

~: INTRODUCTION OF HIGHWAY

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ENG. G. S. S.

Highway Development & planning :-

→ Historical development of Road construction :-
ORDER OF ROAD DEVELOPMENT

(1) Roman Road :-

(i) First time Roman started construction of Roads in large scale.

(ii) In 312 BC, they constructed "Appian way" of length over 680 km.

→ Layers of Roman Road :-

(1) Large foundation stones in lime mortar (10 to 20 thick).

(2) Broken stones in lime mortar (25 to 40cm thick).

(3) Lime concrete (25 to 40cm thick).

(4) Large stone slabs in lime mortar (10 to 15cm thick). Total thickness - 0.75 to 1.2m.

→ Main features of Roman Road :-

(1) They were built straight regardless of gradient.

(2) Total thickness was as high as 0.75 to 1.2m.

(3) The wearing course consisted of large dressed stone blocks in lime mortar.

(2) Tresaguet construction :-

(1) "Pierre Tresaguet" (1716 - 1796) developed an improved method of Road construction by the year 1964 A.D.

→ Layers of Tresaguet construction :-

(1) Large foundation stone on edge, 17cm thick.

(2) Broken stones, 8cm thick.

(8) Sloping wearing surface, 5cm thick.
(Slope - 1 in 45').

Total thickness = 30cm.

→ Main features of Tressaguet construction:

- (i) The thickness was of the order of 30cm.
- (ii) Consideration was given to subgrade moisture & drainage of surface water.
- (iii) Shoulder sloping was provided of order of 1 in 20.

(3) Metcalf construction :-

- (i) "John Metcalf" was working in England during the period of "Tressaguet".
- (ii) He followed the recommendation of "Robert Phillips" & was responsible for construction of about 290 km of road in the northern region of England.

(4) Telford construction :-

- (i) "Thomas Telford" founder of Institution of Civil Engineers at London began his work in early 19th century.

→ Layers of Telford construction :-

- (i) Foundation stones of varying size (17-22cm).
- (ii) Broken stone in lime mortar at the edge (11cm thick) + Two layers of

Angular Broken stone (7cm size) (10cm & 5cm thickness).

(iii) Binding layer of wearing course 4cm thick with cross slope of 1 in 45.

→ Main features of Telford construction:-

(i) In this construction leveled subgrade of width 9m was provided.

(ii) Wearing course slope & of about 1 in 45.

(5) Macadam construction:-

(i) ~~John~~ "John Macadam", Surveyor or General of Roads in England put forward an entirely new method of road construction.

(ii) This was the first method based on scientific thinking.

(iii) This new concept came in the year 1827.

→ Construction steps

(i) Subgrade is compacted & prepared with a cross slope of 1 in 36 upto a desired width of 9m.

(ii) Broken stones, all passing through 5cm sieve size of compacted to a uniform thickness of 10cm.

(iii) The 2nd layer of broken stone of size 3.7cm was compacted to thickness of 10cm.

(iv) The top layer consisted of stones less than 2cm & compacted to a thickness of 10cm.

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about 5cm & maintaining the slope of about 1 in 36.

~~Construction step :-~~

~~(i) Importance was given to subgrade drainage & comp~~

→ Main features are :-

- (i) Importance was given to subgrade drainage & compaction so that subgrade was compacted & prepared with cross slope of 1 in 36.
- (ii) The size of broken stone for top layers was decided ~~was~~ on the basis of stability under animal drawn vehicles.
- (iii) The thickness of each layer was kept uniform from edge to the centre & the total thickness also kept uniform to a minimum value of 25cm.
- (iv) The ~~po~~ pavement surface was also given the cross slope of 1 in 36.

→ Comparison betⁿ Macadam & Telford method :-

Macadam Method	Telford Method
(i) The subgrade was given a cross slope of 1 in 36 to facilitate subgrade drainage.	(i) The subgrade was kept horizontal & hence the subgrade drainage was proper.
(ii) The bottom layer of	(ii) Heavy foundations

sub-base
pavement on the sub-base
course consisted of
broken stones of less
than 5cm size of to
uniform thickness
of 10cm only.

stones of varying size
about 14cm towards the
edge & 22cm towards the
centre were hand packed
& prepared to serve as
sub-base course.

(iii) Base & surface courses
consisted of broken
stones of smaller
size to compacted
thickness of 10cm & 5
cm respectively & top
surface was given
a cross slope of 1
in 36.

(iii) Two layers of broken
stones were compacted
over the foundation stones
before laying the wearing
course of thickness 4cm
with slope 1 in 45.

(iv) The total thickness of
pavement was kept
uniform from edge
to the centre to a
minimum value of
25cm only.

(iv) The total thickness of
construction varied from
about 35cm at the edge
to about 41cm at
the centre.

→ Highway Development in India :-

(a) Jayakar committee & the Recommendations :-

(i) A resolution was passed by both chambers
of Indian legislature in 1927, in response
to which "Jayakar committee" was constituted
with "M.R. Jayakar" as chairman.

→ Recommendations by the committee :-

(i) The road development in country should be considered as a national interest as this has become beyond the capacity of provincial government and local bodies.

(ii) An extra tax should be levied on petrol from the road users to develop a road development fund called "Central Road fund".

(iii) A semi official the technical know how from various parts of the country and to act as an advisory body on various aspects of roads.

(iv) A Research organization should be instituted to carry out research & development work & to be available for consultations.

→ Most of the "Jayakar committee" Recommendations were accepted & following steps were taken :-

(i) The "Central Road fund" was formed by the year 1929.

(ii) A semi official technical body named as "Indian Road congress" was formed in 1931.

(iii) "Motor vehicle Act" was started in 1939 to regulated the road traffic in the form of traffic laws, ordinances & regulations and later on it has been revised in the year 1988.

(iv) A research organisation named as "Central Road Research Institute" (CRRI) was formed in 1950 and at New Delhi for research in various aspects of highway engineering.

→ Other measures are taken as following:—

(1) National Highway Act:—

→ This act was passed in the year 1956.

→ Main features of this act are:—

(i) The responsibility of development & maintenance of the national highway (NH) to be provisionally taken by the central govt.

(ii) The central government to be empowered to declare any other highway as NH or to omit any other existing national highway from the list.

(2) "Highway research board" was setup in 1973 with view to give proper direction & guidance to road research activities in India.

(3) The "National Transport Policy Committee" (NTPC) was in 1978.

→ IRC (Indian Road Congress) has played important role in formulation of the last three 20 years road development plans in India.

→ Road plan:—

(1) First 20 years Road plan (Nagpur Road plan) — (1943-63) but it over in 1961.

