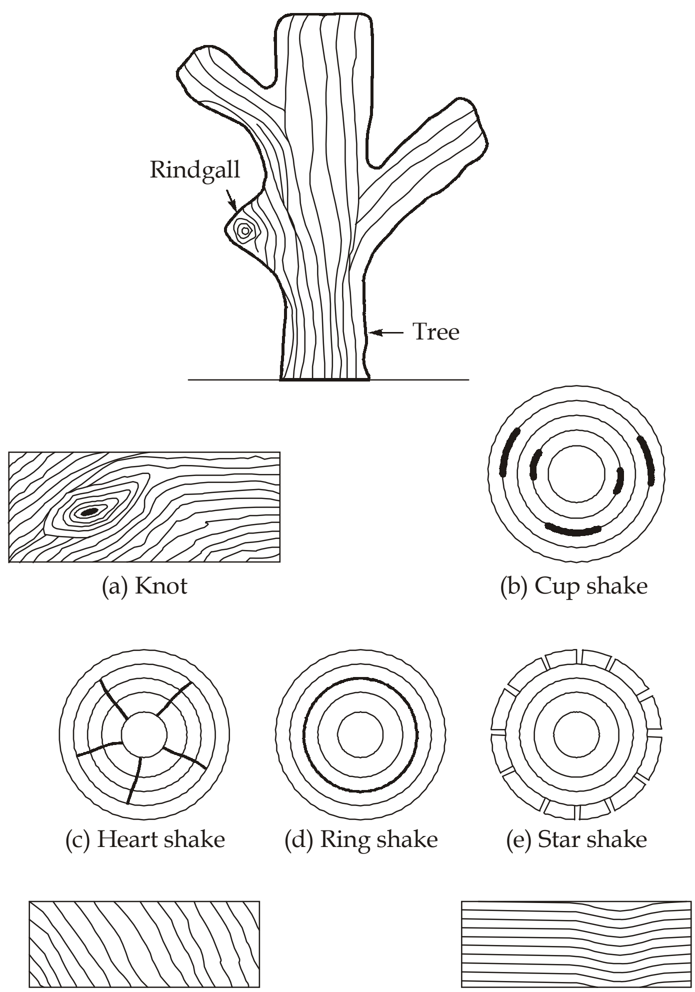
2. **Defects due to fungi:** The following defects are caused in timber by the fungi.
   - **(a) Blue stain:** The sap of wood is stained to bluish colour by action of certain kind of fungi.
   - **(b) Dry rot:** The fungi of certain type feed on wood and during feeding, they attack on wood and convert it into dry powder form. This is known as the dry rot. It occurs where there is no free circulation of air, absence of sunlight, presence of sap.

(c) **Brown rot:** The fungi of certain type remove cellulose compounds from wood and hence the wood assumes the brown colour. This is known as brown rot.

(d) **Wet rot:** Some varieties of fungi causing chemical decomposition of wood of the timber and in doing so, they convert timber into a greyish brown powder.

(e) **White rot:** Fungi attack lignin of wood and wood assumes the appearance of a white mass consisting of cellulose compounds.

3. Defects due to Natural forces



(a) Knot (b) Cup shake

(c) Heart shake (d) Ring shake (e) Star shake

(f) Twisted fibres (g) Upset

(a) **Shakes:** Shakes are longitudinal separations in the wood between rings. These lengthwise separations reduce the allowable shear strength.

- **Heart shake:** Occurs due to shrinkage of heart wood, when tree is overmatured. Cracks starts from pitch and run towards sap wood.

- **Cup shake:** Appears as curved split which partly or wholly separates annual rings from one another.
- **Star shake:** These are radial splits or cracks wide at circumference and diminishing towards the centre of the tree.

(b) **Rindgall:** Rindgall is characterized by swelling caused by the growth of layers of sap wood over wounds after the branch has been cut off in an irregular manner.

(c) **Knots:** Knots are bases of twigs or branches buried by cambial activity of the mother branch.

(d) **Twisted fibres:** Twisted fibres are caused by high speed wind which constantly turns the trunk of young tree in one direction.

4. **Defects due to seasoning:** There may be following defects due to seasoning of timber.

(a) **Bow:** It is a curvature of the timber in the direction of its length.

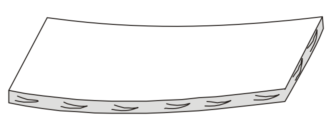
(b) **Cup:** A curvature in the transverse direction of the timber.

(c) **Twist:** It is a spiral distortion along the length of the timber.

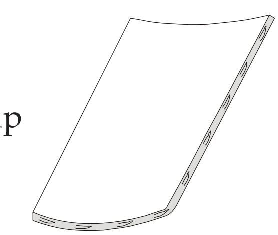
(d) **Spring:** It is a curvature of the timber in its own plane due to unequal shrinkage in radial and tangential direction.

(e) **Warp:** When a piece of timber has twisted out of shape, it is said to have warped.

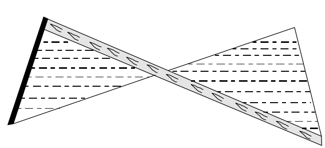
(a) Bow



(b) Cup



(c) Twist



5. **Defects due to insects:**

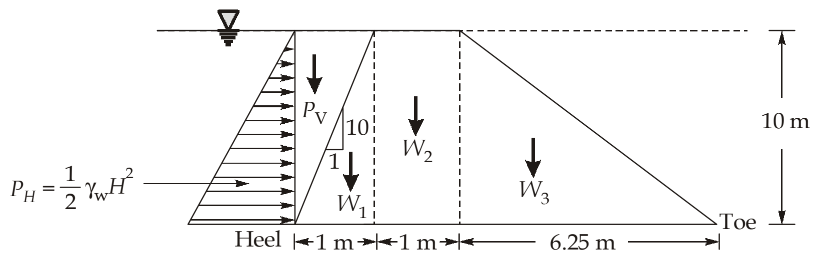
(a) **Beetle:** They form pin holes to attack the sap wood and convert timber into flour like powder. They do not attack shell or cover of timber, hence it looks sound from outside but weak from inside.

(b) **Marine Borers:** Found in salty water make holes of bore tunnels in wood for taking shelters.

(c) **Termites:** Known as white ants found abundantly in tropical and subtropical climate eat core of wood very fast.

Q.3 (a) Solution:

The cross section of the masonry dam is shown in the figure below



All the forces will be calculated by considering unit length of masonry dam. Let W be the self weight of the masonry dam, P_H be the horizontal force due to water and P_V be the vertical force due to triangular block of water. Neglecting uplift forces, we calculate the respective parameters as tabulated below:

Force	Description	F_V (tonnes)	F_H (tonnes)	LA from toe(m)	M_R (t.m)	M_0(t.m)
W_1	$(+)\frac{1}{2}\times 1\times 10\times 1\times 2240$	11.2 t	-	7.583	84.93	-
W_2	$(+)\, 1\times 10\times 1\times 2240$	22.4 t	-	6.75	151.20	-
W_3	$(+)\frac{1}{2}\times 6.25\times 10\times 2240$	70.0 t	-	4.17	291.90	-
P_V	$(+)\frac{1}{2}\times 1\times 10\times 1000$	5.0 t	-	7.92	39.6	-
P_H	$(-)\frac{1}{2}\times 1000\times 10^2\times 1$	-	(–) 50 t	3.33	-	(–) 166.5
		ΣF_V = 108.6 t	**ΣF_H = –50 t**		**ΣM_R = 567.63 t-m**	**ΣM_0 = – 166.5 t-m**

(i) Factor of safety against overturning about toe is given by

$$F_0 = \frac{\Sigma M_R}{\Sigma M_0} = \frac{567.63}{166.5} = 3.409 > 1.5 \quad \text{(Hence OK)}$$

Thus, the masonry dam is safe against overturning.

