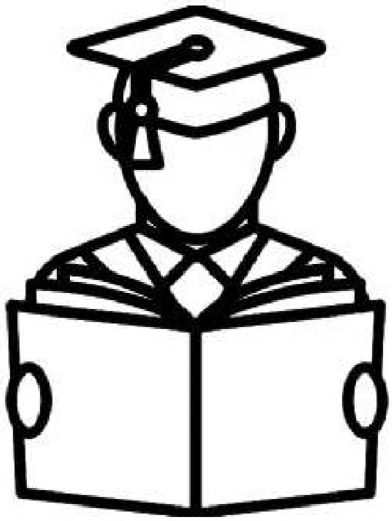
चौधरी PHOTOSTAT

"I don't love studying. I hate studying. I like learning. Learning is beautiful."



"An investment in knowledge pays the best interest."

Hi, My Name is

Civil Engineering for GATE/IES

(*MADE EASY*)

STRUCTURE ANALYSIS

S.A
- I.E.S
  - Objective — 15 to 20 ques
  - Conventional — 40 marks
- GATE — 8 to 10 marks

- Stability & Degree of indeterminacy — Ob
- Influence line diagrams — Ob + Conv.
- Arches — Ob
- Method of analysis —
  - Strain Energy
  - Slope deflection
  - moment distribution
  - Matrix

  } Ob + Conv
- Analysis of trusses —
  - Determinate
  - Indeterminate
  - Deflection of truss joint

  } Ob + Conv

Reference book —

(1) Theory of Structure — S. Ramamurtham
[Strain Energy, Moment Distribution & truss Analysis]

(2) Structure Analysis — Negi & Jangid.
[Slope deflection, Influence line]

(3) Theory of Structure — Gupta & Pandit.
[Basic concept Stability & Determinacy, Matrix method]

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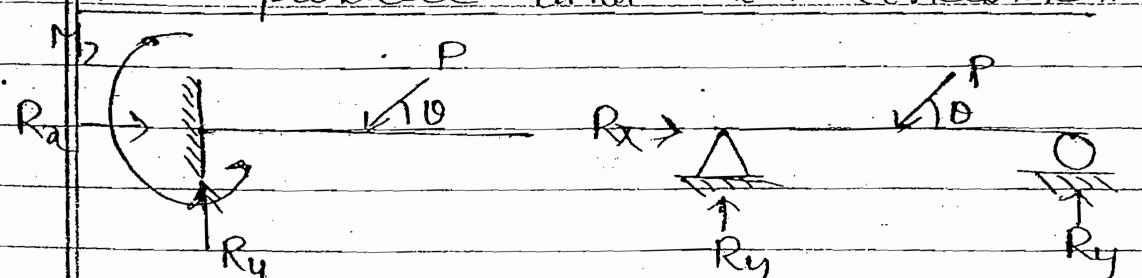
Stability And Indeterminacy

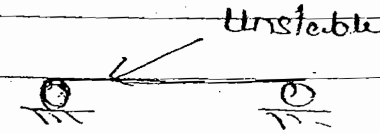
Stability
- External [Related to Support Condⁿ]
- Internal [Related to Geometry]

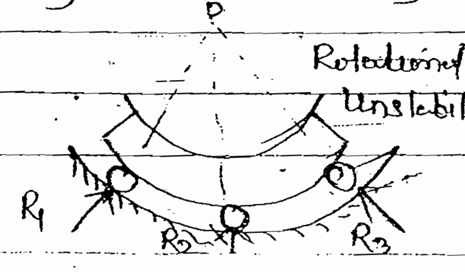
External Stability –

Large displacement of support or intire structure are not permitted therefore there should be enough reacⁿ at support to prevent movement and also reacⁿ should be arrange in appropriate.
It mean there will not rigid body motion however elastic deflect in members may occur.

In plan structure (2D) there should be a min. of 3 independ external reacⁿ which should be non parallel and non concurrent







For stability of 2D structure following 3 condⁿ of static equilibrium should be satisfied

(1) $\Sigma F_x = 0$ ..... To prevent Δ_x
(2) $\Sigma F_y = 0$ .... To prevent Δ_y
(3) $\Sigma M_z = 0$ ..... To prevent θ_z

In case of 3D structure there should a min. of 6 independent external reaxⁿ to prevent rigid body displacement at support. The displacement to be prevent are Δ_x, Δ_y, Δ_z, θ_x, θ_y & θ_z. Therefore there will be 6 (Six) equations of static equilibrium.

(1) $\Sigma F_x = 0$ .... To prevent Δ_x
(2) $\Sigma F_y = 0$ " Δ_y
(3) $\Sigma F_z = 0$ " Δ_z
(4) $M_x = 0$ " θ_x
(5) $M_y = 0$ " θ_y
(6) $M_z = 0$ " θ_z

2D — plane structure
3D — Space structure

In 3D structure for stability

all the rxn should non ~~plane~~ coplanar ~~parallel~~ and non concurrent.

Internal Stability –

No part of the structure can move relative to the other part so that geometry of the structure is preserve however small elastic deformation are permitted. To preserve the geometry enough no. of members and their adequate arrangement is required. For geometric stability there should not be formed of cond^n of mechanism (there should not be three co-linear hinges)

For 2D truss the min. no. members needed for geometric stability is

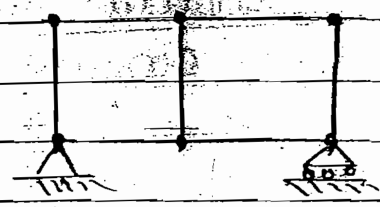
$$M = 2J - 3$$

and for 3D truss –

$$M = 3J - 6$$

~~The~~ All the members should be arranged such that truss is devided in triangular block. There should not be rectangular or poly gonal block.

eg.



