5.(c) An expressway passing through a rolling terrain has a horizontal curve of radius equal to the ruling minimum radius. Design the following geometric elements of this expressway for ruling design speed of 100 kmph, assuming any missing data suitably:
(i) Ruling minimum radius
(ii) Super elevation
(iii) Extra widening
(iv) Length of transition curve
(v) SSD, ISD and set-back distance
(vi) The minimum set-back distance from the center line of the two lane expressway on the inner side of the curve to provide a clear vision assuming the length of circular curve greater than the sight distance.

Answer:

(i) Ruling minimum radius of curve for radius design speed of 100 kmph

$$\text{Ruling} = \frac{V^2}{127(e+f)}$$

$$\frac{100^2}{127(0.07+0.15)}$$

= 359.909 m

Say 360 m

(ii) Super elevation

$$e = \frac{V^2}{225R}$$

$$= \frac{100^2}{225 \times 360}$$

As the value is higher than the maximum super elevation of 0.07 limit the value of e to 0.07 the curve should he safe for the full speed of 100 kmph as the ruling minimum radius has been adopted

Check transverse skid resistance developed

$$f = \frac{v^2}{127R} - e = \frac{100^2}{127 \times 360} - 0.07$$

= 0.148 [< 0.15, safe]

(iii) Extra ladening

Assume 2- lane pavement i.e n = 2 and l = 6m

$$we = \frac{nl^2}{2R} + \frac{v}{9.5\sqrt{R}}$$

$$= \frac{2 \times 6^2}{2 \times 360} + \frac{100}{9.5 \times \sqrt{360}}$$

= 0.1 + 0.5547 = 0.6547 m

Total widhth of pavement = 2 × 3.75 + 0.6547

= 8.1547 m

(iv) Length of transition curve:
It is designed by calculating the values based on,
1. rate of change of centrifugal acceleration.

$$c = \frac{80}{75 + v} = \frac{80}{75 + 100} = 0.457$$

(this value should be lateen 0.5 to 0.8)
So take C = 0.5

$$L_s = \frac{0.0215 \times v^3}{CR}$$

$$= \frac{0.0215 \times 100^3}{0.5 \times 360}$$

= 119.44 m

2. Rate of introduction of superelevation: -
Sol. Total amount of super elevation E, i.e raising the outs edge of pavement w.r.t
Inner edge = B × e
= 8.1547 × 0.07
= 0.57 m
As the tension in rolling assume the pavement to be rotated about the center as the rate of in 150

$$L_s = \frac{E}{2} \times N = \frac{0.57 \times 150}{2}$$

= 42.75 m

3. Minimum length formula: -
As per 1 RC, $L_s = 2.7 \frac{V^2}{R}$

$$= 2.7 \times \frac{100^2}{360} = 75m$$

Adopting the highest of these values
Design length of transition curve
= 119.44 m

(v) SSD = 0.278 vt + $\frac{V^2}{254 f}$

$$= 0.278 \times 100 \times 2.5 + \frac{100^2}{254 \times 0.35}$$

= 181 .986 m
≈ 182 m
ISD = 2 × 550 = 2 × 182 = 364 m

(vi) Assuming length of circular curve grater than the sight distance:

$$\frac{\alpha'}{2} = \frac{180\,S}{2\pi(R-d)}$$

$$= \frac{180 \times 364}{2\pi \times (360 - 2.038)}$$

= 29.13

d = distance lateen the center line of the pavement and center line of inside lane = $\frac{W}{9}$

$$= \frac{8.1547}{4} = 2.038\,m$$

Set – back distance in = R – (R – d) $\cos\frac{\alpha'}{2}$

= 360 – (360 – 2.038) × cos 29.13°

= 47.314 m

5.(d) Find out the steepest gradient on a straight track using the following data for a train having 25 wagons:

Weight of each wagon = 20 tonnes

Rolling resistance of wagon = 2.5 kg/tonne

Speed of the train = 60 kmph

Weight of locomotive with tender = 120 tonnes

Tractive effort of locomotive = 45 tonnes

Rolling resistance of locomotive = 3.5 kg/tonne

12

Answer.

Total train weight W = 20×25 + 120 = 620 t

Total resistance =RT1+RT2+RT3+Wtanθ

RT1 = rolling resistance independent of speed

RT2 = resistance dependent on speed

RT3 = atmospheric resistance

Rolling resistance RT_1 = (3.5×120 + 2.5×500)/1000 = 1.67 t

Speed- dependent resistance RT_2 = 0.00008WV= 0.00008×620×60= 2.976 t

Atmospheric resistance $RT_3 = 0.0000006 \times W \times V^2 = 0.0000006 \times 620 \times 60^2$ = 1.3392 t