(ii) Factor of safety against sliding is given by

$$F_S = \frac{\mu \Sigma F_V}{\Sigma F_H} = \frac{0.75\times 108.6}{50} = 1.63 > 1 \quad \text{(Hence OK)}$$

Thus, the masonry dam is safe against sliding too.

(iii) Shear friction factor $= \frac{\mu \Sigma F_V + bq}{\Sigma F_H}$

where b = width of dam at the joint = 8.25 m

q = permissible shear stress at the joint = 14 kg/cm^2

$\therefore$ Shear friction factor = $\dfrac{(0.75 \times 108.6) + (8.25 \times 14 \times 10^{-3} \times 10^{4})}{50} = 24.73 > 3$

Thus, the dam is safe in shear friction factor criterion too.

Q.3 (b) Solution:

(i)

Actual operations in the construction of a tunnel depend upon the size of the tunnel, kind of formation encountered and method of attacking the heading etc. However, following operations may be carried out during construction of a tunnel :

- Setting up and drilling.
- Loading holes with explosives and firing them.
- Ventilations and removing the dust after explosion.
- Loading and hauling muck.
- Removing ground water if necessity arises.
- Erecting supports for sides and roof if necessary.
- Placing reinforcement.
- Placing concrete lining.

(ii)

Mechanical ventilation : The mechanical ventilation can be provided by one or more electric fans or blowers, which may blow fresh air into the tunnel and/or exhaust the foul air and dust etc. from the tunnel.

Systems of mechanical ventilation

There are following three systems of mechanical ventilation

1. **Blowing :** In this method the fresh air is blown or forced by one or more motor driven fans through a light weight pipe or a fabric duct near the working face. As it flows back to the portal through the tunnel it carries gasses and dust along with it.

Advantages:

This method has the advantage of supplying fresh air right near the working face.

Disadvantages:

This method has the following disadvantages:

- Foul air, smoke and dust move slowly out of tunnel, as they travel a long distance from face to portal.
- In long tunnels, the fumes etc. form a fogging atmosphere in the tunnel, thereby reducing the visibility.

- The approach to the working face from portal become unhealthy with poor visibility.

2. **Exhausting method :** In this method, the foul air and dust are drawn into an exhausting duct near the working faces, creating a flow of fresh air into the tunnel from the entrance or portal. For this method, a rigid pipe is essential to prevent it from collapsing under partial vacuum.

Advantages:

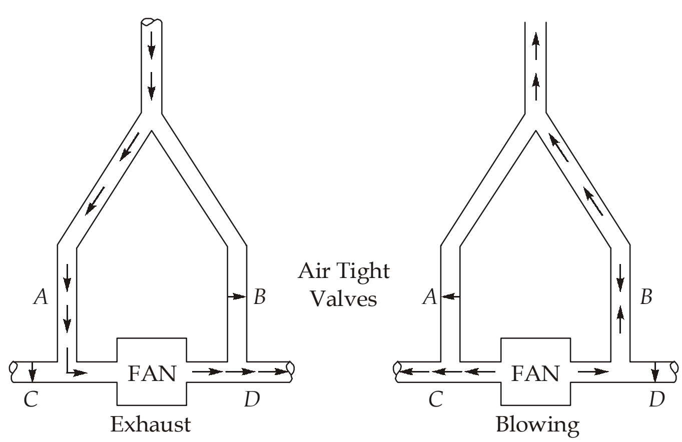
This method has the special advantage of quick removal of dust, foul gasses and smoke etc. from the working face.

Disadvantages:

This method has the following draw backs:

- The fresh air has to travel a long distance before reaching the working face.
- During the interval of travelling, it absorbs moisture, foul gasses, heat etc. resulting in unpleasant working conditions at the face.

3. **Combination of blowing and exhausting :** In recent times many systems has tried to combine both blowing and exhausting systems utilizing the advantages of either system. Immediately after the blasting operation, the exhausting system is operated for 15 to 30 minutes to remove the objectionable air, after which blowing system operates for the rest of the working period to supply the fresh air. The reverse operation can be carried out by valve and duct arrangement. The fan rotates in one direction only, but the valves A, B, C, D can be manipulated either the exhaust from or blow into the tunnel. A, B, C and D are air tight valves.



Q.3 (c) Solution:

(i)

Distempering : Distemper is prepared with white chalk (as base) and water (as thinner). The main object of applying distemper to the plastered surfaces is to create a smooth surface. The distempers are available in the market under different trade names and are available in powder and paste forms. They are cheaper than paints and varnishes and they present a neat appearance. They are available in a variety of colours.

Properties of Distemper :

Following are the properties of distempers:

- On drying, the film of distempers shrinks. Hence it leads to cracking and flaking, if the surface to receive distemper is weak.
- The coatings of distemper are usually thick and they are more brittle than order types of water paints.
- The film developed by distemper is porous in character and it allows water vapour to pass through it. Hence, it permits new walls to dry out without damaging the distemper film.
- They possess poor workability.
- They are less durable than oil paints.
- They are treated as water paints and they are easy to apply.
- They can be applied on brickwork, cement plastered surface, lime plastered surface, insulating boards, etc.

(ii)

Nuclear concrete : Due to its excellent characteristics for neutron and gamma-ray attenuation, the ease of construction and a relatively low initial as well as maintenance costs, make concrete the most suitable material for radiation shielding. The concrete primarily used for radiation shielding may be called as nuclear concrete. To design nuclear concrete for effective radiation shielding, it is desirable to understand the type of radiation and the effective resulting hazards. In the electromagnetic waves category, the high-energy, high frequency waves known, as X-rays and gamma rays are the only ones that require shielding for the users. These waves are similar to light rays but have higher energy with greater penetrating power. Although both X-rays and gamma-rays are highly energy penetrating, they can be adequately absorbed by an appropriate thickness of specially constructed nuclear concrete shield.

Gap-graded concrete : This type of concrete is obtained when a gap graded aggregate is used in the production of concrete. In case of gap grading certain undesirable sizes of aggregates are omitted from the conventional continuous gradings. The undesirable sizes are those which prevent the efficient packing of the other sizes. Sometimes available single-sized aggregate only is used.

The gap-grading is normally aimed at achieving strength from the efficient packing of the aggregates. A well-packed aggregate will require minimum cement paste to fill the minor voids. Gap-graded concrete exhibits less segregation and is more workable and permits lower water-cement ratios. Creep and shrinkage are also less in gap-graded concrete.

Q.4 (a) Solution:

(i)

$$\because \quad S = \frac{f^{5/3}}{3340Q^{1/6}}$$

$$\Rightarrow \quad Q = \left(\frac{f^{5/3}}{3340S}\right)^6 = \frac{f^{10}}{(3340S)^6} = \frac{0.9^{10}}{\left(3340 \times \frac{1}{5000}\right)^6}$$

$$\Rightarrow \quad Q = 3.92 \text{ m}^3/\text{s}$$

$$\therefore \quad \text{Welded perimeter, } P = 4.75\sqrt{Q} = 4.75\sqrt{3.92} = 9.4 \text{ m}$$

Also, $\quad$ Hydraulic radius, $R = \frac{5}{2}\frac{V^2}{f} \Rightarrow R = \frac{5}{2}\cdot\frac{Q^2}{fA^2}$

$$\Rightarrow \quad RA^2 = \frac{5}{2}\frac{Q^2}{f} = \frac{5}{2} \times \frac{3.92^2}{0.9} = 42.68 \qquad \text{...(i)}$$