$J = 6$

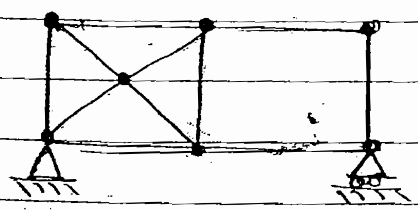
no. member needed for geometric stability,

$$m = 2J - 3$$
$$= 2 \times 6 - 3$$
$$= 9$$

no. members p/s
$= 7$

Hence, above truss geometrically unstable therefore such is called "Deficient Structure".

eg.



$m = 9$
$= 2J - 3$.

In above case arrangement of members is not adequate hence right pannel is unstable and left pannel is over stable.

For geometric stability all pannels of truss or members should stable.

HYDROLOGY IRRIGATION

Hydrology :-

Hydrology is the Science of Wate Which deals with the occurens circulation & distribution of water on Earth Surface and its atmosphere.

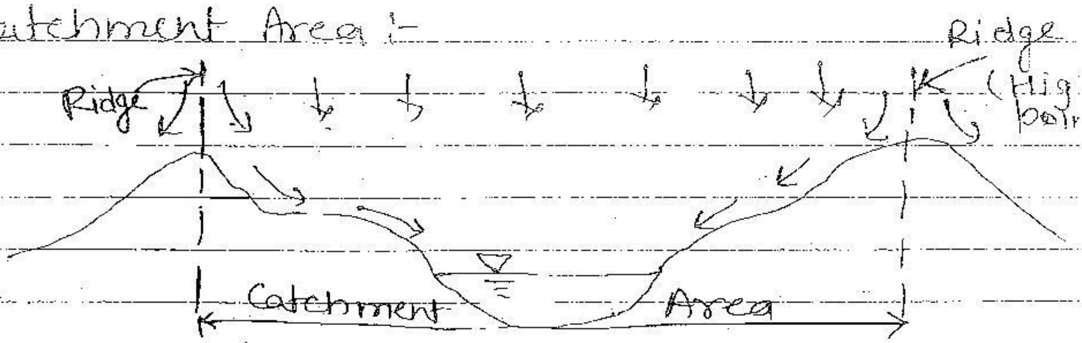
Hydrological Cycle :-

This is a cycle in which wat moves from one phase to another face.

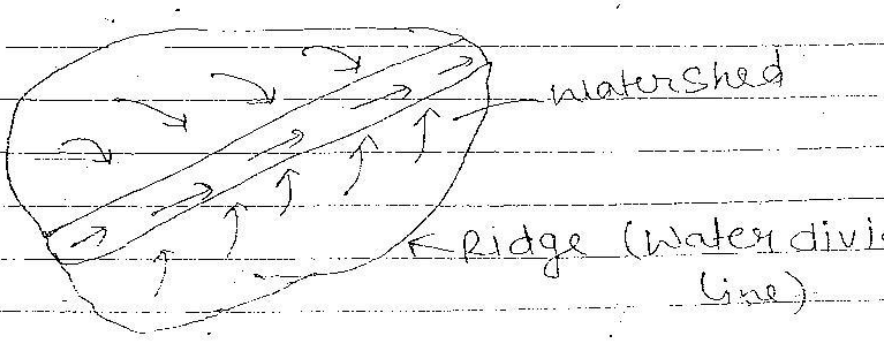
Residence time :-

This is the time taken by a water particle in ~~prass~~ crossing one particul face of hydrological cycle.

Catchment Area :-



The Area draining into a river or stre is called the Catchment area for that particu Stream or river.



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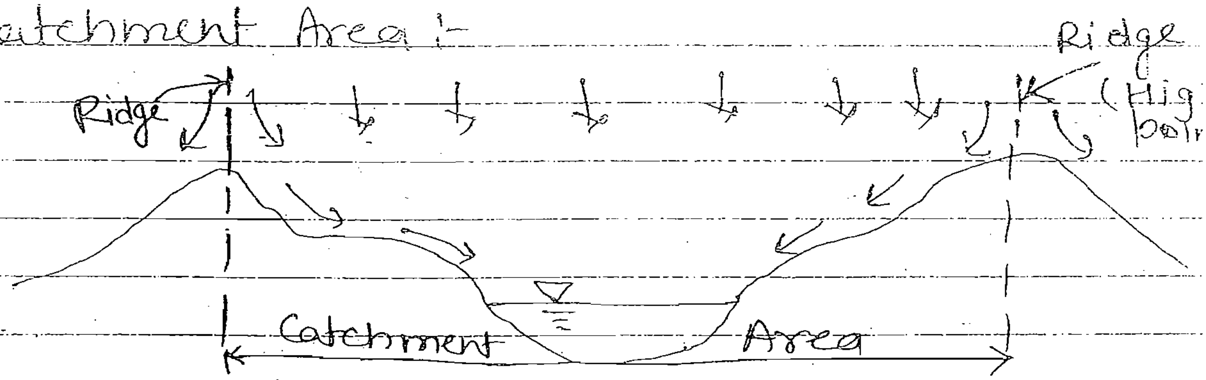

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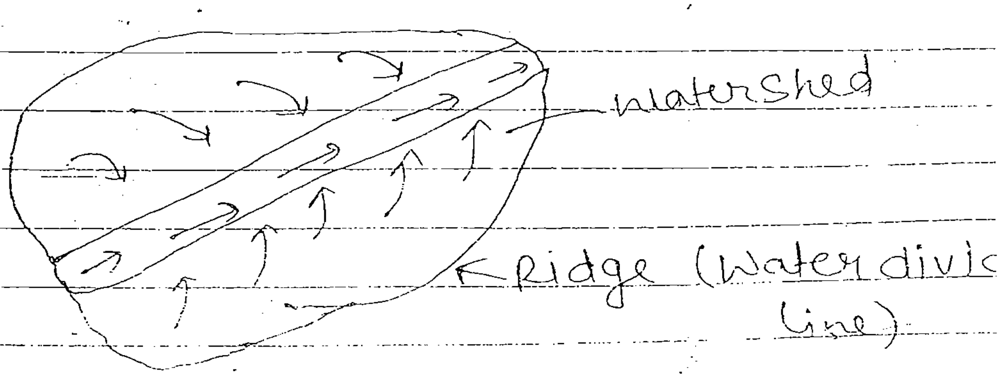

Catchment area is also called as water-shed.