Total other resistances = $RT_1 + RT_2 + RT_3$ = 5.9852 t

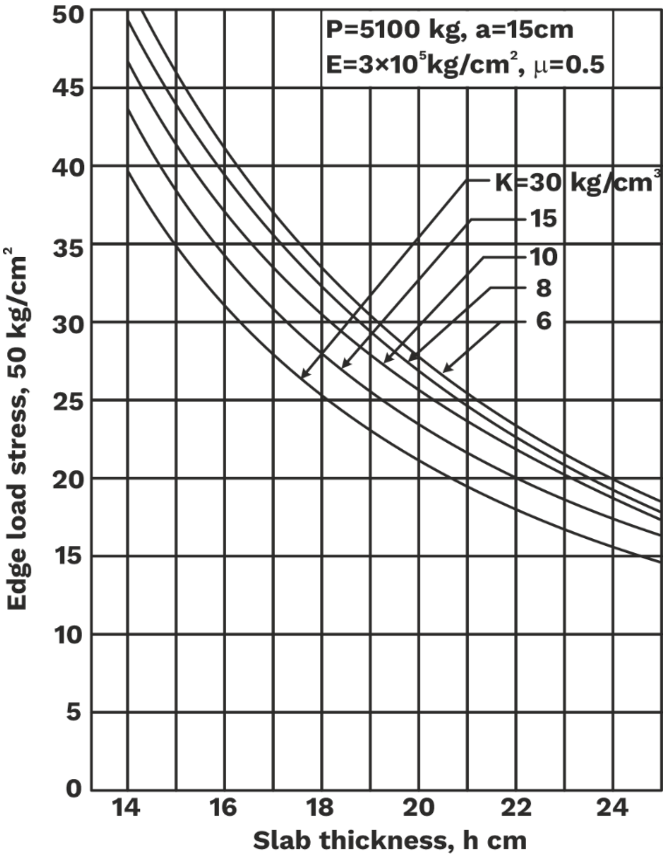
For limiting gradient: Te = Tr

45 = 5.9852 + 620 tanθ

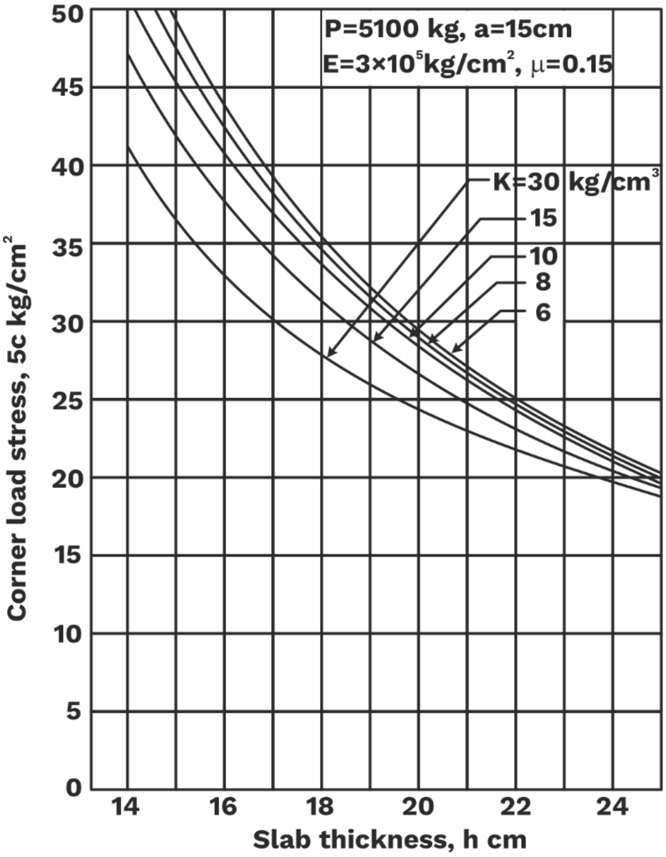
$\tan\theta = 0.06292$

Gradient = $1 / \tan\theta \approx$ 1 in 15.89 ≈ 1 in 16

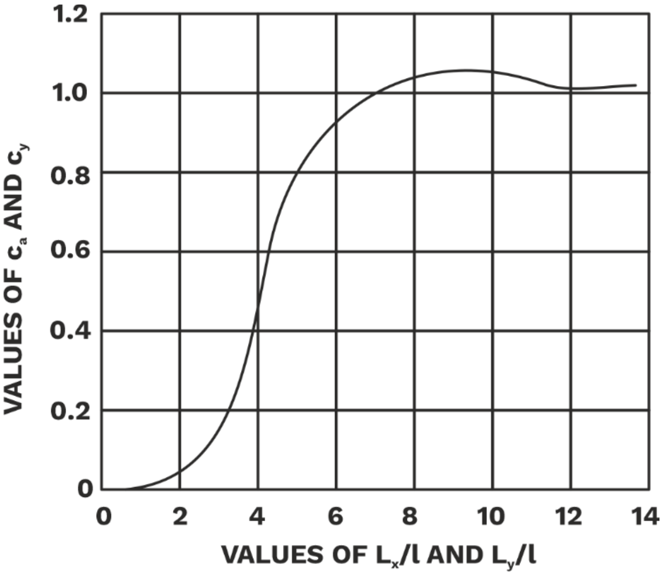
8.(a) A CC pavement slab of thickness 20 cm is constructed over a granular sub-base having modulus of reaction 15 kg/cm^3. The maximum temperature difference between the top and bottom of the slab during summer day and night is found to be 18°C. The spacing between the transverse contraction joint is 4.5 m and that between longitudinal joint is 3.5 m. The design wheel load is 5100 kg, radius of contact area is 15 cm, E value of CC is 3×10^5 kg/cm^2, Poisson's ratio is 0.15 and coefficient of thermal expansion of CC is 10×10^{-6} per °C and friction coefficient is 1.5. Using the edge and corner load stress charts given by IRC and the chart for the warping stress coefficient (given below), find the worst combination of stresses at the edge.