But $\quad P = \frac{A}{R} = 9.4$

$$\Rightarrow \quad A = 9.4R \qquad \text{...(ii)}$$

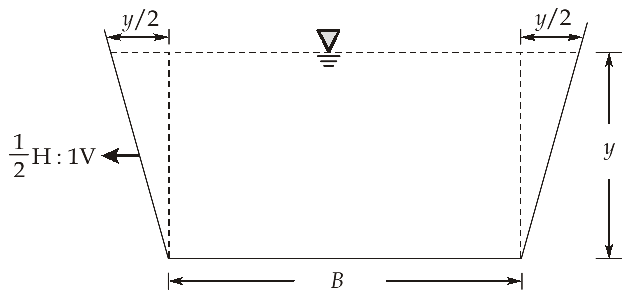
From (i) and (ii),

$$\frac{A^3}{9.4} = 42.68$$

$$\Rightarrow \quad A = 7.37 \text{ m}^2$$

So, $\quad P = 9.4$ m

and $\quad A = 7.37$ m^2



$$A = \frac{1}{2}[2B + y] \times y = 7.37$$

$\Rightarrow$ $$2By + y^2 = 14.75 \quad ...(iii)$$

$$P = B + 2\sqrt{1 + \left(\frac{1}{2}\right)^2} \times y$$

$\Rightarrow$ $$P = B + \sqrt{5}y = 9.4$$

$\Rightarrow$ $$B = 9.4 - y\sqrt{5} \quad ...(iv)$$

From (iii) and (iv)

$$2 \times (9.4 - \sqrt{5}\,y)y + y^2 = 14.75$$

$$18.8y + (1 - 2\sqrt{5}\,)y^2 = 14.74$$

$\Rightarrow$ $$2.472y^2 - 18.8y + 14.75 = 0$$

On solving,

$$y = 4.46 \text{ m}, 0.95 \text{ m}$$

Taking $y = 4.45$ m,

$$B = 9.4 - \sqrt{5} \times 4.46 = -0.57 \text{ m} < 0$$

So, $y = 4.45$ m can be neglected

Now, $y = 0.95$ m

$\therefore$ $B = 9.4 - \sqrt{5} \times 0.95 = 7.28 > 0$ (OK)

So, $B = 7.28$ m, $y = 0.95$ m

(ii)

Given : $a = 0.3$ m

$$C_a = 1000 \text{ ppm}$$

$$D = 5 \text{ m}; y = 2.5 \text{ m}$$

$$S = \frac{1}{4000}$$

$$V_s = 2 \text{ cm/s} = 0.02 \text{ m/sec}$$

Shear friction velocity, $V^* = \sqrt{gRS}$

where $R \simeq D$ for wide rectangular stream section

$$= \sqrt{9.81 \times 5 \times \frac{1}{4000}} = 0.1107 \text{ m/s}$$

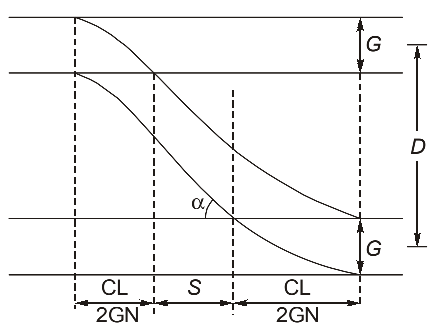
$$\therefore \quad \frac{V_s}{V^* k} = \frac{0.02}{0.1107 \times 0.4} = 0.452$$

$$\frac{C}{C_a} = \left[\frac{a}{y} \cdot \frac{D-y}{D-a}\right]^{\frac{V_s}{V^* k}}$$

$$\Rightarrow \quad C = 1000\left[\frac{0.3}{2.5} \times \frac{5-2.5}{5-0.3}\right]^{0.452} = 288.32 \text{ ppm}$$

Q.4 (b) Solution:

(i)



Data given:

Two parallel BG tracks, $G = 1.676$ m

Crossing number of both tracks, $N = 12$

Center-to-center (c/c) distance between the tracks,

$$D = 5.0 \text{ m}$$

Straight distance of track/cross-over,

$$S = (D-G)N - G\sqrt{1+N^2} = (5-1.676)\times 12 - 1.676\sqrt{1+12^2}$$

$$= 19.71 \text{ m}$$

Total length *of* cross-over, $L = (D-G)N - G\sqrt{1+N^2} + (2GN)\times 2$

$$= (5-1.676)12 - 1.676\sqrt{1+12^2} + (2\times 1.676\times 12)\times 2$$

$$= 100.16 \text{ m}$$

(ii)

Functions of a railway station:

1. To control the movement of trains.
2. To enable incoming priority train to overtake the low priority trains.
3. For boarding and de-boarding of passengers.
4. For loading and unloading of cargo.
5. For detaching and reattaching of rolling stock.
6. To take resupply of fuel for locomotives.
7. For de-boarding and boarding of running staff of train.
8. For hosting emergencies response and relief vehicle.

Following factors should be taken in account while selecting site for railway station:

1. **Availability of land:** Sufficient amount of land should be available to house the various components of station like tracks, platforms, station building, staff quarters and for future extension of station.
2. **Topography of land:** Land of railway station should have minimum gradient preferably level ground is considered ideal.
3. **Alignment of land:** Station site should not be on a curve. It should be straight so that easy visibility of signals can be ensured.
4. **Drainage:** Site should provide suitable drainage facility for quick disposal of water.
5. **Proximity to town:** Station should be close to populated town / city for easy transport of goods and passengers.
6. **Approach road:** Station site should be well connected and accessed by road and other transport mode.
7. **Station utilities:** Utilities like water, electricity, public conveniences, etc. should be provided at station site.
8. **Type of station yard:** Type of land and whether it is one side open or two side open depends on type of station. A station may be through type or a terminal station.

Q.4 (c) Solution:

(i) The various defects in bricks are as follows:

(a) Over-burning of bricks: Bricks should be burned at temperatures at which incipient, complete and viscous vitrification occur. However, if the bricks are overburnt, a soft molten mass is produced and the bricks loose their shape. Such bricks are not used for construction purposes.

(b) Under burning of bricks: When bricks are not burnt to cause complete vitrification, the clay is not softened because of insufficient heat and the pores are not closed. This results in higher degree of water absorption and less compressive strength. Such bricks are not recommended for construction works.

(c) Bloating: This defect is observed as spongy swollen mass over the surface of burned bricks and is caused due to the presence of excess carbonaceous matter and sulphur in brick clay.

(d) Black core: When brick clay contains bituminous matter or carbon and they are not completely removed by oxidation, the brick results in black core mainly because of improper burning.

(e) Efflorescence: This defect is caused due to presence of alkalies in bricks. When bricks come in contact with moisture, water is absorbed and the alkalies crystallize. On drying, grey or white powdery patches appear on the brick surface. This can be minimized by selecting proper clay materials for brick manufacturing, preventing moisture to come in contact with masonry by providing water-proof coping, using water repellant materials in mortar and by providing damp proof course.

(ii) Refractory bricks or fire clay bricks as they are sometimes called are made from fire clay. Fire clay is a term loosely applied to include those sedimentary or residual clays which vitrify at a very high temperature and which, when so, burnt, possess great resistance to heat.

Fire clays are pure hydrated silicates of alumina and contain a large proportion of silica (55-75%), alumina (20-35%), iron oxide (2-5%) with about 1 per cent of lime, magnesia and alkalis. The greater the percentage of alumina, the more refractory the clay will be. Fire clays are capable of resisting very high temperatures upto 1700°C without melting or softening. Iron oxide or other alkalis reduce refractory qualities of fire clay. The process of manufacture of refractory bricks is same as that of ordinary bricks.

The properties of refractory bricks are as follows:

(a) These bricks are whitish yellow or light brown in colour.

(b) The weight of refractory bricks is about 30 to 35 N.