Ridge :- It is the line which demarkets one Catchment area from its neighbouring area. This is also called as water divide line or divide line.

Water budget Equation :-

This Eq^n is based on the law of Conservation of mass and according to it,

Mass Inflow - Mass outflow = Change in Storage.

Q. A lake has a water surface Elevation of 103.2 m above datum. In a month the lake recevices an avg. inflow of 6 cumecs and in the same period outflow from the lake was 6.5 cumec. In that month the lake recevies the rainfall of 145 mm & Evaporation from lake surface is Estimated as 6.1 cm. Calculate the water surface of Elevation at the and of month. Surface area of lake is 5000 hectare.

Sol

Inflow = 6 cumecs + 145 mm

Outflow = 6.5 cumecs + 6.1 cm

$$\text{Inflow} = \left(6\ m^3/s \times 60 \times 60 \times 24 \times 30\right) / \text{Area}$$

$$+ .145\ m$$

one year is called Anual Rainfall.

Avg. annual rainfall is the avg. value of annual rainfall for the last 35 years

Index of Wetness :-

This Index is used to find the rainfall variation for particu-lar year and it is calculated as.

$$\text{Index of Wetness} = \frac{\text{Rainfall in a year}}{\text{Avg. Annual Rainfall}} \times 100$$

eg. $\text{Index of wetness} = \frac{90cm \times 100}{120cm} = 75\%$

This shows that the rainfall deficiency is 25%.

If rainfall deficiency is in b/w 30-45%, It is called large deficiency.

If it in b/w 45-60% It is called Serious deficiency

If it is more than 60% It is disaster deficiency.

If Index of Wetness is Equal to 100%. It Indicates that rainfall is normal.

If this Index is less than 100% It is called a bad year.

If this Index is more than 100% then It is called a good year.

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Drought :-
This is the climatic situation which is characterised by
Drought can be classified as follows:-

1 Metrological drought :-
This represents deficiency in precipitation. If the decrease in precipitation is more than 25%. It is called
If it is in b/w 25% - 50% it is called modrate drought
If it is more than 50% it is called

An year is called drought year if area effected by drought is more than 25% of the total area of the country.

If drought occures in an area with a probability of ·2 to ·4 then that area is called drought Prone Area. and If this probability is greater than ·4 it is called Chronologically drought ~~porne~~ prone area.

2. Hydrological drought :-
This refers to the below avg. value of stream flow, water content in lakes, reservoir, underground water

3 Agriculture drought :-
This type of drought is charactrised by deficieny of moisture available for a plant grows. This can be calculated using a

$$\text{outflow} = 6.5\ m^3/s \times (60 \times 60 \times 24 \times 30) / \text{Area} + .061\ m$$

$$= \left(\frac{6 \times 60 \times 60 \times 24 \times 30}{5000} + .145\right) - \left(\frac{6.5 \times 60 \times 60 \times 24 \times 3}{5000} + .061\right)$$

$$= .456 \qquad\qquad 0.398$$

$$103.2 + 0.456 - 0.398 = 103.258\ m$$

Precipitation :-

Precipitation denotes all forms of water or moisture that reaches the Earth Surface.

following are the different forms of precipitation :-

1) Rain :-

This is the principal mode of precepitation in India. This denotes water droplets of size ranging from 0.5 mm to 6 mm. On the basis of Intensity rainfall is classified as

0 – 2.5 mm/hr → Light rain
2.5 – 7.5 mm/hr → Moderate
> 7.5 mm/hr → Heavy Rain

NOTE In India rainfall data is collected Every day at 8:30 A.M and If this rainfall is more than 2.5 mm on a perticular day then that day is called rainy day.

from mm → we can calulate total vol. by multiplying the area × depth.

and its discharge can be calculated m^3/s

SURVEYING

Surveying:-

Introduction:-

Earth is oblate spheroid.

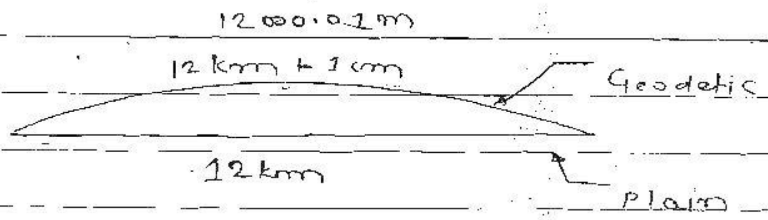
Polar Axis = 12713.80 km (less)

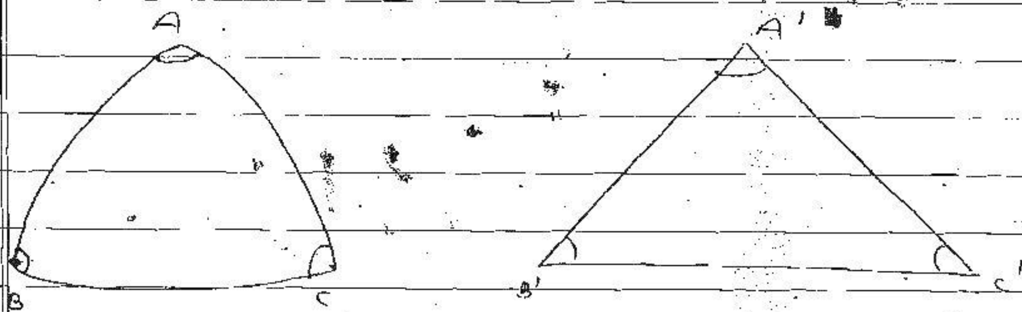
Equatorial axis - 12756.75 km (More)