C-1-Edge Load Stress Chart (IRC)



C-2-Corner Load Stress Chart (IRC)



C-3-Warping Stress Coefficient

Answer:

Given: CC pavement slab

Thickness h = 20 cm

Modules of reaction k = 15 kg/cm^2

1. Edge load stress from chart C – 1
for h = 20 cm and = 15 kg/cm^2
edge load stress se = 24 kg/cm^2
Radius of relative stiffness

$$l = \left(\frac{E - h^3}{12k(1 - 4^2} \right)^{1/4}$$

$$= \left(\frac{3 \times 10^5 \times 20^3}{12 \times 15 \times (1 - 0.152} \right)^{1/4}$$

Say 60.8 cm
Length of slab L_x = 9.5 m = 450 m
Warping stress w – efficient C_x from chart C – 3

$$\frac{L_x}{l} = \frac{450}{60.8} = 7.4, C_x = 1.02$$

Similarly $\frac{L_y}{l} = \frac{350}{608} = 5.75, C_y = 0.87$

t = 18° C
maximum warping stress at edge

Ste = $\frac{C_x E \times t}{2}$

$$= \frac{1.02 \times 3 \times 10^5 \times 10 \times 10^{-6} \times 18}{2}$$

= 27.54 kg/cm^2

3. Frictional stress

S_f = $S_f = \frac{w L_x f}{2 \times 10}$

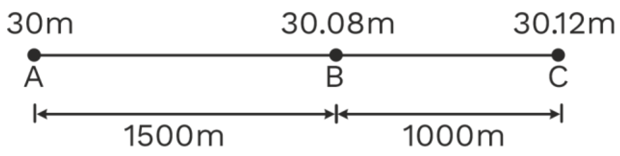
Assume w = unit wgt of concrete = 2400 kg/m^3

$$= = \frac{2400 \times 4.5 \times 1.5}{2 \times 10^4}$$

= 0.81 kg/cm^2
Combined stress at edge region:
Critical combination of stress during summer mid -day
= load stress t wiping stress – frictional /stress
= 50.73 kg/cm^2

5.(e)(ii) A distance of 1500 m was measured by a 30 m chain. Later, it was detected that the chain was 8 cm too long. Thereafter, another 1000 m was measured and it was detected that the chain was 12 cm too long. If the chain was correct initially, determine the exact length that was measured.

Answer :



Correct length of AB $= \frac{l^1}{l} \times L$

$$= \frac{\left(\frac{30 + 30.08}{2}\right)}{30} \times 1500$$

= 1502 m

Corrected length of BC $= \frac{\left(\frac{30.08 + 30.12}{2}\right)}{30} \times 1000$

= 1003.33 m

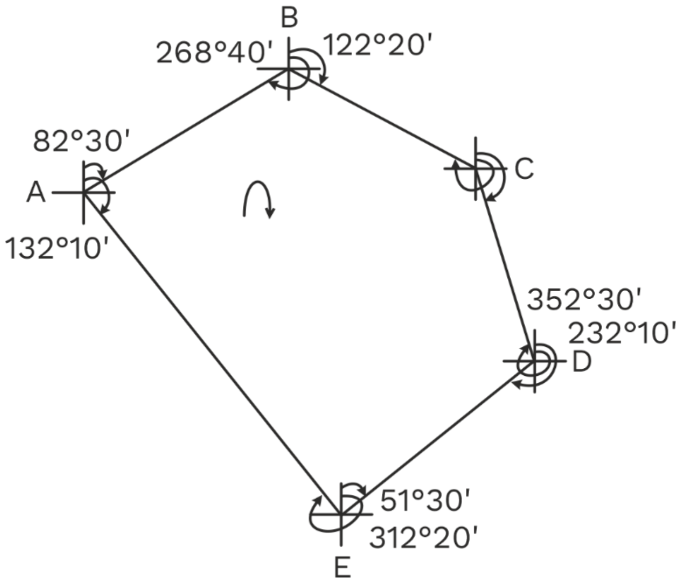
Exact length = 1502 + 1003.33 = 2505.33 m

6.(a)(i) The following are the bearings taken on a closed compass traverse:

Line	Fore Bearing	Back Bearing
AB	82°30’	260°40’
BC	122°20’	303°40’
CD	172°50’	352°30’
DE	232°10’	51°30’
EA	312°20’	132°10’

Compute the interior angles and correct them for observational errors. If the observed bearing of the line BC is correct, adjust the bearings of the remaining sides.