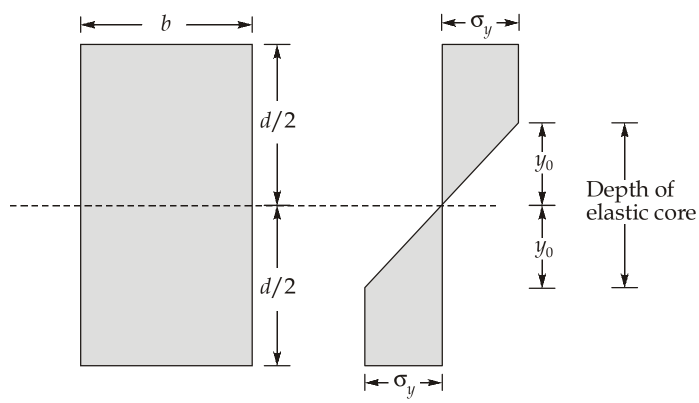
(c) The refractory bricks can resist high temperature without softening or melting. Hence, they are used for lining blast furnace, ovens, kilns, boilers and chimneys.

(d) The water absorption of refractory bricks varies from 4 to 10%.

(e) The compressive strength of refractory bricks varies from 150 to 220 N/mm^2.

Section B : Design of Steel Structure-2 + Hydrology-2

Q.5 (a) Solution:



Stress diagram

Let the total depth of the elastic core = $2y_0$. Therefore, the depth of the plastic zone = $\frac{d}{2} - y_0$, on either side. Distance of c.g. of force on one side from N.A.

$$= \frac{b\left(\frac{d}{2} - y_0\right) \times \sigma_y \times \left\{y_0 + \frac{1}{2}\left(\frac{d}{2} - y_0\right)\right\} + by_0 \frac{\sigma_y}{2} \cdot \frac{2}{3} y_0}{b\left(\frac{d}{2} - y_0\right)\sigma_y + by_0 \frac{\sigma_y}{2}}$$

$$= \frac{\left(\frac{bd}{2} - by_0\right)\left(\frac{d}{4} + \frac{y_0}{2}\right) + \frac{by_0^2}{3}}{\frac{bd}{2} - by_0 + \frac{by_0}{2}}$$

$$= \frac{3d^2 - 4y_0^2}{12(d - y_0)}$$

Total internal moment of the forces about NA

$$= 2 \times \left\{ b\left(\frac{d}{2} - y_0\right) + \frac{by_0}{2} \right\} \sigma_y \times \frac{3d^2 - 4y_0^2}{12(d - y_0)}$$

$$= \frac{(3d^2 - 4y_0^2)}{12} \times b \times \sigma_y$$

Externally applied moment $= 0.9\,M_P = 0.9 \frac{bd^2}{4}\sigma_y \quad \left(\text{Since } M_P = Z_P \cdot \sigma_y = \frac{bd^2}{4} \cdot \sigma_y\right)$

Equating the two moments, we get

$$\left(\frac{3d^2 - 4y_0^2}{12}\right) b\sigma_y = 0.9 \times \frac{bd^2}{4}\sigma_y$$

$$\Rightarrow \quad 3d^2 - 4y_0^2 = 2.7d^2$$

$$\therefore \quad 4y_0^2 = 0.3d^2$$

$$\therefore \quad y_0 = 0.274d$$

Hence, depth of elastic core $= 2y_0 = 0.548d$

Q.5 (b) Solution:

(i)

Flood control measures:

Flood control measures generally consists of two approaches viz:

- Constructing high earthen walls along the banks of the river to protect over-spills into the adjoining areas. Such a measure can be adopted only for a particular length of the river, where the river passes through densely populated and settled area, because otherwise it will not be economically viable.
- Storing excess water during heavy rains at appropriate place(s) in the river reach, so as to reduce the river flow downstream. This may be achieved by constructing a dam type obstruction across the river, and storing water in the upstream portion to form a reservoir. The stored water can be released after heavy rain subsides, and natural flow in the river reduces.

Besides the above two general methods of controlling floods, certain other methods may also be employed to supplement them and to make them successful.

These supplementary or localized measures can be divided into three categories viz:

- Increasing the river capacity by improving the river cross-section, so as to increase the flow velocity, thereby reducing water depth. Development of cutoffs in meandering rivers to help reduce river length, thereby increasing channel slope and flow velocity, also, falls under this method of flood control.
- Construction of diversion channels to reduce the discharge in the main river, may also sometimes be adopted, purely as a localized measure.
- Constructing terraces to help increase ground infiltration, thereby reducing river runoff.
- Adopting soil and water conservation techniques to help increase the vegetative cover in the catchment area of the river to reduce the runoff.

These flood control measures may be adopted either in isolation or in combination, depending upon the need at a particular location. There are not two countries with the same hydrology; in the same country, there are no two rivers with the same regimes; and even in the same river, there are no two floods of the same characteristics. Flood control measures therefore, vary from place to place and from time to time, and may also depend upon the funds available at that time.

A particular flood control method, found successful on a particular river, may not provide the best solution for another river in the same country or outside, or even on the same river. The choice of a particular method or a combination of methods, widely depends upon the intelligence, intuition and experience of the engineers, designing and recommending such measures.

(ii)

Advantages and disadvantages of dikes are discussed below:

Advantages:

- It is the least expensive method to start with, although at higher levels it may become quite expensive.
- It is a simple method, requiring less skilled labour and less technical knowledge.
- The materials required for their construction are usually locally available.
- It is the only single method for preventing inundation on tidal areas, where the land is below the maximum tidal level.

Disadvantages:

- The dikes are fragile works and their breaching may cause tremendous loss of life and property.

- The maintenance and supervision cost is very high.
- Their construction becomes uneconomical, if carried to greater heights.
- They are open to direct attack by river flow, which may erode and undermine the dikes, and may result in their failure.
- They make the drainage of the low lying area more difficult, and special works are to be constructed through the dikes.
- On diked river, silt is not deposited in the flood plains, and thus the silt charge which the river carries upto its point of confluence to the sea is more in a diked river. All the silt will be deposited in its deltaic region, and hence the process will hasten the extension of delta towards the sea, resulting in increasing the flood stage and the rate of aggradation of the river bed in these area.

Q.5 (c) Solution:

The depth of the plate girder for which the area of steel used is minimum (thin and deep webs) and thus will have minimum weight is called optimum depth of plate girder.

Expression for optimum depth

If the moment M is assumed to be resisted entirely by the flanges, then for an I-section beam, approximately

$$M_z = f_y b_f t_f d \qquad \text{...(i)}$$

where, f_y = design strength of the flanges, b_f = width of the flange, t_f = thickness of the flange, d = depth of the web

The gross-sectional area of the beam is given by

$$A = 2\,b_f\,t_f + dt_w \qquad \text{...(ii)}$$

where t_w is the thickness of web.

Eliminating $b_f\,t_f$ using equation (i)

$$A = \frac{2M_z}{df_y} + dt_w \qquad \text{...(iii)}$$

Let, the web slenderness ratio be $k = \frac{d}{t_w}$, equation (iii) reduces to

$$A = \frac{2M_z}{kt_w f_y} + kt_w^2 \qquad \text{...(iv)}$$

The optimum value of t_w may be obtained by differentiating equation (iv) with respect to t_w and equating it to zero.

$$\therefore \quad \frac{\partial(A)}{\partial t_w} = \frac{\partial}{\partial t_w}\left(\frac{2M_z}{kt_w f_y}\right) + \frac{\partial}{\partial t_w}\left(kt_w^2\right)$$

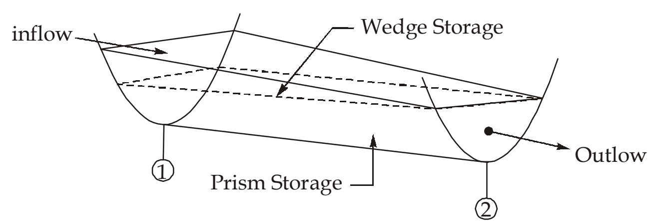
$$\Rightarrow \quad 0 = \frac{-2M_z}{kf_y t_w^2} + 2kt_w$$

$$\Rightarrow \quad \frac{2M_z}{kf_y t_w^2} = 2kt_w$$

$$\Rightarrow \quad t_w^3 = \frac{M_z}{f_y k^2}$$

$$\Rightarrow \quad t_w = \left(\frac{M_z}{f_y k^2}\right)^{0.33}$$

Q.5 (d) Solution:



Storage in a channel reach

(i) Prism Storage: It is the volume which exist if uniform flow occurs at the downstream depth. It means it is the volume found by an imaginary plane parallel to the channel bottom drawn at the outflow section of the water surface.