Difference = 42.75 km (0.34%)

1. Plane Surveying:- If earth curvature is not consider (for small area)

2. Geodetic Surveying:- Earth curvature is considered (suitable for large area)





for Area 195 km² $A + B + C = 180°$

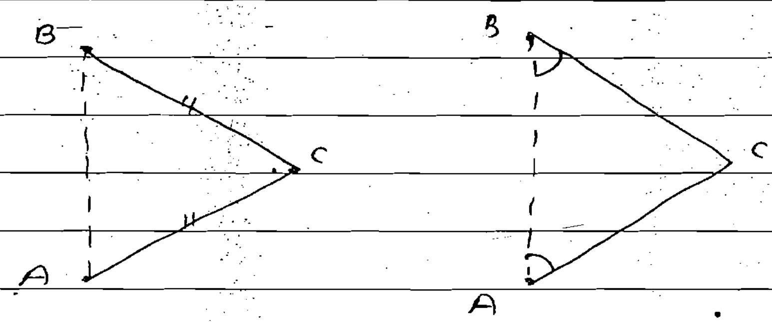
$(A+B+C) - (A'+B'+C') = 0° 0' 1''$

* Principal of Surveying

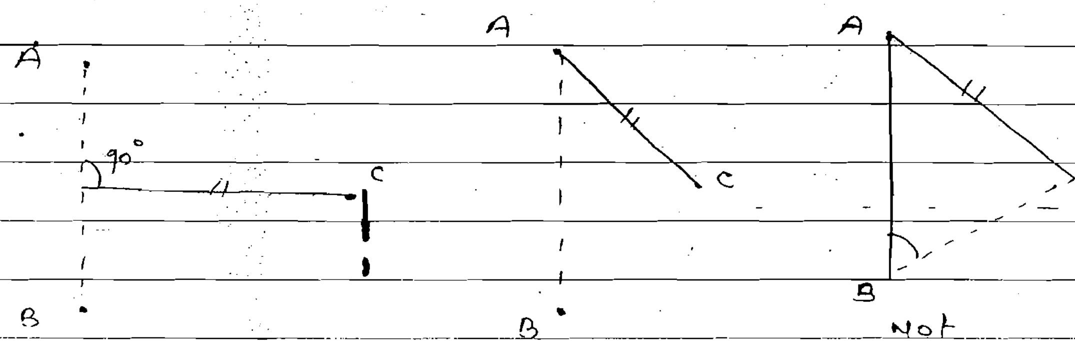
In this method major control points are fixed and measured with higher accuracy minor details can be taken even with less precision.

In this case mistakes/error in taking minor details will not reflected in major measurment.

2) Location of a point:- w.r.t. two refference point,



Chain Surveying Compass.



Offset Method Traversing Not Common.

Accuracy and Errors :-

1. Precision :- Degree of perfection used in a measurment using correct instrument, correct manner of measurment.

2. Accuracy :- Degree of perfection obtained in a measurment (The measured value should be near to the true value)

3. True value :- The actual value of a quantity.

True Error - Difference between a measured value and true value.

4. Descrepancy :- Difference between the two measurments of a same quantity.

Sources :- [of errors]

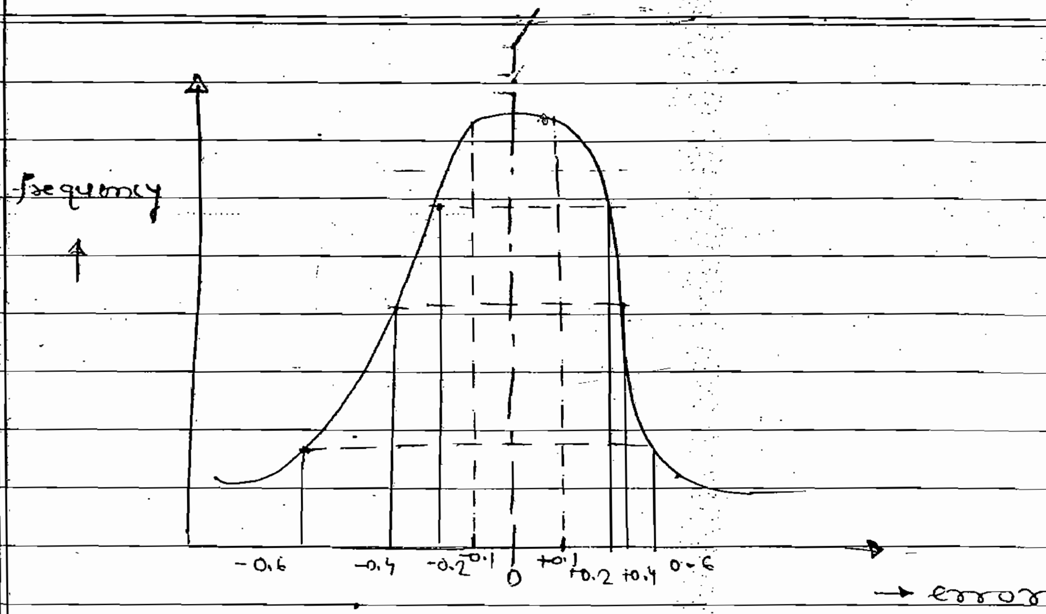
1. Instrumental - Due to faulty instrument
2. Personal - Error in reading or writing
3. Natural - Temperature, wind, humidity etc.