Answer:



Interior angle (Incorrect)
∠A = 132°10’ – 82°30’ = 49°40’
∠B = 260°40’ – 122°20’ = 138°20’
∠C = 303°40’ – 172°50’ = 130°50’
∠D = 352°30’ – 232°10’ = 120°20’
∠E = 360° – (312°20’ 51°30’) = 99°10’
Sum = 938°20’
Theoretical sum of interior angle = (2n – 4) × 90°
= (2 × 5 – 4) × 90
= 540°
Total Error = 540° – 538°20’ = 1°40’
Error for each angle $= \frac{1°40'}{5} = 0°20'$
Corrected Interior angles –
∠A = 49°40’ + 0°20’ = 50°
∠B = 138°50’ + 0°20’ = 138°40;
∠C = 130°50’ + 0°20’ = 131°10’
∠D = 120°20’ + 0°20’ = 120°40’
∠E = 99°10’ + 0°20’ = 99°30’
Sum = 540°
Given Bearing of BC = 122°20’ corrected
BB of AB = 122°20’ + 138°40’ = 261°
FB of AB = 261° – 180° = 81°
BB of EA = 81° + 50° = 131°
FB of EA = 131° + 180° = 311°
BB of DE = 99°30’ – (360° - 311°) = 50°30’
FB of DE = 50°30’ + 180° = 230°30’
BB of CD = 230°30’ + 120°40’ = 351°10’
FB of CD = 351°10’ + 180° = 171°10’
BB of BC = 171°10’ + 131°10’ = 302°20’
FB of BC = 302°20’ – 180° = 122°20’

8.(d)(i) A closed traverse was conducted round an obstacle and the following observations were made:

Line	Length (m)	Azimuth
AB	400	95°0’
BC	496	32°30’
CD	375	302°30’
DE	?	225°0’
EA	?	150°30’

Compute the missing quantities.

Answer:

$\sum L = 0$

400 cos 95° + 496 cos 32°30' + 375 cos 302°30' + l_1 cos 225° + l_2 cos 150°30' = 0

l_1 cos 225° + l_2 cos 150°30' = –584.95

$\sum D = 0$

400 sin 95° + 496 sin 32°30' + 375 sin 302°30' + l_1 sin 225° + l_2 sin 150°30' = 0

l_1 = sin 225° + l_2 sin 150°30' = 0

l_1 = sin 225° + l_2 sin 150°30' = –348.71

on solving eq (1) & (2)

l_1 = 613.87 m

l_2 = 173.35 m

Q. 7 (c) (i) A Track Management System (TMS), or Transportation Management System, is a logistics platform that uses software to help businesses manage the movement of goods, from planning and execution to optimization.

- It streamlines transportation processes, offering real-time visibility into shipments, and enhancing communication among supply chain partners.
- TMS solutions offer numerous advantages, including reduced costs, improved customer service, and increased operational efficiency.

Key advantages of track management system is:

- **Real-time Tracking and Visibility:**

  TMS provides up-to-the-minute updates on shipment locations and status, enabling businesses to proactively address potential delays and keep customers informed.

- **Cost Reduction:**

  By optimizing routes, selecting the best carriers, and automating processes, TMS helps minimize transportation expenses and improve overall cost-effectiveness.

- **Enhanced Efficiency:**

  TMS automates many transportation tasks, such as route planning, load building, and documentation, freeing up resources and streamlining operations.

- **Improved Customer Service:**

  Real-time tracking, accurate delivery estimates, and proactive communication contribute to increased customer satisfaction.

- **Data-driven Insights:**

  TMS collects vast amounts of data that can be analyzed to identify trends, optimize performance, and make informed decisions for future planning.

- **Streamlined Communication:**

TMS facilitates better collaboration and communication among various stakeholders in the supply chain, including shippers, carriers, and consignees.

- **Increased Compliance and Safety:**

  By ensuring proper documentation and adherence to regulations, TMS helps businesses maintain compliance and reduce the risk of accidents or errors.

- **Sustainability:**
  By optimizing routes and minimizing empty miles, TMS can contribute to reduced fuel consumption and lower carbon emissions.

Q.7 (c) (ii) Groundwater makes tunnelling and shaft sinking more difficult, however, with careful planning, and the right technology, groundwater can be controlled, and tunnels and shafts successfully constructed.
there are two potential groundwater problems:

1. The first and most obvious problem is flooding or inundation by groundwater inflow. This is addressed by dewatering methods.

2. The second, and perhaps more subtle problem, is instability caused by groundwater seepage. This requires groundwater depressurisation.