(ii) Wedge Storage: It is the triangular volume enclosed between the actual water surface profile and the top of the prism storage.

Difference between prism storage and wedge storage

- At fixed depth at a downstream section of a river reach, the prism storage is constant while the wedge storage changes from a positive value at an advancing flood (in this case depth increases) to a negative value during receding flood (in this case depth decreases).
- The prism storage is steady so it is similar to reservoir storage and is expressed as a function of outflow discharge

  $$S_p = f(Q).$$

  Wedge storage is a function of inflow discharge.

  It can be expressed as $s_w = f(I)$.
- The total storage is expressed as;

$$S = K[xI^m + (1 - x)Q^m]$$

where,

x = Weighing factor

$0 < x \leq 0.5$

$0.1 \leq x \leq 0.3$ for natural channel

K = Storage time constant which has dimension of time

m = Constant = 1 for natural channel

Q.5 (e) Solution:

Shear load capacity of I-section $= \tau_{va} \times d \times t_w$

$$= 276 \times 12 \times \frac{f_y}{\sqrt{3} \times 1.1}$$

$$= \frac{276 \times 12 \times 250}{\sqrt{3} \times 1.1 \times 10^3} = 434.59 \text{ kN} \quad \text{...(i)}$$

Let shear force at the section $= V$ kN

Shear stress at the level of weld,

$$\tau = \frac{V}{I_x \times b} \times A \times \bar{y}$$

$A\bar{y}$ = Moment of area above weld about neutral axis

$$= 14 \times 1.2\left(15 - \frac{1.2}{2}\right) = 241.92 \text{ cm}^3$$

$$I_x = \frac{1.2}{12}(30 - 2 \times 1.2)^3 + 2 \times 14 \times \frac{1.2^3}{12} + 2 \times 14 \times 1.2\left(\frac{30}{2} - \frac{1.2}{2}\right)^2$$

$$= 9073.7856 \simeq 9073.79 \text{ cm}^4$$

$$\tau = \frac{V}{I_x \times b} \times A \times \bar{y}$$

$$\frac{f_u}{\sqrt{3} \times 1.25} = \frac{V \times 241.92 \times 10^3}{9073.79 \times 10^4 \times (2 \times 0.7 \times 6)}$$

$$\frac{410}{\sqrt{3} \times 1.25} = \frac{288}{907379}V$$

$$V = 596.64 \text{ kN} \quad \text{...(ii)}$$

From (i) and (ii), maximum shear load the section can carry = 434.59 kN.

Q.6 (a) Solution:

(i)

1. Load at first yield

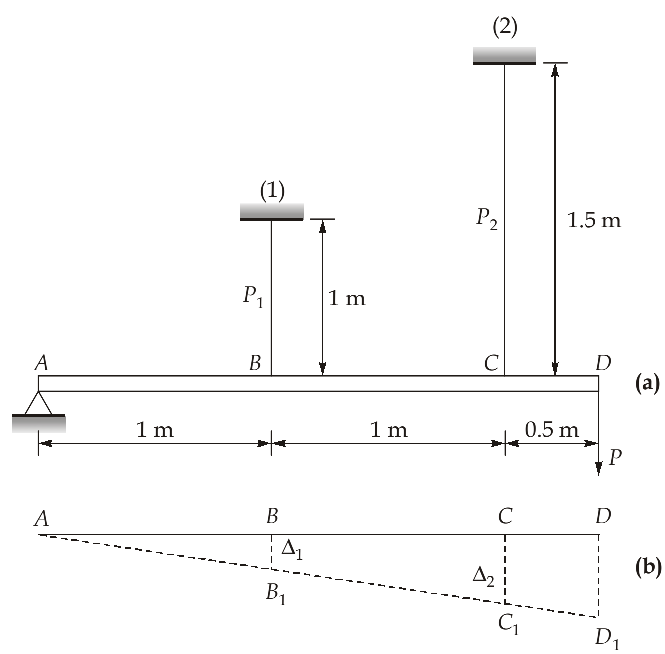
From statics, $P_1 + P_2 + R = P$ ... (i)

where P_1 and P_2 are the forces in rods at B and C respectively and R is the reaction at A. Reaction R will invariably act upwards otherwise the system will not be statically stable.

Taking moments about A, we get

$$P_1 + 2P_2 = 2.5P \quad \text{... (ii)}$$

Figure below also shows the deformed shape of the arrangement. Let Δ_1 and Δ_2 are the vertical extensions of the two vertical rods.



$$\frac{\Delta_1}{\Delta_2} = \frac{1}{2}$$

$$\Rightarrow \quad 2\Delta_1 = \Delta_2$$

$$\Rightarrow \quad 2\frac{P_1 \times 1}{AE} = \frac{P_2 \times (1.5)}{AE}$$

$$\Rightarrow \quad P_2 = \frac{2}{1.5}P_1 = 1.33P_1 \quad \text{... (iii)}$$

Equation (iii) shows that P_2 is greater than P_1. Since the area of sections of both the rods are equal, it is evident that yield first occurs in rod 2. As the load P is increased, the force P_2 will go on increasing till yield occurs in it. Hence at the first yield,

$$P_2 = \sigma_y.A = 250 \times 200 = 50000 \text{ N}$$

Corresponding value of P_1 is $P_1 = \frac{1.5}{2}P_2 = 0.75P_2$

Substituting these in equation (ii) the load at the first yield is given by

$$P_{el} = \frac{1}{2.5}(P_1 + 2P_2) = \frac{2.75}{2.5}P_2 = \frac{2.75}{2.5}\times 50000$$
$$= 55000 \text{ N}$$

Thus load when first yield occurs in any of the rod is 55000N or 55 kN.

2. Load at complete collapse

When the load P is further increased, the load in rod 1 increases while the load in rod 2 remains constant at a value of 50000 N. When yield is reached in rod 1, the whole structure collapses. The force P_1 corresponding to yield in the first rod is evidently equal to σ_y = 250 × 200 = 50000 N. Substituting these values of P_1 and P_2 (each equal to 50000 N) in equation (ii), we get

$$P_u = \frac{1}{2.5}(P_1 + 2P_2) = \frac{3}{2.5}\times 50000$$
$$= 60000 \text{ N}$$

(ii)

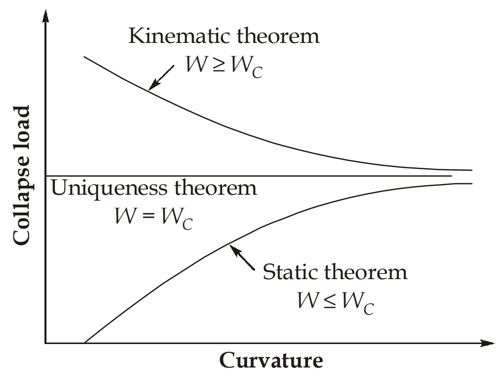
Basic Theorems of Plastic Analysis :

1. **Static theorem or lower bound theorem:** The static theorem states that for a given frame and loading, if there exists any distribution of bending moment throughout the frame which is both safe and statically admissible, with a set of loads *W*, the value of *W* must be less than or equal to the collapse load W_C.

   The distribution of bending moment, such that it satisfies all the conditions of equilibrium is called statically admissible distribution. If the distribution of bending moment is such that the fully plastic moment is not exceeded anywhere in frame, it is called safe distribution. Static method represents the lower limit to the true ultimate load with maximum factor of safety. Static method satisfies the equilibrium and yield conditions.