Type of Errors :-

1. Mistakes :- Human errors. (may be + or - ve)
2. Systematic Errors :- (Commulative errors) :
   That always occure in same direction.
   [Always + ve or Always - ve]

3. Accidental Errors [Compensating errors or Random Error]
   May occures some times in one direction (say +ve) and sometimes in other (say -ve)

Accidental errors follow a rule -
" Law of probability "



As per this law of errors:-

1. Small errors are more frequent than large errors (frequency of large error shall be less)

2. The +ve and -ve value error of same value has equal frequency.

Most Probable value (MPV):-
The value of measurement which has more chances of being the correct value of the quantity is called Most Probable value.

5.2 . 5.2 5.3 5.4 5.6 5.7

Principle of least square:-
Most probable value of a quantity is that value for which sum of square of errors is least.

case-1: if weight of each measurement is one-
$x_1, x_2, x_3, \ldots\ldots, x_n$ are different measurements
a same quantity,

if x is most probable value :-

	Errors	Square of Errors
x_1	$(x-x_1)$	$(x-x_1)^2$
x_2	$(x-x_2)$	$(x-x_2)^2$
x_3	$(x-x_3)$	$(x-x_3)^2$
x_4	$(x-x_4)$	$(x-x_4)^2$
x_n	$(x-x_n)$	$(x-x_n)^2$

As per principle of least square :-

$$y = (x-x_1)^2 + (x-x_2)^2 + \cdots\cdots + (x-x_n)^2$$

for y to be least value.

$$\frac{dy}{dx} = 0$$

$$\frac{dy}{dx} = 2(x-x_1) + 2(x-x_2) + \cdots\cdots 2(x-x_n) = 0$$

$$2\left[x \times n - (x_1 + x_2 + x_3 + \cdots\cdots x_n)\right] = 0$$

$$x = \frac{x_1 + x_2 + x_3 + \cdots\cdots x_n}{n}$$ .. Most probable value.

MPV = Mean value

Case-II : when different measurement have weights

Measurement	Weight	MPV	Errors	Square of Errors	Total square of errors
x_1	W_1		$(x-x_1)$	$(x-x_1)^2$	$W_1(x-x_1)^2$
x_2	W_2		$(x-x_2)$	$(x-x_2)^2$	$W_2(x-x_2)^2$
–	–	x	–	–	–
–	–		–	–	–

classmate

Date

Page

As per principle of least square -

$$y = w_1(x-x_1)^2 + w_2(x-x_2)^2 + \dots = \text{least}$$

$$\frac{dy}{dx} = 2w_1(x-x_1) + 2w_2(x-x_2) + \dots = 0$$

$$\therefore x = \frac{(w_1 x_1 + w_2 \cdot x_2 + \dots w_m x_m)}{(w_1 + w_2 + w_3 + \dots w_m)}$$

MPV = weighted Average.

1. The probable error of single measurement :-

$$E_s = \pm 0.6745 \sqrt{\frac{\Sigma V^2}{n-1}}$$

where. V = difference between any single observations and mean of the series

n = number of observations.

2. The probable error of mean of a number of observations :-

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

3. If measurements of have different weights ($x_1 - w_1$, $x_2 - w_2$, ...)

(a) Probable error of single measurement

$$E_s = \pm 0.6745 \sqrt{\frac{\Sigma (wV^2)}{n-1}}$$

(b) Probable error of any observation of wt W.

CE- 4

Introduction :- RCC
(RCC)

WSM :-

1. Cement concrete :-

Cement + Sand (fine agg) + Coarse agg

a) Young's modulus of elasticity (E_c) as per IS 456 : 2000

$$E_c = 5000\sqrt{f_{ck}}$$

where f_{ck} = characteristic strength

b) Characteristic strength f_{ck}:-

The value of strength below which not more than 5% of test results are expected to fall.

if 100 cubes are tested

21.0, 19.0, 21.5 . . . . – – –

arrange all value in increasing order

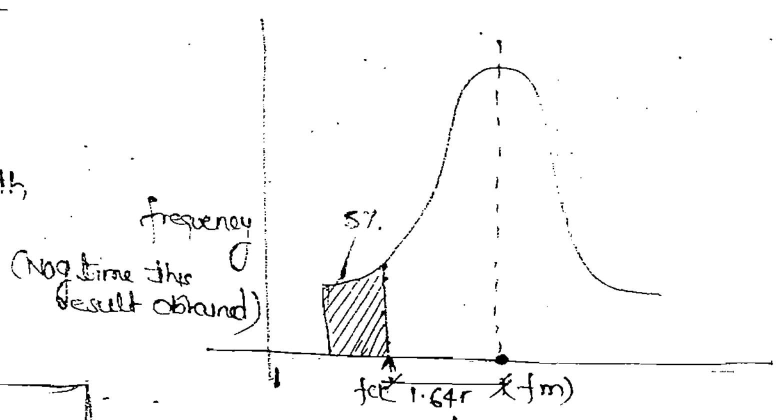
16.5, 17, 18, 18.3, 19, (20), 21, 21, 21, 21

less (5%) ← (f_{ck}) → (95%) more

Probabilistic curve :-

f_{ck} = Characteristic strength

f_m = mean strength



$f_m > f_{ck}$

$$f_m = f_{ck} + 1.64\sigma$$

σ → 3 to 4 (Standard value)

→ 4 N/mm² – M20 & M25 –

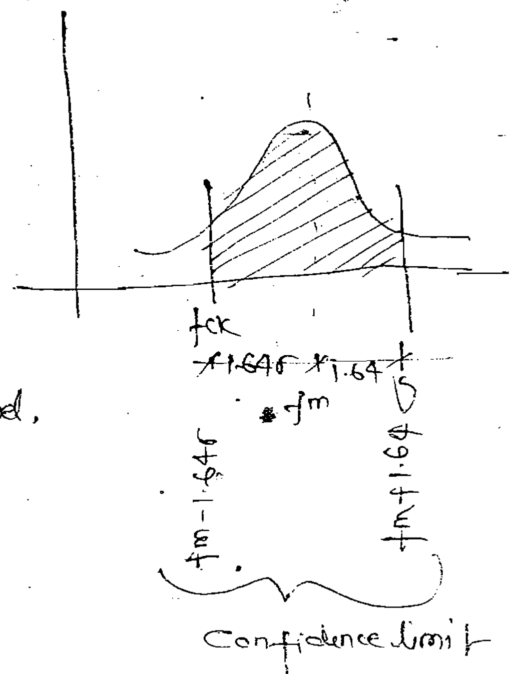
5 N/mm² – M30 & M50

: If ~~xxx~~ not more than 50% of test results are expected to fall be characteristic strength, in this case $f_{ck} = f_m$

Confidence limit :-

maxim. probability of a particular test result shall lie within a range of
($f_m - 1.64\sigma$) to $f_m + 1.64\sigma$ these two limits are called confidence limits.