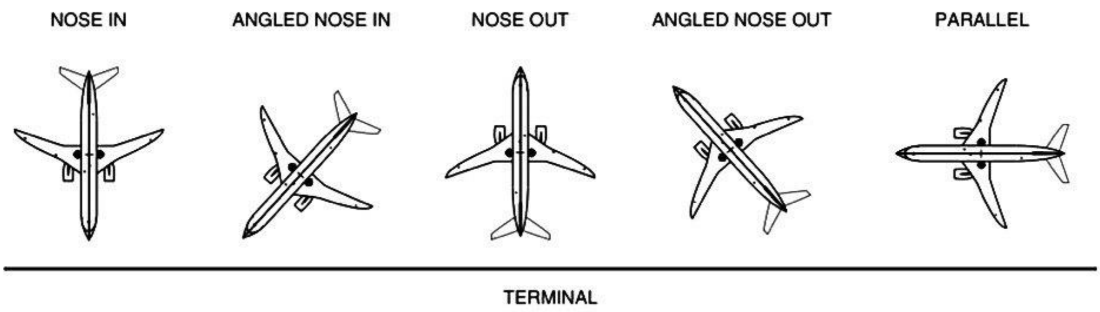
- Dewatering is the dominant problem in relatively stable ground conditions (such as fractured rock) where high rates of inflow can occur, but do not cause instability of the exposed ground.
- In this case, groundwater control focusses on pumping away the inflow, and the challenge is to deploy pumps (and associated discharge pipes and power supplies) of sufficient capacity to handle the water, without excessively hindering excavation and lining.
- If inflows are too large to handle by pumping alone, grouting can be used to reduce the permeability of the material ahead of the face; this can reduce (but not eliminate) inflows. However, some inflow can be good, and in hard rock tunnels the urge to seal every inflow should be resisted, as the inflows may gradually depressurise the ground ahead of the face, and inflows to the tunnel may reduce with time.
- The risk of groundwater-induced instability of exposed ground is often the primary concern in soils and weak rocks, and groundwater depressurisation can be used as a solution.
- In problem soils such as fine-grained sands and silts, even small flow rates of water seeping into a tunnel face or the base of a shaft can cause significant instability and loss of ground.
- When a face is cut or an excavation is made in running sand, the exposed soil will flow or 'run' into an excavation, filling it up with fluid sand/silt. These conditions are obviously a problem and would preclude tunnelling by the SEM (sequential excavation method) where short-term face stability is essential.

Q.6 (b)
(i) Airport construction and operation can significantly impact the environment. Key concerns include habitat loss and fragmentation due to land take, air and water pollution from various airport activities, noise pollution, and greenhouse gas emissions. Airports also generate solid and hazardous waste that requires proper management.

Specific environmental impacts include:

- Habitat Loss and Fragmentation: Airport construction necessitates large land areas, leading to the destruction and fragmentation of natural habitats, impacting local biodiversity.
- Air Pollution: Aircraft operations, ground support vehicles, and airport facilities contribute to air pollution, emitting pollutants like nitrogen oxides, carbon monoxide, and volatile organic compounds.
- Water Pollution: Runoff from airport surfaces, fuel spills, and improper disposal of de-icing fluids can contaminate water bodies with hydrocarbons, heavy metals, and other pollutants.
- Noise Pollution: Aircraft noise is a major concern for communities surrounding airports, affecting residents' quality of life.
- Waste Generation: Airports produce significant amounts of solid waste, including construction debris, operational waste, and catering waste, requiring proper disposal and management.
- Greenhouse Gas Emissions: Aviation is a significant contributor to greenhouse gas emissions, primarily from fuel combustion.
- Wildlife Impacts: Bird strikes, while infrequent, can be a safety hazard for aircraft and a threat to wildlife.
- Soil and Groundwater Contamination: Leakage or spills of hazardous substances can contaminate soil and groundwater, posing long-term risks.

Q.6 (b) (ii) Five aircraft parking configurations at terminals is:



1. Nose-in configuration: In this configuration, aircraft are parked with their noses pointing towards the terminal building. Passengers board directly via jet bridge or stairs. This configuration is widely used at commercial service airports for large jet aircraft, allowing for direct connection to the terminal via loading bridges and maximizing space for boarding gates and efficient passenger flow.

2. Angled nose-in or nose- out configuration: In this configuration, aircraft are parked at an angle (often 45° to 60°), either nose- in or nose- out to the terminal or taxiway. This can improve access and easy maneuvering for certain aircraft types or airport layouts.

3. Parallel parking configuration: Here, aircraft is parked parallel to the terminal building. It needs no pushback; can taxi- out directly. It needs more lateral apron space, and boarding bridges can be complex to position.

4. Remote parking: Here, aircraft parks away from the terminal building and passengers are bused to/ from the terminal. It ensures flexible use of space, and useful for overflow and low-cost carriers.