2. **Kinematic theorem or upper bound theorem:** The upper bound theorem states that for a given frame subjected to a set of loads *W*, the value of *W* which is found to correspond to any assumed mechanism will always be greater than or equal to

the actual collapse load W_C. This theorem satisfies the equilibrium condition as well as mechanism condition, and provides the upper bound or limit of collapse load. If the values of W corresponding to a number of mechanisms for a given frame under a given set of loading are found, the collapse load W_C will be the smallest of all these loads so found.



Q.6 (b) Solution:

Hydro power developed, $P = \rho QgH\eta$

But, $P = 7.5\text{ MW} = 7.5 \times 10^3\text{ kW} = 7.5 \times 10^6\text{ W}$

$\therefore \quad 10^3 \times 9.81 \times 0.85 \times Q \times 25 = 7.5 \times 10^6$

$$\Rightarrow \quad Q = \frac{7.5\times10^6}{10^3\times9.81\times0.85\times25} = 35.98\text{ m}^3/\text{s}$$

$$= (35.98 \times 3600 \times 24)\text{ m}^3/\text{day}$$

$$= 3.1087\text{ Mm}^3/\text{day}$$

$\therefore$ Uniform water demand $= 3.1087\text{ Mm}^3/\text{day}$

The computations of cumulative deficit are carried out in table below.

Month	Inflow Mm^3	Outflow Mm^3	Surplus Mm^3	Deficit Mm^3	Cumulative surplus	Cumulative deficit
Jan	105	$3.1087 \times 31 = 96.370$	8.6370	–		
Feb	111	$3.1087 \times 28 = 87.044$	23.956		32.586	
March	93	96.370	–	3.370		
April	84	93.261	–	9.261		
May	75	96.370	–	21.370		
June	90	93.261	–	3.261		37.262
July	120	96.370	23.630	–	23.630	
August	90	96.370	–	6.370		6.370
September	96	93.261	2.739	–		
October	102	96.370	5.630	–		
November	103	93.261	9.739			
December	99	96.370	2.630		20.738	

The minimum storage required to meet the demand is equal to the maximum of the cumulative deficit = 37.262 Mm^3.

Q.6 (c) Solution:

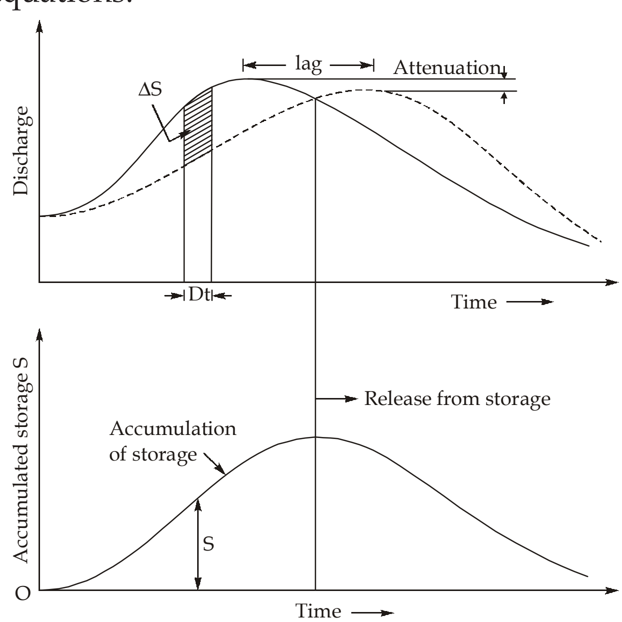
(i)

Stream channel routing: Flood routing is the technique of determining the flood hydrograph at a section of a river by utilizing the data of flood flow at one or more upstream sections. As water wave moves down, the shape of the wave gets modified due to channel storage, resistance, addition or withdrawal of flows etc. Modification in the wave (hydrograph) is studied through flood routing. There are two methods of flood routing:

- **Hydrological routing:** This method uses equation of continuity with some relationship between storage, outflow, and possibly inflow. These relationships are usually assumed, empirical, or analytical in nature. In long channels entire flood wave travels a considerable distance resulting in a time redistribution and time of translation as well. Thus, in a river, the redistribution due to storage effects modifies the shape, while the translation changes its position in time.

  In reservoir, the storage is a unique function of the outflow discharge i.e. $S = f(O)$.

- **Hydraulic routing:** This method makes use of equation of motion of unsteady flow along with continuity equation. These equations are collectively called as St. Venant's equations.



(ii)

Following methods of flood estimation are used:

- Rational method
- Empirical formula
  - (a) *Dicken's formula,* $Q_P = C_D A^{3/4}$
  - (b) *Ryve's formula,* $Q_P = C_R A^{2/3}$
  - (c) *Inglis formula,* $Q_P = \dfrac{124A}{\sqrt{A+10.4}}$
- Use of hydrograph and unit hydrograph : This method is suitable for moderate size catchment having area less than 5000 km^2.
- Probability method or flood frequency studies.

Rational Method: This method is suitable for small catchment having area less than 50 km^2. It uses the concept of time of concentration which is the period after which whole catchment area will start to contribute to runoff. The runoff resulting from rainfall duration less than time of concentration will not be maximum as whole catchment will not contribute to flood. Further if rainfall duration is more than time of concentration then intensity of rainfall reduces with increase in its duration. Flood discharge is calculated as

$$Q_P = \frac{1}{36} k p_c A$$

where,

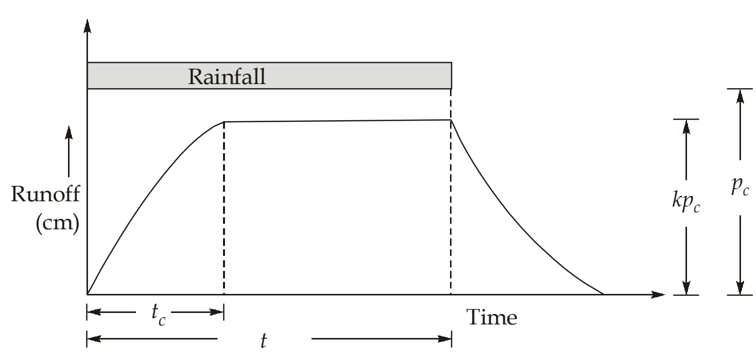
Q_P is peak flood discharge in m^3/s

k is coefficient of run-off

A is catchment area in hectares

p_c is mean rainfall intensity in cm/hr for duration equal to time of concentration

Note : *It is applicable only when* $t \geq t_c$*; where* t_c *= time of concentration and* t *= duration of rainfall*



Q.7 (a) Solution:

Design rainfall = 40 mm/h

Excess design rain of 1 hr duration in 1st case (i.e. before urbanization)

$$= (40 \text{ mm} - 7 \text{ mm}) = 33 \text{ mm} = 3.3 \text{ cm}$$

Excess design rain of 1 hr duration in 2nd case (i.e. after urbanization)

$$= (40 \text{ mm} - 4 \text{ mm}) = 36 \text{ mm} = 3.6 \text{ cm}$$

Peak discharge in 1st case = Peak ordinate of UH × Excess rain

Ordinates of UH always imply rainfall excess depth of 1 cm

$$= \left[3.6 \text{ m}^3/\text{s} \times 3.3\right] = 11.88 \text{ m}^3/\text{s} \quad \text{...(i)}$$

$$\text{Peak discharge in 2nd case} = \left[6.0 \text{ m}^3/\text{s} \times 3.6\right] = 21.6 \text{ m}^3/\text{s} \quad \text{...(ii)}$$

$$\text{Percentage increase in peak storm runoff} = \frac{21.6 - 11.88}{11.88} \times 100\% = 81.82\%$$

Volume of water contained in 1st flood hydrograph

$$= \frac{1}{2} \times 11.88 \text{ m}^3/\text{s} \times 10 \text{ h}; \qquad \text{(i.e. area of } \Delta)$$

$$= \frac{1}{2} \times 11.88 \times (10 \times 3600) \text{ m}^3 = 213840 \text{ m}^3 \quad \text{...(iii)}$$