) The probability % of lying the test result with confidence limit is called confidence level.



Grade of concrete :-

As per IS-456.
) Ordinary concrete — M10 to M20
) Standard Concrete — M25 to M55
) High Strength Concrete — M60 to M80

M - mix
25 - characteristic strength.

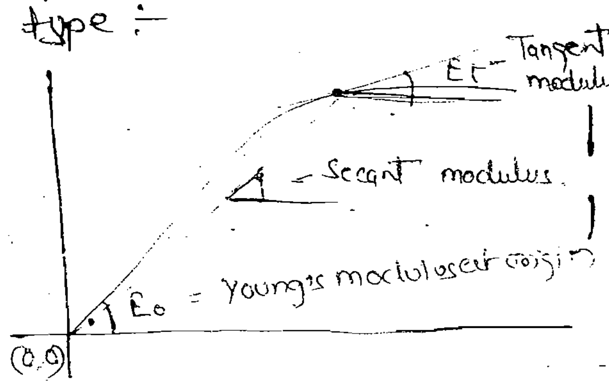
→ For RCC min grade of co recommended = M20

) Young's modulus :- effects of creep diff type :-

) Youngs modulus of elasticity at origin :-
Slope of stress strain curve at origin.
$E_o = E_c = 5000\sqrt{f_{ck}}$

Secant modulus of elasticity
Slope of line joining any point with origin

) Tangent modulus of elasticity
Slope of tangent at any point of the curve.



Effect of creep :- Long term modulus of elasticity

$$E_{cl} = \frac{E_c}{1+\theta} = \frac{5000\sqrt{f_{ck}}}{1+\theta}$$

where θ = creep co-efficient = $\frac{\text{Creep strain}}{\text{elastic strain}}$

as per IS: 456: (Pr. 6.25.1 / page-16)

Age of loading	Creep loading
7 day	2.2
28 days	1.6
1 year	1.1

E_{cl} reduces due to effect of creep

Tensile strength of concrete in ~~flexure~~ bending :-

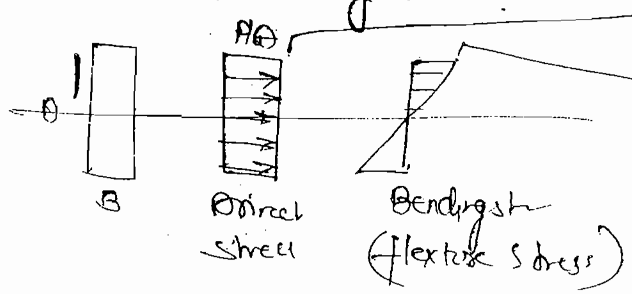
$$f_{cr} = 0.7\sqrt{f_{ck}}$$

Grade	M20	M25	M30	M35	M40
f_{cr}	3.13	3.5 N/mm²	3.83	4.14	4.43

B. Permissible stress in concrete (for WSM)

Grade	Tensile strength		Compressive strength	
	Direct	Bending	Direct	Bending (σ_{cbc})
M15	2.0	2.71	4.0	5.0
M20	2.8	3.13	5.0	7.0
M25	3.2	3.5	6.0	8.5
M30	3.6		8.0	10.0
M35	4.0		9.0	11.5
M40	4.4		10.0	13.0
	N/mm²			

Direct & bending stress :-



* Chances of failure is more in the section is subjected to same stress

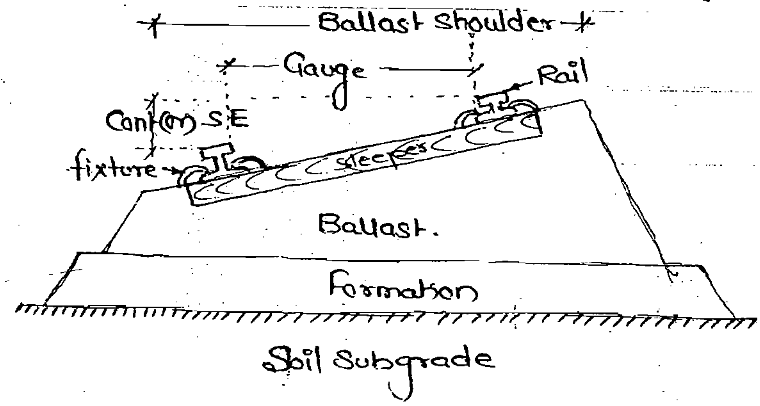
* Chances of failure is less, as only in top & bottom fibre are at maximum stress, stress in other fibres are less than failure value

CE-5

Railway TRANSPOTATION

Introduction ÷

1. Cross-section of a railway track (on a curved track)

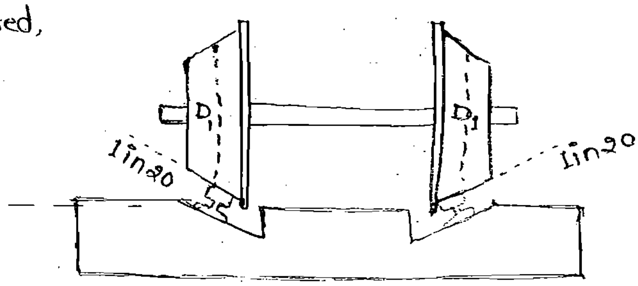


2. Gauge ÷

1. BG [Broad Gauge] – 1.676m
2. MG [Meter Gauge] – 1.0m
3. NG [Narrow Gauge] – 0.762m
4. LG [Feedertrack Gauge] (or) Light gauge – 0.61m