→ Features :-

- (i) The Nagpur Road Plan formulae were prepared on the basis of "star & grid" pattern.
- (ii) The total road length of 5,32,700 km with a density of 16 km of road length per 100 km² area would be available by the year 1963.
- (iii) All roads are classified into 5 categories.
NH, SH, VR, MDR, ODR.
NH → National Highway.
SH → State Highway.
VR → Village Road.
MDR → Major District Road.
ODR → Other District Road.
- (iv) Length of railway track in the area was considered within the total road length.

→ Result :-

Through total achievements were higher than the targeted value, but the length of NH & SH achieved were lesser than the targeted value.

(B) Second 20 year Road plan (Bombay Road plan) - (1961 - 81).

→ Features :-

- (i) At the end of the plan, the target road length ~~was~~ aimed was 32 km per 100 km² Area.
- (ii) Maximum distance of any place in a

- developed on agricultural areas would be 6.1 km from a metalled road and 2.4 km from any category of ~~metalled~~ Rocks.
- (iii) Every town with a population above 2000 in plains 1000 in semi hill areas and above 500 in hilly areas and be connected by metalled Road.
- (iv) 1600 km of Express ways have been considered in this plan within proposed target of NH.
- (v) A development factor of 5% is provided for future development.

→ Result :-

- (i) Total achievement was higher than targeted but NH & SH were constructed lesser than targets.
- (ii) It should be noted that allowance for development of ~~agri~~ agriculture & industry in the next 20 years was made in Nagpur plan allowing 5% increase in the calculated road length. This allowance is 5% only according to 2nd plan.
- (c) Third 20 year Road plan (Lucknow Road plan) - (1981 - 2001)
- (i) In this plan, Roads are classified into 3 road system.
- Primary road system.
 - Secondary road system.
 - Tertiary road system.
- (ii) The overall road density was targeted as

82 km/100 km².

- (iii) The NH network should be expanded to form square grids of 100 km. So that no part of the country is more than 50 km away from a NH.
- (iv) Express ways should be constructed along major traffic corridors to provide fast travel.
- (v) There should be improvement in environmental quality & road safety.

(A) Primary Road system :-

This Road system includes :-

- (i) Express ways of total length 200 km.
- (ii) NH based on the concept of 100 km square grids $100 \times 100 = 200 \text{ km}$ of NH length are provided per $100 \times 100 = 10000 \text{ km}^2$ area (i.e., 1 km/50 km² area).

According to this concept Total length of NH in the country = 66000 km.

(B) Secondary Road system :-

This Road system includes :-

- (i) State Highway (SH)
- (ii) Major District Road (MDR)

→ State Highway (SH) :-

→ Length of SH in km = $\frac{\text{Area of state (km}^2\text{)}}{25}$

= $62.5 \times \text{no. of towns in state} - \text{length of NH}$

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→ Length of NH in km = $\frac{\text{Total area of state}}{50}$

→ Major District Road (MDR) :-

→ Length of MDR in km = $\frac{\text{Area of state (km}^2\text{)}}{12.5}$

or
= 90 x No. of towns in state.

(C) Tertiary Road system :-

~~ODR~~ This road system includes :-

- (i) Other District Roads (ODR)
- (ii) Village Roads (VR)

→ CLASSIFICATION OF ROADS :-

(1) Depending on weather / season :-

- (a) All weather roads.
- (b) Fair weather roads.

(2) Based on type of carriage way :-

- (a) Improved Road :- provided with a hard pavement e.g, WBM (Water Bound Macadam) etc.
- (b) Unimproved Road :- provided w/o a hard pavement course. e.g, earth, gravel road etc.

(3) Based on type of pavement surfacing :-

- (a) Surface Road (Bituminous or cement conc. ~~surfacing~~ surfacing).
- (b) Unsurfaced Road.

(4) Based on traffic volume :-

- (a) Heavy traffic road.

- (b) Medium traffic road.
(c) Light traffic road.

(5) Based on location & function as per Nagpur road plan:-

- (a) National highway (NH) → Main highway running across country.
(b) State highway (SH) → Arterial road of a state connecting with the NH of adjacent states.
(c) Major district Road.
(d) Other district Road.
(e) Village Road.

→ Road Pattern:-

- (a) Rectangular or Block pattern (Adopted in Chandigarh).
(b) Radial or star & Block pattern.
(c) Radial & circular pattern (Adopted at centre - right place of Delhi).
(d) Radial & Grid (Adopted in Nagpur road plan).
(e) Hexagonal pattern.
(f) Minimum travel pattern.

→ BASIC REQUIREMENTS OF IDEAL ALIGNMENT:-

- (i) Short
(ii) Easy
(iii) Safe
(iv) Economy.

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→ FACTORS CONTROLLING ALIGNMENT:-

- (i) Obligatory points:- These are control

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- points governing the alignment of highway:
- (i) Traffic
 - (ii) Geometric design.
 - (iii) Economics.
 - (iv) Stability.
 - (v) Drainage.
 - (vi) Existing Length.

→ Planning Surveys:—

for assessing the road length requirement following studies are made:—

- (i) Economics studies.
- (ii) Traffic or road use studies.
- (iii) Engineering studies.

→ Engineering surveys for highway location:—

Before highway alignment is finalized in highway project, the engineering surveys are to be carried out.

The stages of Engineering Surveys are:—

(a) Map study:—

- (i) Topographic maps are available from the survey of India with 15 to 30m contour interval.
- (ii) Valley, ponds or lakes etc. can be avoided & approximate position of bridges etc. can be planned.

(b) Reconnaissance Study:—

This is used to examine the general character of the area for deciding most feasible route for detailed studies.

(c) Preliminary Survey :-

(i) This is carried out to collect all the physical information which are necessary in connection with the proposed highway alignment.

(ii) This work consist of -

- Primary traverse.
- Topographical features.
- Levelling work.
- Drainage studies & hydrological data.
- Soil survey.
- Material survey.
- Determination of final centre line.

(d) Final location & Detail Survey :-

(i) The centre line of road finalised is translated on the ground during location survey.

(ii) Detailed Survey is done to fix temporary bench mark & levelling work is done for drainage & earthwork calculations.

~~→ Alignment :-~~

→ Alignment :-

(i) Fixing centre line of a road.

(ii) Alignment

(iii) Short

(iv) Easy

(v) Safe

(vi) Economy

Notes :-

Population (1000 to 2000) → 0.25

" (2000 - 5000) → 0.5

" (5000 - 10000) → 1

" (greater than 10000) → 2.5

Utility

Problem 01:-

Three new roads P, Q, R all pumped in & divert the sale for these roads were given in the table given below based on the principle of max^m utility order of priority for these 3 roads should be.