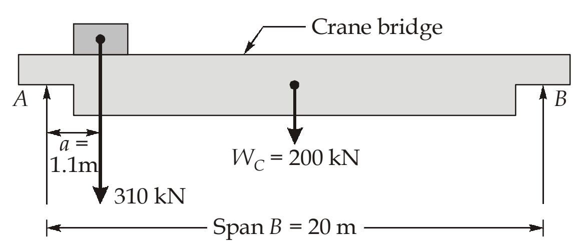
Volume of water contained in 2nd flood hydrograph

$$= \frac{1}{2} \times 21.6 \text{ m}^3/\text{s} \times 6\text{h} \quad [\textit{i.e.} \text{ Area of } \Delta]$$

$$= \frac{1}{2} \times 21.6 \times (6 \times 3600) \text{m}^3 = 233280 \text{ m}^3 \quad \text{...(iv)}$$

$$\text{Percentage increase in flood volume} = \frac{233280 - 213840}{213840} \times 100\% = 9.09\%$$

Q.7 (b) Solution:



The above data are shown diagrammetrically in figure above.

Step 1 : Determination of loads:

$$W_c = 200 \text{ kN}$$
$$W_t = 60 + 250 = 310 \text{ kN}$$

Maximum static wheel load reaction at A will occur when the crane hook is at minimum distance of $a = 1.1$ m.

$$R_A = \frac{W_c}{2} + \frac{W_t(B-a)}{B}$$
$$= \frac{200}{2} + \frac{310(20-1.1)}{20} = 392.95 \text{ kN}$$

Since there are two wheel loads at A

$$W = \frac{1}{2} \times 392.95 = 196.475 \text{ kN}$$

Step 2 : Determination of BM due to vertical loads

Static wheel load = 196.475 kN

Add impact allowance @ 25% = 49.119 kN

Total, W = 245.594 kN

Wheel base, b = 3.4 m;

Span of girder, L = 7 m

$0.586L = 0.586 \times 7 = 4.102$ m

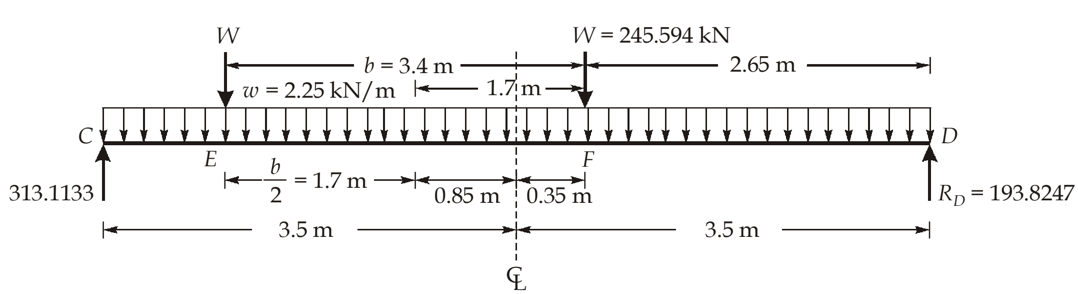
Since $b < 0.586L$ maximum BM will occur when centre of span is midway between CG of loads and one wheel load. Hence distance of one wheel, from centre of span = $\frac{1}{4}b = \frac{1}{4} \times 3.4 = 0.85$ m

$$\text{Let self weight of girder, } w_1 = \frac{2W}{250} = \frac{2 \times 245.594}{250} = 1.96 \text{ kN/m}$$

$$\text{Weight of rail, } w_2 = 30 \times 9.81 \times 10^{-3} \simeq 0.29 \text{ kN/m}$$

$$\therefore \quad w = 1.96 + 0.29 = 2.25 \text{ kN/m}$$

The positions of wheel loads for maximum bending moment are shown in figure below. Maximum BM will occur under wheel load at F which is nearer to the centre of span.



Vertical loads for maximum bending moment

Now, $$R_D = \frac{1}{7}\left[\left(2.25\times 7\times\frac{7}{2}\right)+245.594(0.95+4.35)\right]$$

$$= 193.8247 \text{ kN}$$

$$R_C = \frac{1}{7}\left[\left(2.25\times 7\times\frac{7}{2}\right)+245.594(2.65+6.05)\right]$$

$$= 313.1133 \text{ kN}$$

Check : Total of reactions = 506.938 kN

$$\therefore \quad M_x \text{ (at } F) = (193.8247\times 2.65)-\frac{2.25(2.65)^2}{2} = 505.735 \text{ kN-m}$$

Step 3 : Selection of section for gantry girder

$$Z = \frac{M_x\times 1.1}{f_y} = 2225.234 \text{ cm}^3$$

Q.7 (c) Solution:

Factored live load = 1.5 × 25

= 37.5 kN/m

Factored dead load = 1.5 × 0.377 kN/m

= $0.5655 \simeq 0.566$ kN/m

Total factored load will be = 37.5 + 0.565

w_u = 38.065 kN/m

$$\therefore \quad \text{Service load, } w = \frac{38.065}{1.5} = 25.38 \text{ kN/m}$$

1. Check for flexure:

$$Z_{\text{available}} = \frac{I_{xx}}{y}$$

$$= \frac{7332.9\times 10^4}{150} = 0.488 \times 10^6 \text{ mm}^3$$

$$Z_{\text{req.}} = \frac{M}{\left(\frac{fy}{1.1}\right)}$$

$$= \frac{w_u l^2/8}{\left(\frac{fy}{1.1}\right)} = \frac{\frac{38.065\times(5)^2}{8}\times 10^6}{\left(\frac{250}{1.1}\right)}$$

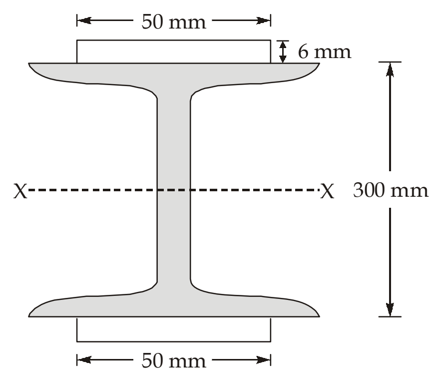
$$= 0.523 \times 10^6 \text{ mm}^3 > Z_{available}$$

∴ Amount of area required, to be provided by cover plates is

$$A = \frac{Z_{req.} - Z_{available}}{D} = \frac{(0.523\times 10^6)-(0.489\times 10^6)}{300}$$

$$= 113.33 \text{ mm}^2$$

∴ Provide two cover plates of (50 mm × 6 mm) each



ISLB 300

$$(I_{xx})_{comb} = (I_{xx})_{ISLB} + 2\left[\frac{50\times(6)^3}{12} + (50\times 6)\times(153)^2\right]$$

$$= 7332.9\times 10^4 + 2\left[\frac{50\times(6)^3}{12} + (50\times 6)\times(153)^2\right]$$

$$= 87.38 \times 10^6 \text{ mm}^4$$

∴ $$(Z_{xx})_{new} = \frac{(I_{xx})_{comb.}}{y} = \frac{87.38\times 10^6}{156} = 560.13\times 10^3 \text{ mm}^3$$

$(Z_{xx})_{comb} > Z_{available}$ (OK)

2. Check for shear:

$$\text{Shear stress, } f_1 = \left(\frac{V}{D\cdot t_w}\right)$$

$$= \frac{wl/2}{D\cdot t_w} = \frac{\frac{38.06\times 5}{2}\times 10^3}{300\times 10} = 31.72 \text{ MPa}$$

$$\le \left(\frac{f_y}{1.1\sqrt{3}} = \frac{250}{1.1 \times \sqrt{3}} = 131.22 \text{ MPa} \right) \quad \text{(OK)}$$

3. Check for deflection

Deflection of beam, $\delta_1 = \frac{5}{384}\frac{wl^4}{EI}$

$$\Rightarrow \quad \delta_1 = \frac{5}{384} \times \frac{25.38 \times (5)^4}{2 \times 10^5 \times 87.38 \times 10^6} \times (10^3)^4 = 11.82 \text{ mm}$$

Maximum deflection in limit state of serviceability is,

$$\delta_{max} = \frac{l}{300} = \frac{5000}{300} = 16.67 > \delta_1 (= 11.82 \text{ mm})$$

$$\therefore \quad \delta_1 < \delta_{max}$$

It is safe in deflection.