Q.6 (b) (iii) Crosswind is the component of wind that is blowing across the runway, making landings and take-offs more difficult than if the wind were blowing straight down the runway. The force exerted by the wind can be resolved into two vectors:

1. The component parallel to the direction of the motion is called a headwind or tailwind.
2. The component perpendicular to the direction of motion is called a crosswind.

It is determined by multiplying the wind speed by the sine of the angle between the wind and the direction of travel.

According to ICAO, the permissible limit of cross- wind component are as follows:

Types of aircraft	Permissible limit of cross- wind component
Small aircraft	15 kmph
Mixed aircraft	25 kmph
Big aircarft	35 kmph

Q. 6 (b) (iv) An artificial harbor typically includes breakwaters for wave protection, an entrance channel for ship access, a turning basin for maneuvering, berthing structures like wharves or piers for loading/unloading, and sometimes docks for more enclosed operations. These components work together to provide a safe and efficient area for ships to load, unload, and navigate within the harbor.

The breakdown of the key components and their functions are:

1. Breakwaters: Breakwaters are massive structures, often made of stone or concrete, designed to absorb or deflect wave energy, protecting the harbor from damaging waves and currents. They create a calm area within the harbor.

2. Entrance Channel: The entrance channel is a dredged or naturally deep passage that allows ships to safely enter and exit the harbor. It needs to be wide and deep enough to accommodate the largest vessels using the harbor.

3. Turning Basin: A turning basin is a designated area within the harbor where ships can maneuver and turn around. This is crucial for ships to change direction and align themselves for berthing or departing.

4. Berthing Structures:

Wharves: These are platforms alongside which ships dock for loading and unloading cargo.

Quays: Similar to wharves, but often longer and parallel to the shoreline.

Piers: Structures that extend perpendicularly from the shoreline, providing multiple berths for ships.

Function:

All berthing structures provide a place for ships to safely moor and facilitate cargo operations.

5. Docks: Docks are enclosed basins with gates that allow for regulated water levels, often used for ship repairs, maintenance, or for handling specific types of cargo.

6. Other Important Components:

Navigation Aids: Lighthouses, buoys, and other aids to navigation help ships navigate safely within the harbor.

Cargo Handling Equipment: Cranes, conveyor systems, and other machinery are used to efficiently load and unload cargo.

Customs and Security: Buildings and facilities for customs clearance, security checks, and other administrative functions.

Storage and Transportation: Warehouses, storage yards, and transportation links (rail or road) are essential for handling and distributing cargo.

Q. 5 (e) (i) A mistake is a human action or decision that is not intended or that deviates from the outcome that is expected or good. Mistakes can be made due to lack of knowledge, carelessness, or poor judgment and can be corrected with careful practice and attention to detail. For example- misreading a measurement, misplacing a decimal point, or using the wrong formula.

An error, on the other hand, is an inherent deviation from the true value that arises from limitations of instruments, environmental conditions, or other factors and can be minimized but not eliminated. For example- instrumental errors (e.g., a faulty measuring tape), atmospheric errors (e.g., temperature affecting tape length), or natural variations in the terrain.

1. Systematic errors (Cumulative errors): It is an error that, under the same conditions, will always be of the same size and sign. It always follows some definite mathematical or physical law, and a correction can be determined and applied. Such errors are of constant character and are regarded as positive or negative according as they make the result too great or too small. Their effect is, therefore, cumulative.
2. Accidental errors (Compensating errors): These remain after mistakes and systematic errors have been eliminated and are caused by a combination of reasons beyond the ability of the observer to control. They tend sometimes in one direction and sometimes in the other, i.e. they are equally likely to make the apparent result too large or too small. They obey the law of chance and therefore, must be handled according to the mathematical law of probability.

The most probable value (MPV) of a quantity is the one which has more chances of being correct than has any other. The most probable error is defined as that quantity which when added to and subtracted from, the most probable value fixes the limits within which it is an even chance the true value of the measured quantity must lie.

Probable error of single measurement:

$$E_s = \pm 0.6745 \sqrt{\frac{\sum v^2}{n-1}}$$

Where, v = difference between any single observation and the mean of the series
And n = number of observations in the series

Probable error of mean:

$$E_m = \pm 0.6745 \sqrt{\frac{\sum v^2}{n(n-1)}} = \frac{E_s}{\sqrt{n}}$$

Q. 6 (a) (ii)

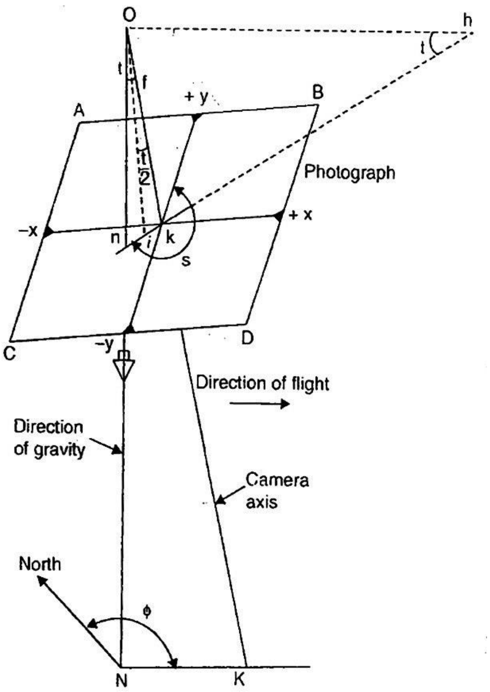
1. Fiducial marks: Fiducial marks in aerial survey are precisely placed reference markers visible on aerial photographs, used to define the internal geometry of the image and establish a frame of reference for spatial measurements. These marks, typically located at the edges or corners of the image frame, are crucial for determining the image center (principal point) and are essential for rectification and georeferencing. Their functions are:

- Establish Coordinate System: Fiducial marks define the x and y axes of the photograph's coordinate system, allowing for precise measurements and calculations.
- Locate the Principal Point: They help locate the principal point, which is the center of the photograph and a key reference point for mapping and measurement.
- Correct for Lens Distortion: By knowing the precise location of fiducial marks, distortions caused by the camera lens can be corrected.
- Georeferencing: They are used to relate the photograph to real-world coordinates, enabling the creation of accurate maps and 3D models.
- Image Registration: Fiducial marks can be used to register or align multiple images, such as in creating a mosaic of aerial photographs.
- Scale Determination: They aid in determining the scale of the photograph, which is crucial for accurate measurements and mapping.

How they are used:

- In photogrammetry, fiducial marks are used to define the principal point and are essential for mapping and 3D modeling.
- Software algorithms use the known positions of fiducial marks to correct for lens distortions and calculate the geometric properties of the photograph.
- By connecting opposite fiducial marks, the principal point can be located, and the photograph's coordinate system can be established.
- In essence, fiducial marks are fundamental for transforming raw aerial images into accurate and reliable spatial data for various applications, including mapping, surveying, and geographic information systems (GIS).

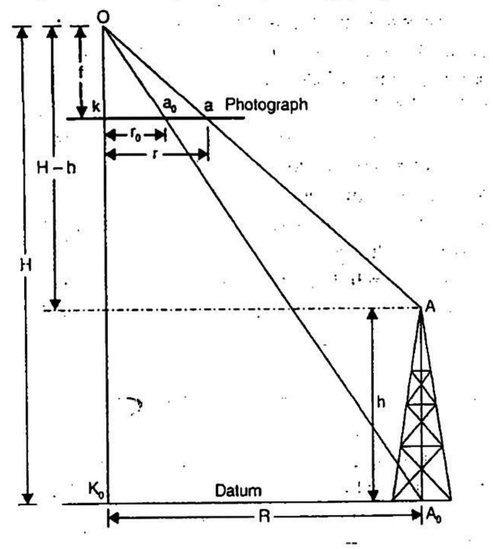
2. Isocentre: It is the point in which the bisector of the angle of tilt meets the photographs.



In above figure, oi is the bisector and ‘i’ is the isocentre. The angle of tilt lies in the principal plane, and hence the isocentre (i) lies on the principal line at a distance of $f\ tan\frac{t}{2}$ from the principal point, where t = tilt and f = principal distance. On a vertical photograph, the isocentre and the photo- nadir point coincide with the principal point.

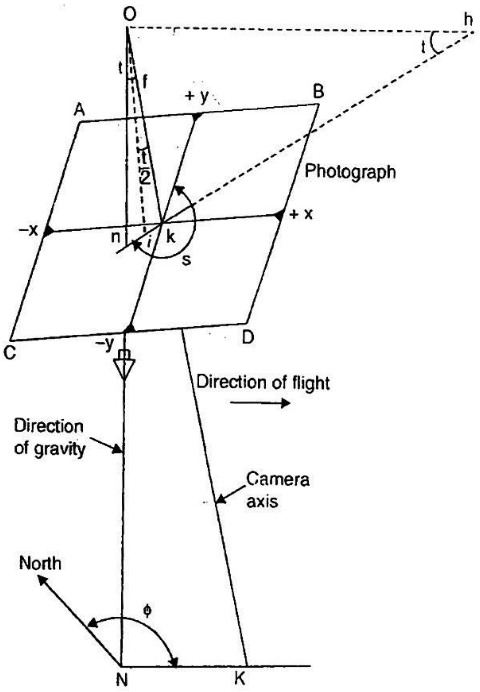
3. Relief displacement:

- If the photograph is truly vertical and the ground is horizontal, and if other sources of errors are neglected, the scale of the photograph will be uniform. Such a photograph represents a true orthographic projection and hence the true map of the terrain.
- In actual practice, however, such conditions are never fulfilled. When the ground is not horizontal, the scale of the photograph varies form point to point and is not constant.
- Since the photograph is the perspective view, the ground relief is shown in perspective on the photograph. Every point on the photograph is therefore, displaced from their true orthographic position. This displacement is called relief displacement.



$$\text{Relief displacement} = d = r - r_0 = \frac{rh}{H} = \frac{r_0 h}{H-h}$$

4. Tilt or tip: Tilt or tip is the vertical angle defined by the intersection, at the exposure station, of the optical axis with the plumb line. In below figure, ∠ kon = t = tilt.