Road	Length (km)	No. of village with population		
		2000	2000-5000	7500
P	20	8	6	1
Q	28	19	8	4
R	12	7	5	2

- (a) P, Q, R (b) Q, R, P (c) R, P, Q (d) R, Q, P

Ans:- Priority of P =
$$\frac{(8 \times 1) + (6 \times 2) + (1 \times 3)}{120}$$

Priority of Q =
$$\frac{(19 \times 1) + (8 \times 2) + (4 \times 3)}{28}$$

Priority of R =
$$\frac{(7 \times 1) + (5 \times 2) + (2 \times 3)}{12}$$

Priority = 1.15, 1.68, 1.92
(P), (Q), (R)

Problem 02:-

4 new roads links are to be constructed P, Q, R and S with different road length the details of population & products seen as follows, suggest the order of

priority for phasing the road construction project maximum utility appres.

Road	length (cm)	No. of villages with population ranges				Indiv. value
		1000-2000	2000-5000	5000-10000	>10000	
P	300	100	80	30	6	255
Q	400	200	90	0	8	270
R	500	240	110	70	10	315
S	600	248	112	73	12	335

(A) RSPQ (B) PQRS (C) RPSQ (D) PQSR

Ans:-

Population weigh age consumed	1000-2000	2000-5000	5000-10000	>10000
	1	2	3	4

Priority of Road (P)

$$= \frac{(100 \times 1) + (80 \times 2) + (30 \times 3) + (6 \times 4)}{300}$$

$$= \text{over } 1.24$$

Priority of Road (Q)

$$= \frac{(200 \times 1) + (90 \times 2) + (0 \times 3) + (8 \times 4)}{400}$$

$$= \text{over } 1.03$$

Priority of Road (R)

$$= \frac{(240 \times 1) + (110 \times 2) + (70 \times 3) + (10 \times 4)}{500}$$

$$= \text{prior } 1.42$$

Prior of Road (S)

$$= \frac{(248 \times 1) + (112 \times 2) + (73 \times 3) + (12 \times 4)}{550}$$

$$= 1.34$$

$$\text{Priority} = 1.42 > 1.34 > 1.24 > 1.03$$

(R) (S) (P) (Q)

———— 0 ————

—: Road Geometrics :—

→ Highway geometrics Design Basic element:-

Design specialized:-

→ Design Specialized:-
Most important features controlling design of highway is the geometrical design.

→ Factors considered are:-

- (1) Importance of Road.
- (2) Terrain/Topographic.

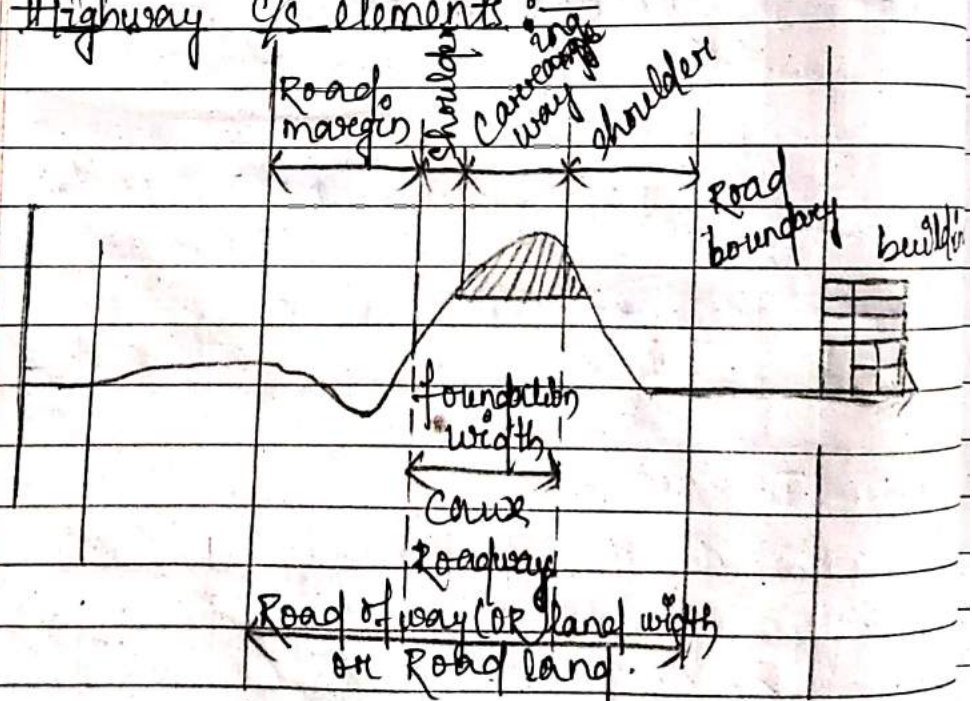
→ For plain terrain cross slope taken as $(0 - 10\%)$.

→ For rolling terrain $(10 - 25\%)$.

→ For mountainous terrain $(25 - 60\%)$.

→ For steep $(> 60\%)$.

→ Highway c/s elements:-



→ Friction or Spd Resistance :-

- (1) Longitudinal frictional co-efficient $\mu = 0.35$ recommended by IRC for calculation of stopping sight distance.
- (2) for horizontal curve design frictional co-efficient is 0.15.

→ Pavement unevenness :-

The pavement surface condition is commonly measured by using an equipment called bump integrator in terms of an evenness index.

→ Camber / cross slope :-

Camber is provided to drain off rain water from the road surface.

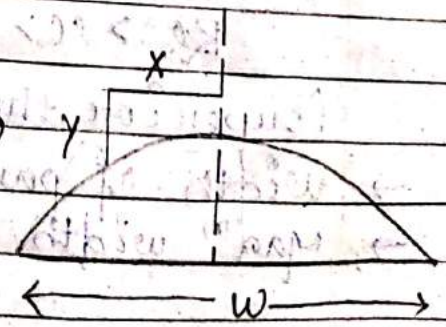
→ Type of camber :-

- (1) Parabolic camber :-

~~flexible pavement~~
Parabolic space is given so that the profile is flat at the middle and slopes towards the edge which is prepared by fast moving vehicles as they have to frequently cross the crown line during over-laying operation on a 2 lane highway.

flexible pavement - (WBM, Gravel, earth, BT)

$$y = \frac{2x^2}{w}$$



Camber, slope = i GNT
 m max^m central rise.
 for $a = w/2$
 $y = (m \cdot a) = \frac{2(w/2)^2}{4w} = \frac{w}{2L}$

(II) Straight-line camber :-
 Rigid pavement (RCC, CC)

(III) Combination camber :-
 Camber should be half of longitudinal gradient (G).
 $G = 2c$ (BT) $\frac{SR}{Parabolic}$ (BT)

→ Types of Road :-

	Range of camber in road Heavy traffic Light traffic	
Cement-concrete high type bituminous surface.	1 in 50	1 in 60
Thin bituminous surface.	1 in 40	1 in 50
WBM, gravel pavement.	1 in 33	1 in 40
Earth	1 in 25	1 in 33

RCC > CC > Thick BT >> thin BT > WBM

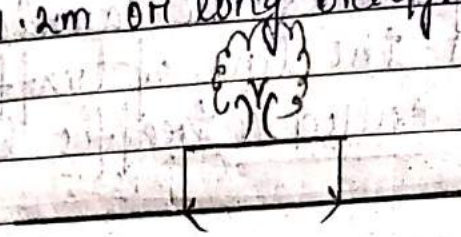
(Superior the road, flatter the camber).