Q.8 (a) Solution:

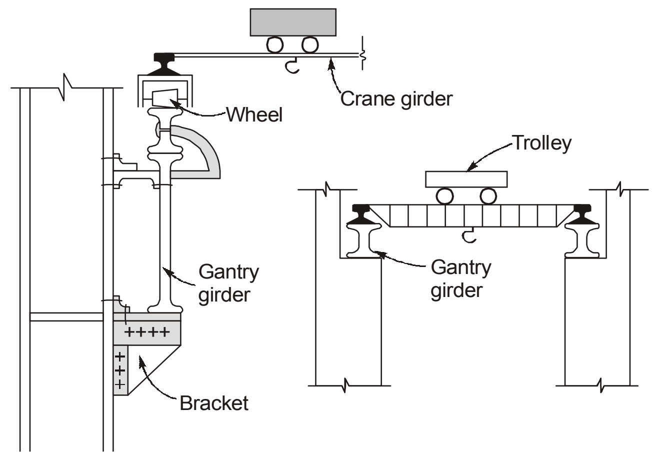
Let FH, DRH and U be flood hydrograph, direct runoff hydrograph and unit hydrograph. R_1 and R_2 are rainfall excess due to two successive 1 cm storms respectively. Also assuming base flow as 10 m^3/s. The calculations are tabulated below:

Time (hr)	*FH*	Base Flow	DRH (COL. 2 – COL. 3)	R_1U	R_2U	col. 4 = $R_1 U + R_2 U$	*U*
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
0	10	10	0	U_1		$U_1 = 0$	0
6	30	10	20	U_2	U_1	$U_2 + U_1 = 20$	20
12	90	10	80	U_3	U_2	$U_3 + U_2 = 80$	60
18	220	10	210	U_4	U_3	$U_4 + U_3 = 210$	150
24	280	10	270	U_5	U_4	$U_5 + U_4 = 270$	120
30	220	10	210	U_6	U_5	$U_6 + U_5 = 210$	90
36	166	10	156	U_7	U_6	$U_7 + U_6 = 156$	66
42	126	10	116	U_8	U_7	$U_8 + U_7 = 116$	50
48	92	10	82	U_9	U_8	$U_9 + U_8 = 82$	32
54	62	10	52	U_{10}	U_9	$U_{10} + U_9 = 52$	20
60	40	10	30	U_{11}	U_{10}	$U_{11} + U_{10} = 30$	10
66	20	10	10	U_{12}	U_{11}	$U_{12} + U_{11} = 10$	0
72	10	10	0	U_{13}	U_{12}	$U_{13} + U_{12} = 0$	0
					U_{13}	$U_{13} = 0$	0

Thus the ordinates of 6-hr unit hydrograph are:

Time (hr)	0	6	12	18	24	30	36	42	48	54	60	66	72
UH	0	20	60	150	120	90	66	50	32	20	10	0	0

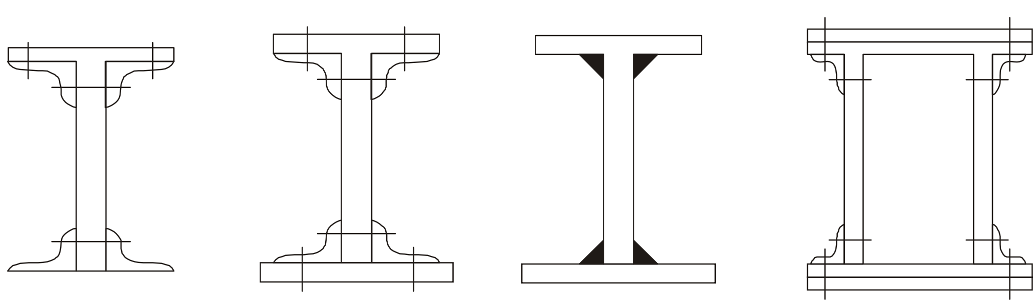
Q.8 (b) Solution:



(*i*) Gantry girders are provided in almost all the industrial and residential towers for lifting and transportation of heavy loads. A gantry girder is the piece of crane that contains the equipment allowing the crane to roll over during the operation. The girder is designed to support the crane and the load inflicted on the crane throughout its life. A gantry girder is supported by columns to avert the twisting and bending of the girder metal.

Use of gantry girder: the main function of gantry girder to support rail mounted on gantry girder, on that rail the wheels of crane girder moves.

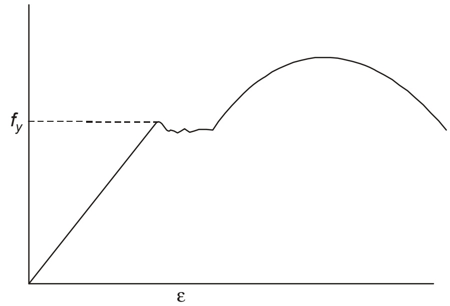
(*ii*) **Plate girder and its use:** A plate girder is a builtup beam fabricated mainly by plate sections as shown in figure.

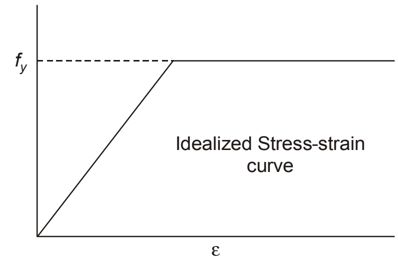


Usually angle sections are used to connect flange plate and web plate by rivets.

Use of plate girder: A plate girder is used when the span is very large beyond 20 m and loads are very heavy. Generally plate girders are used for bridge spans.

(*iii*) **Plastic design of frame:** In conventional methods, structure is designed for strength of steel till it yields at a point in the section. However if yielding occurs at any point it does not mean collapse of structure. Due to plastic deformations and strain hardening of material, structure is actually able to resist greater load.





So, in the plastic design of frames, this plastic zone is utilized and for design purpose strain hardening range has been committed, which infect add margin of safety.

Note that the plastic design is only applied to redundant frames.

Assumptions:

(*i*) Material should posses ductility so that it can deform in plastic range.

(*ii*) Strain distribution is linear.

(*iii*) Modulus of elasticity is same in compression and tension.

(*iv*) The cross-section must be symmetrical w.r.t plane of loading, it means no twisting.

Q.8 (c) Solution:

Time (h)	Ordinate of 4-h UH (m^3/s)	S-curve addition (m^3/s)	S-curve ordinate (m^3/s) (Col. 2+ Col. 3)	S-curve lagged by 12 h (m^3/s)	(Col. 4 - Col. 5)	$\frac{\text{Col. 6}}{(12/4)}$ = 12-h UH ordinates (m^3/s)
1	**2**	**3**	**4**	**5**	**6**	**7**
0	0	–	0	–	0	0
4	20	0	20	–	20	6.7
8	80	20	100	–	100	33.3
12	130	100	230	0	230	76.7
16	150	230	380	20	360	120.0
20	130	380	510	100	410	136.7
24	90	510	600	230	370	123.3
28	52	600	652	380	272	90.7
32	27	652	679	510	169	56.3
36	15	679	694	600	94	31.3
40	5	694	699	652	47	15.7
44	0	699	699	679	20	6.7
48		699	699	694	5	1.7
52			699	699	0	0

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