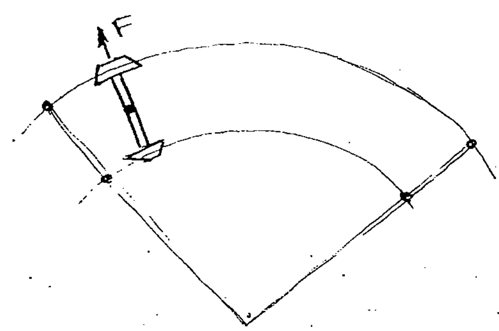
3. Conning of wheels ÷

Conning of wheels are made tapered, with slope of 1 in 20, so that diameter of wheel is different at different cross section.



Purpose ÷

1. To keep the train just in central position during movement
2. To adjust the distance travelled on two rails on a curved track where larger distance is required to be travelled on other track.
3. To reduce the wear & tear of rail & wheels.



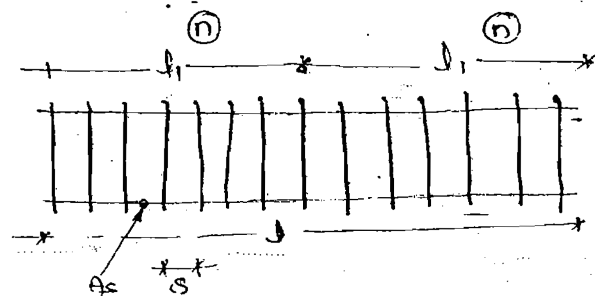
Theory ÷ When on a straight track, when train moves sideways in any direction, diameter of wheel over one rail will increase, & it will decrease over ano thus automatically the train is diverted back in its original central posi due to larger distance travelled over one rail as compared to another.

4. Welded Rail ÷

LWR – Long welded rail ÷ Rails are welded to avoid exponsion joint. In ca of long welded rails, elongation of rails are not allowed, prevented by fixtures over sleeper. To overcome the stresses devel in rails a minimum length of LWR is required.

If minimum length of LWR = l.

Due to T°C temp. increase, Increase in length



$$\delta L = L\alpha T$$

if δl elongation is not allowed strain developed

$$e = \frac{\delta l}{l} = \frac{l\alpha T}{l} = \alpha T$$

Stress developed

$$\frac{\text{stress}}{\text{strain}} = E$$

$$\text{stress} = E \times \text{strain}$$
$$= E\alpha T$$

If As = cross section of Rail force developed in rail section $F = \text{Stress} \times As$

$$\boxed{F = As\,E\alpha T} \quad \text{--- (1)}$$

If R = resistance offered by one sleeper

Min^m no of sleeper :-

Minimum no. of sleepers required to prevent F force

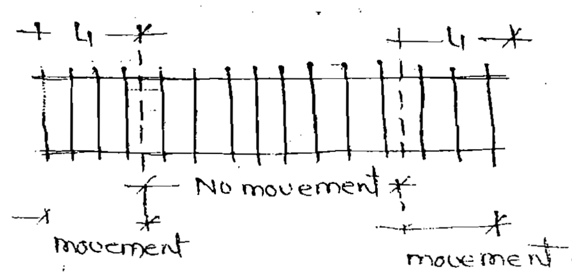
$$\boxed{n = \frac{F}{R} = \frac{As \cdot E\alpha T}{R}}$$

length of rail required in one direction

$$\boxed{l_1 = (n-1)\,S}$$

Total minimum length of LWR so that central portion does not moves

$$\boxed{L = 2l_1}$$



1) Determine the minimum theoritical length of LWR, beyond which central portion of a 56kg rail would not be subjected to longitudinal movement, due to 30° temp. variation use ÷

I. Rail – c/s area 66.15cm²; $E_s = 2.1 \times 10^6$ kg/cm² ; $\alpha = 11.5 \times 10^{-6}$/°c

2. Sleepers – sleeper spacing = 60cm

Average resistance force/sleeper/Rail = 300kg

Sol:–

Due to 30°c temp increase, temp.

$\delta L = L \alpha t$

if above elongation is not allowed

strain $= \frac{\delta L}{L} = \alpha T$

∴ stress developed due to above strain

$P_s = E \alpha T$

$= 2.1 \times 10^6 \times 11.5 \times 10^{-6} \times 30$

$= 724.5$ kg/cm²

force developed in rail section = $A_s \times p_s$

$= 66.15 \times 724.5$

$= 47925.675$kg

minimum no of sleepers required to prevent this above force

$n = \frac{\text{force}}{\text{resistance}} = \frac{47925.675}{300}$

$= 159.75 \simeq 160$ nos.

minimum length required in one direction

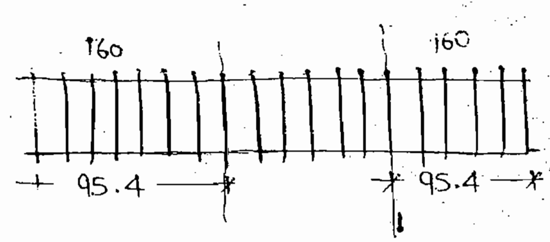
$= (n-1) \cdot S$

$= (160-1) \times 0.6 = 95.4$m.

minimum length of LWR $= 2L_1$

$= 2 \times 95.4$

$= 190.8$ m.



Composite Sleeper Index

* For wodden sleeper ÷ CSI. is an index to determine the stability of a particular timber to be used as sleeper.

$$CSI = \frac{S+10H}{20}$$

where S = strength index of timber at 12% moisture content
H = Hardness index of timber.