- width of pavement of carrying way.
- max^m width of which as per IRC is 2.44

- Single lane	8.75m
- Two lanes, without raised kerbs.	7.0m
- Two lanes with raised kerbs.	7.5m
- Intermediate carriage way (except on important roads).	5.5m
- Pavements.	3.5' per lane

→ Median :-

- Min 6m
- upto 1.2m on long bridge.



→ Minimum width = 8.5m

→ Highway Geometric Design :-

→ Introduction :-

→ Importance of Geometric Design :-

The geometric design of highway deals with the dimension & layout of visible features of the highway such as alignment, sight distances and intersections.

→ Geometric design of highways deals with following elements :-

- Cross section elements.
- Sight distance considerations.
- Horizontal alignment details.

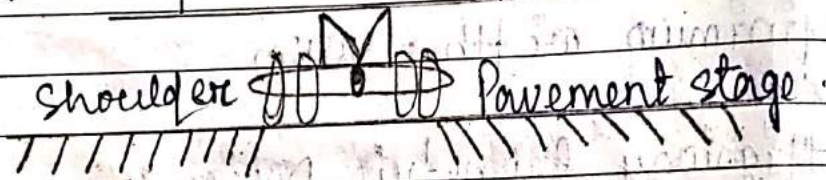
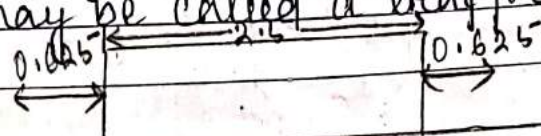
- Vertical alignment details.
- Intersection elements.

→ Cross slope or camber :-

Cross slope or camber is the slope provided to the road surface in the transverse direction to drain off the rain water from the road surface.

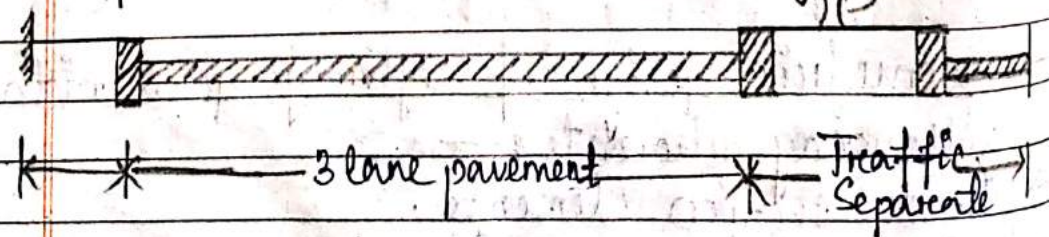
→ Width of pavement or carriage way :-

The pavement or carriage way width depends on the width of traffic lane & ~~number of~~ number of lanes. The carriage way intended for the line of traffic movement may be called a traffic lane.



→ Kerbs :-

Kerb indicates the boundary betⁿ the pavement & shoulder or sometime islands or foot path or kerb parking space.



→ Road Margins :-

The various elements included in the road margin are shoulder, parking lanes, front-
-age road, drive way cycle track, footpath
ground rails & embankment slope.

shoulders are shoulders provided along the road edge to serve as an emergency lane for vehicles that have broken down.

→ Right of way :-

Right of way is the area of land required for the road, along its alignment. The width of this acquired land is known as land width & it depends on the importance of the road and possible future development.

→ Gradients :-

→ Ground slope along road :-

→ IRC has recommended ruling gradient value of 1 in 20 on plane & rolling terrain.

→ Types of Gradients :-
terrace & 1 in 16.7 on steep terrain

(1) Ruling Gradient :-

→ Known as 'Design Gradient'.

→ Gradient on road during normal course.

→ Speed of vehicle should not decrease vehicle moving on gradient.

(2) Limiting Gradient :-

→ $\max^m$ gradient - steeper than ruling gradient for respected length.

Exceptional

- (3) ~~Minimum~~ Limiting ~~Gradient~~ Gradient :-
 → Gradient steeper than limiting gradient
 → Used in shop - sketchy only (< 60 m in 1 km length).
 → In exceptional situations.

- (4) Min^m Gradient :-
 → Based on road drainage requirements.

- (5) Grade compensation :-
 It's the redⁿ in gradient if gradient horizontal curve occurs on road.

$$G_c(\%) = \frac{30 + R}{R} \left(\frac{75}{R} \right)$$

which is less/min^m.

R = Radius of curve (in m).

- compensated gradient = ruling gradient - G_c .
 Gradient more than 4% is to be compensated. There grade compensation, the gradient to be provided on the road should not be less than 4%.

Q:- The longitudinal gradient on a road line 20. If the radius of curve is 150 m the grade compensation is _____?

Ans:-

$$G = 1/20$$

$$= 5\%$$

$$R = 150 \text{ m}$$

$$G_c = \frac{30 + R}{R} = \frac{30 + 150}{150} = 1.2\%$$

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Q. The longitudinal gradient on a road is 1 in 20. If the radius of curve is 30 m. The compensation gradient is _____.

Ans:- $\frac{L \sin 20^\circ}{R} = \frac{5^\circ}{30 + R}$, $R = 30 \text{ m}$ } $\begin{matrix} \text{min} = 2 \\ \text{but} \\ 5 - 2 = 3^\circ \\ < 4^\circ \end{matrix}$

$\Rightarrow \frac{30 + 30}{30} = 2^\circ = \frac{7^\circ}{30} = 2.5^\circ$

$$\Rightarrow G = 1/2 = 50\%$$

$$\Rightarrow G_c = 5.4 = 1.1\%$$

→ Sight Distance:-

→ Introduction : —

→ Introduction:
→ The safe & efficient operation of vehicles on roads depends among other factors on the road length & ~~vehicles~~ which are obstructions if any becomes visible to the drivers in the directions of travel. In other words the feasibility to see ahead or the visibility is very important for safe vehicle operation on a highway.

→ Sight distance available from a point is the actual distance along the road surface, which a driver from a specified height above the carriage way has visibility of stationary or moving objects. In other words, sight distance is the length of road visible ahead to the driver at any instance.