5. Principal point: It is a point where a perpendicular dropped from the front nodal point strikes the photograph. It is also the foot of a perpendicular to the image plane from the rear nodal point in a camera lens system free from manufacturing errors. This principal point is considered to coincide with the intersection of the x- axis and the y- axis. In above figure, k is the principal point. The point K is known as the ground principal point where the line OK produced meets the ground.

Q. 8(d) (ii) The deformities like folds can be of much important from civil engineering point of view. Their importance can be listed as followed:

1. If the beds of limb of the fold dip gently in the upstream direction, it is more favorable and advantageous. This is because at the dam site, the weight of the dam (W) acts vertically downwards, and in addition, there also exists a great lateral thrust (T) due to reservoir water. The resultant force (R) of these two will be always inclined in the downstream direction. Depending on the quantum of reservoir water, the inclination (R) may vary from $10^{o}$to $30^{o}$from the vertical. This means the beds which have a gentle upstream dip will be perpendicular to the resultant force and hence can offer their best competence to withstand the stresses or loads acting in the area.

2. The geological setting of folds can also indirectly contribute to the stability of dam, by completely eliminating the possible uplift pressure. This is because, if any possible leakage of reservoir water is directed to the upstream by virtue of the inclination of beds. Hence there is no scope for the flow of reservoir water beneath of the dam.

3. If the dam is located over the limb of the fold which dips along the downstream direction as shown below. The resultant force of the dam will be parallel or nearly parallel depending on the amount of dip. In this situation the sedimentary beds are less competent, leading to

unfavorable geological setting. In this situation there will be leakage of the reservoir water along the bedding planes, resulting further instability of the dam structure.

Effect of fault on dams:
If the dam site shows any occurrence of faulting, irrespective of its attitude (i.e. dip & strike), under no circumstances, dam construction should not be taken. This is not only because of the fear of possible relative displacement of the site itself but also due to the possible occurrence of earthquakes which endanger the safety and stability of the dam. Further, if the fault zone is crushed or intensely fractured, due to the water pressure or construction load pressure, it becomes physically incompetent to withstand the forces of the dam. In such cases normally there will be more porosity and permeability of water leading to further reduction in competence.

Effect of Geological Structures on location of Reservoirs:
If any of the following geological settings occur at the reservoir site, there will be significant difference in terms of leakage of reservoir water.
1. The case wherein beds of the limb dip in the upstream direction, there will not be any effective leakage of water from the reservoir. This is so because all percolated water will be directed in the upstream direction only, along the bedding planes.
2. The case wherein if strata at the reservoir site are horizontal, there may be little seepage of water of the reservoir in the downstream side along the horizontal bedding planes.
3. The case wherein strata dip in the downstream direction, there shall be considerable leakage of reservoir water along the bedding planes which are dipping in the downstream direction.
4. In the case of strata containing faults, the faults which dip in the downstream direction are more harmful. This is so because they not only cause effective and significant loss of water but also endanger the safety of the dam by creating, uplift pressure over it. However, if the water table occurs at or near the surface of the reservoir site, faults do not contribute to loss of water. If severe fault or shear zone occurs as outcrops along the upstream course of the river, they get eroded quickly and contribute heavily to the load of the river.

Effects of geological structures in tunnelling:
Case of Folds: For tunnelling purposes, folded rocks are in general unsuitable because the affected rocks are under great strain and the subsurface removal of material, i.e., creation of tunnels in such rocks may cause the release of the contained strain which may appear as collapse of the roof, or as caving or bulging of sides, or floor etc. If the tunnelling work is taken up along the thick beds of limbs, parallel to the axis of the fold, because the disadvantages associated with crests and troughs do not occur. This is because, along the crests of folds, the beds contain numerous tensions and other factures and if the tunnel is made through them, frequent falling of rocks from the roof may occur.

Effect of faults at Tunnel site: Normally faults are harmful and undesirable as they create a variety of problems. The problems with faults occurring at tunnel site can be described as followed. 1. Active fault zone: These are the places where there is scope for further recurrence of faulting which will be accompanied by the physical displacement of lithological units. Such faults will lead to dislocation and discontinuity in the tunnel alignment. So occurrence of any active fault in tunnels is very undesirable. 2. Inactive fault zone: These are the places where there is no scope of further occurrence of faulting, yet these prone to intense fractures due to earlier faults. This means that these zones are of great physical weakness. So if such zones occur along the course of a tunnel, it is necessary to provide lining. 3. Highly permeable zones (with or without faulting): Zones that are highly porous, permeable and decomposed may occur at tunnel sites these also require heavy concrete lining.