Minimum value	CSI
Track sleeper	783
Crossing	1352
Bridge	1455

* Sleeper density ÷ (13-14m)
No of sleeper used for one rail length denoted by (n+x)
vary from (n+3) to (n+6)

ex:- If sleeper density for a broad gauge is (n+5), how many sleepers shall be required for 1Km track.

Sol:-
length of one rail = 13m = 12.8m ≈
sleeper density = (n+5) = (13+5) = 18 Nos
for 1Km length = $\frac{1000}{12.8} \times 18$ = 1406 Nos.

Geometrical Design ÷

1. Speed of Train ÷

Maxm speed allowed on a track is decided considering following ÷

a) Maxm speed sanctioned by railway board.
b) On curve speed calculated by martin's formula [Safe speed on curve]
c) Maxm speed as per cant formula
d) Maxm speed as length of transition curve.

Safe Speed on curve [By Martin's formula]

1. On Transitioned curved

a) On BG/MG Track

$$V_{max} = 4.35\sqrt{R-67}$$

b) For NG Track

$$V_{max} = 3.65\sqrt{R-6}$$

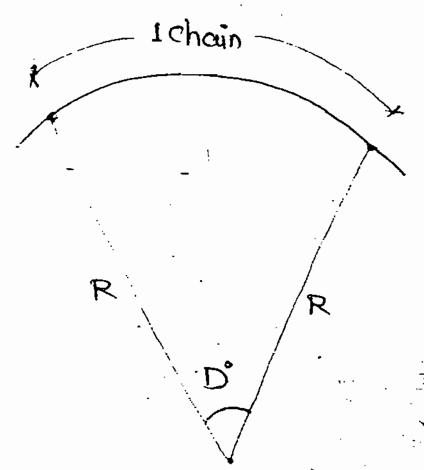
2. On non-transitioned curved

Speed = 80% of for transitioned curve.

3. For high speed train

$$V_{max} = 4.58\sqrt{R}$$

Radius of curve / Degree of curve :-



Angle made at the centre of curve by 1 chain length is called degree of curve [D°].

1. For 30m chain length.

$$\frac{30}{2\pi R} = \frac{D^\circ}{360^\circ}$$

$$D^\circ = \frac{30 \times 360^\circ}{2\pi R} = \frac{1718.9}{R} \simeq \frac{1720}{R}$$

2. For 20m chain length

$$\frac{20}{2\pi R} = \frac{D^\circ}{360^\circ}$$

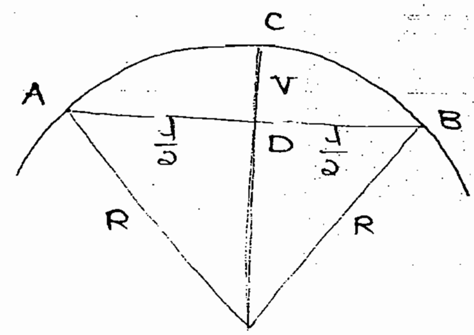
$$D^\circ = \frac{20 \times 360^\circ}{2\pi R} = \frac{1145.9}{R} \simeq \frac{1150}{R}$$

Degree of curve	1°	2°	3°	4°	5°
30m	1720m	860m	573m	430m	344m
20m	1150m	575m	383m	288m	230m

Max^{m} limit of degree of curve ÷

BG	10°
MG	16°
NG	40°

3. Versine of Curve ÷



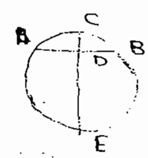
$$AD \times DB = CD \times DE$$

$$\frac{l}{2} \times \frac{l}{2} = V \cdot (2R - V)$$

$$= V \cdot 2R$$

here $2R - V \approx 2R$

$$\therefore V = \frac{l^2}{8R}$$



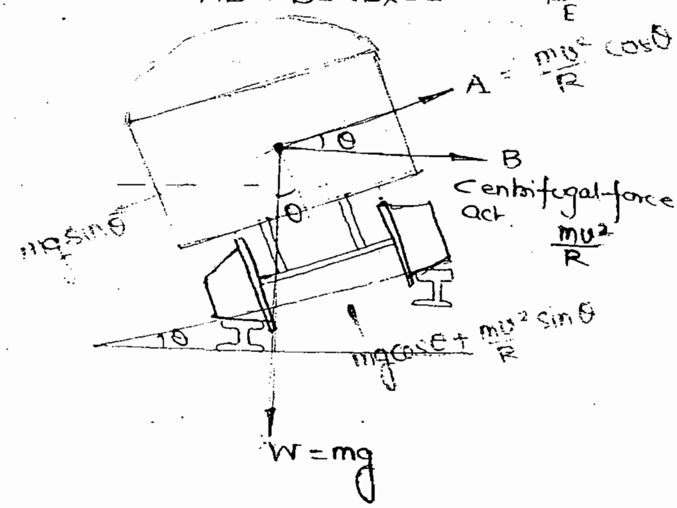
AD·DB = CD×DE

Super Elevation or Cant :-

Equating all forces in the direction of track

$$mg \sin\theta = \frac{mv^2}{R} \cdot \cos\theta$$

$$\boxed{\tan\theta = \frac{v^2}{gR}} \text{ — Slope}$$

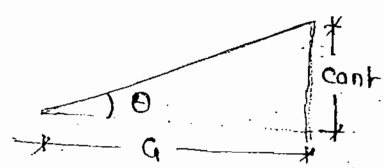


$$\frac{Cant}{G} = \tan\theta$$

$$Cant = G \cdot \tan\theta$$

$$= G \cdot \frac{v^2}{gR}$$

$$= G \cdot \frac{(0.278V)^2}{9.81R}$$



$$\boxed{Cant = e = \frac{G \cdot V^2}{127R}}$$