→ Three sight distance situations are considered to the design:-

- # Stopping or absolute minimum sight distance
- # Safe overtaking or passing sight distance
- # Safe sight distance for entering into uncontrolled intersection.

→ Stopping sight Distance (SSD):-

- # The minimum sight distance available on a highway at any spot should be of sufficient length to stop a vehicle travelling at design speed, ~~safely~~ safely without collision with any other obstruction. The absolute minimum sight distance is therefore equal to the stopping sight distance, which is also some times called non-passing sight distance.

~~The~~ The sight distance available on a road to a driver at any instance depends on 3 features:-

- Features of the road ahead.
- Height of the driver's eye above the road surface.
- Height of the object above the road surface.

→ The distance within which a water vehicle can be stopped depends upon the factors listed below:-

- # Total reaction time of driver.
- # Speed of vehicle.

- II efficiency of ^{brake} ~~brake~~ ~~brake~~.
- III frictional resistance betⁿ the road & the tyres.
- III Gradient of the road, if any.

→ Total reaction time:-

Reaction time of the driver is the time taken from the instant the object is visible to the driver to the instant the brakes are efficiency applied.

-II The stopping distance increase with increase in reaction time of the driver.

-II The total reaction times may be split up into ~~two parts~~ two parts:-

→ Perception time

→ Brake reaction time

→ Perception time:-

The perception time is required for a driver to realise that brake must be applied it is the time from the instant the object comes on the line of sight of the driver to the instant he realises that the vehicle needs to be stopped.

→ Brake reaction time:-

The brake reaction time also depends on several factors including the skill of the driver, the type of the problems & various other environmental factors, after the

total brake reaction time of the driver taken together.

→ PIRV Theory : —

~~and~~ According to this theory the total reaction time of the driver is split into four parts viz, time taken by the driver for

- Perception.
- Intention.
- Emotion.
- Volition.

→ Perception time is the time required for the sensations received by the eyes or ears to be transmitted to the brain through the nervous system & spinal chord. In other words it is the time required to perceive an object or situation. Intention time is the time required for understanding the situation. It is also the time required for comparing the different thoughts, regrouping & registering new sensation.

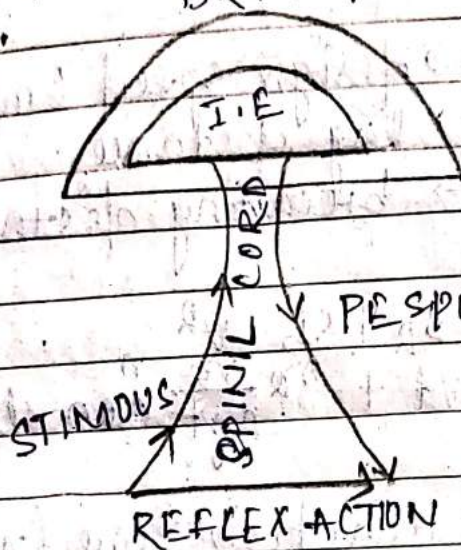
→ Emotion time is the time elapsed during emotional sensations and disturbance such as fear, anger or any other emotional feelings such as superstition etc with reference to the situation. Therefore the emotion time of a driver

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is likely to vary considerably depending upon the problem involved.

→ Volition time is the time taken for the final action :-

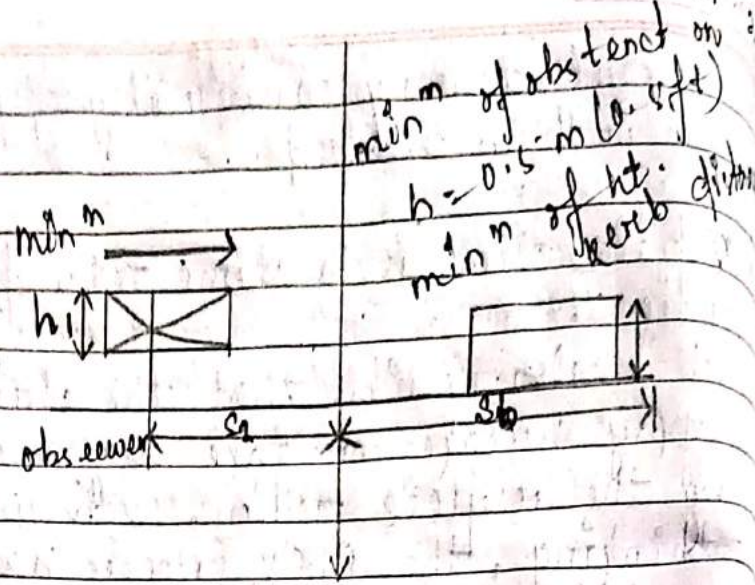
It is also possible that the driver may apply brakes or take any avoiding action by the reflex action, even without ~~thinking~~ thinking, the PIEV process has been illustrated.



P = Perception
I = Induction
E = Emotion
V = Volition.

→ The PIEV time of a driver depends on several factors such as physical and psychological characteristics of the driver, type of the problem involved, environmental condition & temporary factors (mood) of the trip, travel speed, fatigue, consumption of alcohol etc.

→ The total reaction time of an average driver may vary from 0.5 second for simple situations to as much as 3 to 4 seconds or even more in complex problems.



$H = 1.2 \text{ m}$

(4 ft) $v \rightarrow$ design speed (m/s)

$s_2 \rightarrow$ lag distance

$s_b \rightarrow$ braking distance

$SSD = s_2 + s_b + \frac{v^2}{2g}$

$SSD = vt + \frac{v^2}{2g}$ on level ground

where $\rightarrow t =$ reaction time (as per IRC 2.1.1)

is based on PIEV theory.

P = Perception (eyes)

I = Intention (brain)

E = Emotion (brain)

V = Volition (legs/hands)

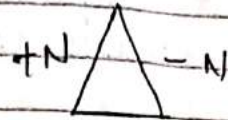
$\rightarrow$ Factors affecting (SSD) :-

(1) Braking efficiency (μ) :-

$$SSD = vt + \frac{v^2}{2g(\mu)}$$

(A) Gradient :-

- upward gradient $\rightarrow (+N)$
- downward gradient $\rightarrow (-N)$



$$SSD = vt + \frac{v^2}{2g(f \pm N)}$$

$N \rightarrow$ gradient - as a ratio i.e. $N = 2\% = 2/100$

(B) Breaking efficiency & Gradient :-

$$SSD = vt + \frac{v^2}{2g(n_f \pm N)}$$

Safe SSD.

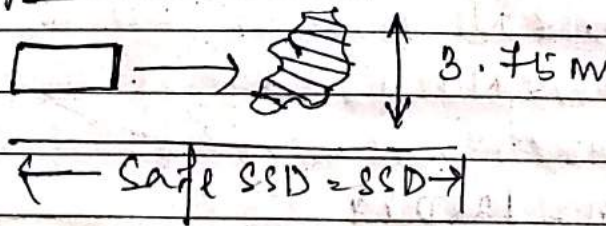
It depends on -

→ No. of lanes.

→ Direction of traffic (one way or two way)

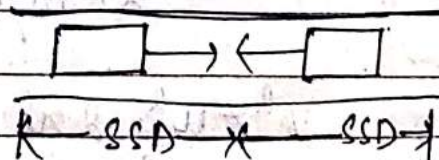
Single lane (one way) :-

safe SSD = SSD



Single lane (two way) :-

Safe SSD = 2SSD



Divided lane (two way) :-

Safe SSD = SSD



Note: Expect in case of single lane two way mode safe SSD = SSD.

At the vehicle skids on the road by turning the linear motion eqⁿ should be used (SSD eqⁿ is not applicable).

$$v = u + at$$

$$v^2 = u^2 + 2as$$

$$s = ut + \frac{1}{2}at^2$$

Ex: A load car of mass 1200 kg is travelling at a speed of 72 km/h, when it is suddenly braked by locking the wheels. The average vehicle comes to a stop in a distance 50 m. steel resistance force is _____?

(a) ~~1000~~ 5027 N

(b) 1189.46 N

(c) 1234.8 N

(d) 1895.5 N

Ans:

$$m = 1200 \text{ kg}$$

$$v = 72 \text{ km/h}$$

$$= 72 \times \frac{5}{18} = \text{m/s}$$

$$= 20 \text{ m/s}$$

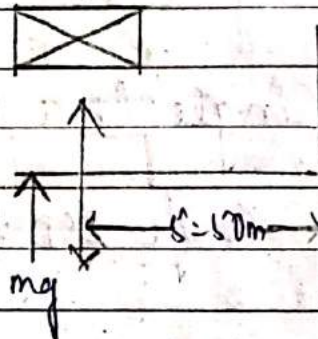
$$v^2 - u^2 = 2as$$

$$\Rightarrow 0 = 2a^2 = 2a \times 50$$

$$\Rightarrow 0 = 400a$$

$$\Rightarrow 100 = a$$

$$\Rightarrow \frac{400}{10} = a$$



$$\Rightarrow a = -4 \text{ m/s}^2 \text{ (retardation)}$$

$$f = a/g = 4/9$$

$$g = 9.81$$

skid resisting force = frictional force.

$$f = f_N = 4/9 \times mg$$

$$= 4 \times 1200 = 5000 \text{ N}$$

Ex: A dust car is braked when travelling at a started speed, the deceleration developed, as measured by a deceleration, fitted on the car is 4.2 m/sec^2 , the skid resisting co-efficient is _____?

(i) 0.39

(ii) 0.43

(iii) 0.28

(iv) 0.49

Ans: $a = 4.2 \text{ m/sec}^2$
 $f = a/g = 4.2/9$

$$= \frac{4.2}{9.81} = 0.42$$

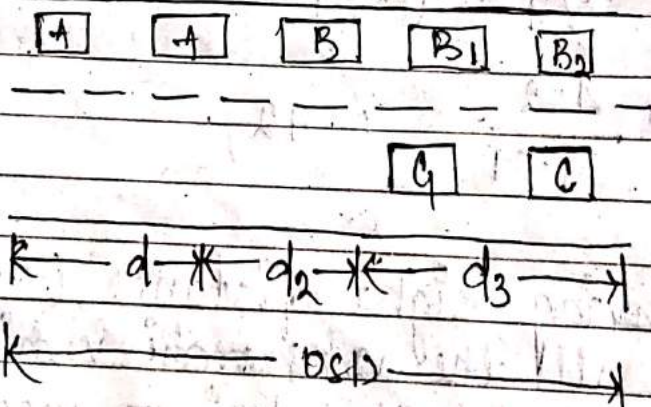
→ Overtaking sight distance (OSD):—

If all the ~~vehicles~~ vehicles travel on a road at the design speed then theoretically there should be no need for any overtaking in fact all vehicles do

not move at the designed speed and this is particularly so under mixed traffic conditions. In such as one circumstance, it is necessary for fast moving vehicles to overtake or pass the slow moving vehicles through length of a road. In such case facilities for overtaking slow vehicles with adequate safety should be made possible of frequent distance interval.

The minimum distance open to the vision of the vehicle ahead with safety against the traffic of opposite direction is known as the minimum overtaking sight distance (MOSD) or the safe passing sight distance ~~avoidable~~.

- For OSD process min^m 2 lanes are req^d.
- If all the vehicles are moving with design speed, there is no need of overtaking the vehicles.



$V_B \rightarrow$ Speed of slow moving vehicle
($V_B = 16 \text{ km/hr}$)

- $V \rightarrow$ Design speed of road (km/hr).
- $\rightarrow$ Reaction time of any direction.
- $t \rightarrow$ 2s (max^m as per IRC).

During overtaking time vehicles, A moves from A_1 to A_2 vehicle B moves from B to B_1 & C from C to C_1 .

$$d_1 = V_B \cdot t$$

$$\begin{aligned} d_2 &= S_1 + b + S_2 \\ d_2 &= S_1 + V_B T + S_2 \end{aligned} \quad \text{--- (2)}$$

$\rightarrow$ Overtaking line
 $S = ut + \frac{1}{2} at^2$

$$d_2 = V_B T + \frac{1}{2} at^2 \quad \text{--- (1)}$$

from eqⁿ (1) & (2)

$$T = \sqrt{\frac{2(S_1 + S_2)}{a}} \quad d_3 = VT$$

$$S = S_1 = S_2 = 0.7 V_B + ?$$

Long distance for an 'ideal' driver while overtaking.

$$St = t V_B$$

$$= 0.07 V_B$$

$\rightarrow$ Reaction time of ideal driver.

(As per IRC)

$$S = 0.7 V_B + 1$$

$$\left\{ L = 6.1 \text{ m as per IRC.} \right.$$

Factors affecting OSD :-

(1) Braking efficiency :-
OSD is independent of braking

(2) Gradient :-
No effect of gradient on OSD.

(3) Safe OSD :-

→ Depends on

(i) No. of lanes.

(ii) Direction of traffic.

→ Two lane (one-way) :-

$$\text{Safe OSD} = d_1 + d_2 + d_3$$

→ Two lane (two-way) :-

$$\text{Safe OSD} = d_1 + d_2 + d_3$$

4 lane (two-way) :-

$$\text{Safe OSD} = d_1 + d_2$$

Note :- Except in 2 lane - 2 way road in all other cases d_3 should not be considered in calculation of OSD.

→ Overtaking zone :-

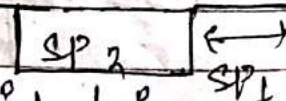
$$\text{min length} = 3 \cdot \text{OSD} \quad \text{SP}_1 \quad \text{OSD} \quad \text{SP}_2 \quad \text{OSD}$$

Desirable length

$$= 5 \cdot \text{OSD}$$

As per IRC

overtaking zone are provided in

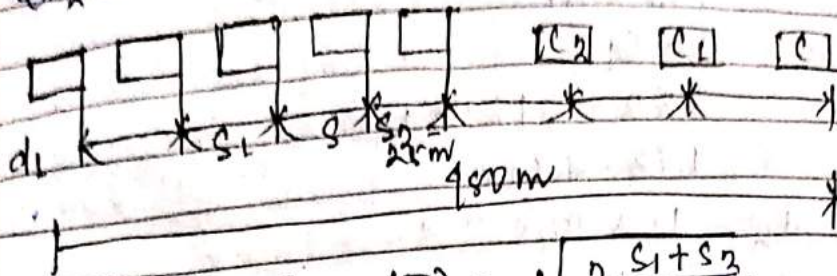


2.7
23 01 20

sight line comp - to facilitate overtaking.

SP₁ = 0.7 zone when (Sn for sign).

SP₂ = End of 1st zone (mndy - to way)



$$\text{Taking zero (T)} = \sqrt{2 \frac{S_1 + S_2}{a}}$$

$$= \sqrt{\frac{2(30 + 25)}{1.2}}$$

$$= 9.575$$

$$d_1 = V_B t = 11.11 \times 2 = 22.22 \text{ m}$$

$$d_3 = V(T) = 22.22 \times 9.57 = 212.65 \text{ m}$$

$$d_4 = V(t) = 22.22 \times 2 = 44.44 \text{ m}$$

$$d_2 = S_1 + b_1 + S_2 = 30 + V_B t + 25$$

$$\Rightarrow 30 + 11.11 \times 9.57 + 25$$

$$= 161.3227$$

$$d_1 + d_2 + d_3 + d_4 = 450$$

Posface b/w i/c of the completion of over take action.

$$\Rightarrow 450 - 22.22 - 44.44 - 161.3227$$

$$\Rightarrow 9.3673 \text{ (safe no collision)}$$

Q:- What is this increase of uniform acc to n not 10?

$$v = ut + at \text{ (zone T)}$$

$$= 27.7 + (0.8 \times 5)$$

$$= 31.7 \text{ m/s}$$

$$S_1 = ut + \frac{1}{2} at^2$$

$$= (27.7 \times 5) + \frac{1}{2} \times 0.8 \times 5^2$$

$$= 148.5 \text{ m}$$

$$S_2 = S - S_1$$

$$= 322 - 148.5$$

$$= 173.5 \text{ m}$$

$$\Rightarrow a_2 = 1.2 \text{ m/s}^2$$

Horizontal curve:-

A horizontal highway curve is a curve in plan to provide change in direction to the central line of a road when a vehicle traverses it. In horizontal curves the centrifugal force acts horizontally outwards through the centre of gravity of the vehicle.

~~Define~~

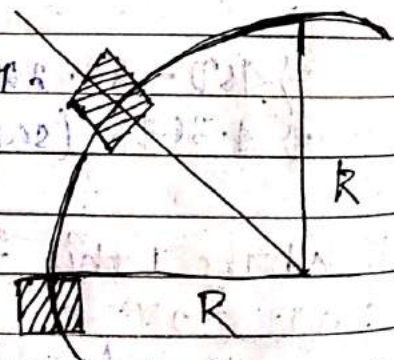
Area of a circle ($R = \text{const}$)

$\rightarrow$ Centrifugal force (kg)

$$P = \frac{mv^2}{R} = \frac{w}{g} \left(\frac{V^2}{R} \right)$$

$\rightarrow$ centrifugal ratio /
imposed factor

$$P/w = \frac{V^2}{gR}$$



Overlapping: —
 At the of overlapping the central — b/w inner
 type. It road will be lost Normal non-
 flow pass-through surface where & more lane
 $= 0$ $P = (b) = w(h/2)$

$P/w = b/w \rightarrow$ resistance against
 overfacing.

Centrifugal
 ratio

-1 $P/w > b/2h \rightarrow$ over turning or no
 $P/w \leq b/2h \rightarrow$ No.
 Higher the b value & lower the h value
 more will be resistance against over
 turning.

Super elevation: —
 In order to counter act the effect of
 centrifugal force & to reduce the len-
 -dency of the vehicle to overturn or slide,
 the outer edge of the pavement is raised
 with respect to the inner edge the provi-
 -ding a transverse slope throughout the
 length of the horizontal curve. This
 transverse inclination to pavement
 surface is known as super elevation or
 can't banking the super elevation.

Super elevation (or) can't (or) angle of
 Banking.

$$e + f = \frac{v^2}{gR}$$

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for level ground but super elevation
($e=0$)

$$f = \frac{v^2}{gn} = P/W$$

$$e = \tan \theta = \sin \theta = E/B$$

$$E = eB$$

There $e \rightarrow$ Rise of outer edge w.r.t inner edge.

$B \rightarrow$ Total width of road over the curve.

$$B = w + w_e$$

(centre width on curved road)

(Actual width)

$e =$ Rate of super elevation (1 in N) or

Equilibrium super elevation (Balance SE) :-

The super elevation required to balance a vehicle moving with design speed over curve without considering friction b/w road & tyre ($f=0$).

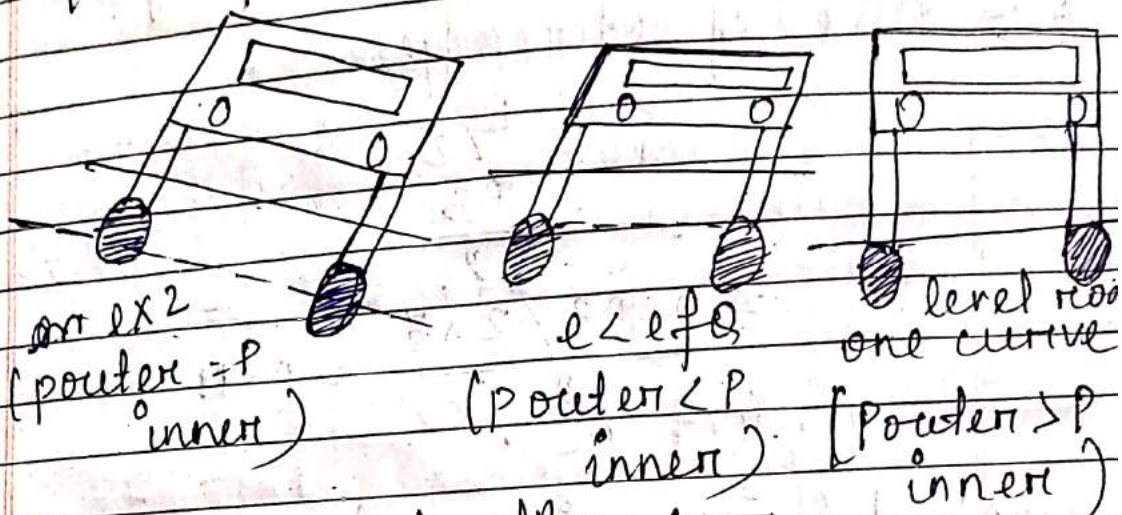
$$e_{eq} = \frac{v^2}{gR}$$

$\rightarrow$ Equilibrium SE is very effective if all the vehicles are moving with design speed.

$\rightarrow$ But for mixed traffic in India design speed over curves is not possible in

such a case the vehicles may skid or overturn in words.

→ However vehicles with design speed with have balanced condⁿ (pressure on center) where = pressure on inner wheel with equilibrium (E).



→ Design Super elevation :-
For mixed traffic use 7.5% design speed (70) (A per to RC)

$$e + f = \frac{v^2}{125 R}$$

$e_{design} < e_{max}$ (given by IRC)
 $e_{max} = 7.5\%$ {In plain & rolling terrain}
In slow bound hilly terrain

= 10% {no. hill roads not bound by snow}.

→ Attainment of super elevation :-

(1) Rotation with inner edge.

→ common method.

(A) Rotation w.r.t centre line
→ common over

Q:- In the problem e max is not given
of the type of terrain through
which road is passing is also given
we calculate e directly super
elevation.

Ans:- Rise of outer edge

$$e = \frac{L}{2}$$

$$= \frac{e_b}{2}$$

$$\Rightarrow 0.03 / 2 \times 7 = 0.011$$

w.r.t GL.

Note:- It if is considered in the eqⁿ the
speed is kept in the general eqⁿ.

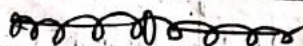
$$e - f = \frac{v^2}{gR}$$

$$\Rightarrow 0.07 + 0.15 = \frac{v^2}{9.81 \times 125}$$

$$v = 16.41 \text{ m/s}$$

$$\Rightarrow 16.42 \times 18/c$$

$$\Rightarrow 29.16 \text{ km/hr.}$$



Sight distance :-

- The safe & efficient operation of vehicles on road depends, among other factors also on road length at which an obstacle, becomes visible to the driver in the direction.
- Sight distance available from a point is the actual distance among the road surface.
- 3 sight distance are considered in the design.

- (i) Stopping or absolute min^m sight distance.
- (ii) Safe overtaking or passing sight distance.
- (iii) Safe sight distance for entering into control intersection.

Stopping sight distance is the sum of =

$$SSD = \text{lag} + \text{Braking distance}$$

Lag Distance :-

The distance travel by the vehicles during the total reaction time is called lag distance (Vt).

Braking Distance :-

The distance travel by the vehicles after the application of brake to a dead stop position which is known as Braking distance. ($\frac{V^2}{2gd}$).

$$SSD = Vt + \frac{V^2}{2gd} \quad (\text{m/sec})$$

OR

$$SSD = 0.278 \cdot Vt + \frac{V^2}{254f} \quad (\text{km/hr})$$

Where,

v = speed of vehicle.

f = design co-efficient of friction
(0.4 to 0.37) from speed
(30 to 80 km/hr)

g = acceleration of gravity.
(9.81 m/sec²)

Q: Calculate the safe stopping sight dis.
for design speed of 50 km/hr.

- (i) for a 2 way traffic of 2 lane road
(ii) 2 way traffic of single lane road
Assuming $f = 0.37$ & $H = 2.5$.

$$\begin{aligned} \text{Sol: (i)} \quad SSD &= 0.278 v t + \frac{v^2}{254 f} \\ &= 0.278 \times 50 \times 2.5 + \frac{(50)^2}{254(0.37)} \\ &= 34.75 + \frac{2500}{93.98} \\ &= 61.4 \text{ m} \end{aligned}$$

$\therefore$ Stopping sight distance when there are
2 lane = 61.4 m

$$\begin{aligned} \text{(ii)} \quad \text{Stopping sight distance for 2 way traffic} \\ \text{with single lane} &= 2 \times SSD \\ &= 2 \times 61.4 \\ &= 122.8 \text{ m} \end{aligned}$$

Q: Calculate the min^m sight distance to
avoid a head collision of two cars
approaching from opposite direction

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$\frac{90 \times 60 \text{ km/hr}}{2.5 \text{ sec}} \times \frac{1}{3.6} = 0.35$

$\text{sol:} = 90 \text{ km/hr}$
 $= \frac{90 \times 1000}{3600} \div \frac{90}{3.6}$
 $= 25 \text{ m/sec}$

$= 60 \text{ km/hr}$
 $= \frac{60 \times 1000}{3600} \div \frac{60}{3.6}$

$= 16.67 \text{ m/sec}$

$$\text{SSD} = Vt + \frac{V^2}{2g \cdot f}$$

$$= 25 \times 2.5 + \frac{(25)^2}{2 \times 9.81 \times 0.35}$$

$$= 62.5 + \frac{625}{6.867}$$

$$= 153.51 \text{ m} \quad \text{--- } (V_1)$$

$$\text{SSD} = Vt + \frac{V^2}{2g \cdot f}$$

$$= 16.67 \times 2.5 + \frac{(16.67)^2}{2 \times 9.81 \times 0.35}$$

$$= 41.675 + \frac{277.88}{6.867}$$

$$= 82.14 \text{ m} \quad \text{--- } (V_2)$$

$$= V_1 + V_2$$

$$= 153.51 + 82.14$$

$$= 235.65 \text{ m}$$

B: Calculate the value of head light sight distance & intermediate sight distance for a highway with a design speed of

65 km/hr. Assume other data are required.

Sol:- $t = 2.5 \text{ sec}$

$f = 0.37$

$V = 65 \text{ km/hr}$

Stopping sight distance is also called head light sight distance.

$$\boxed{ISD = 2 \times HSD}$$

$$\begin{aligned} HSD &= 0.278 V t + \frac{V^2}{254 f} \\ &= 0.278 \times 65 \times 2.5 + \frac{(65)^2}{254 \times 0.37} \\ &= 45.175 + \frac{4225}{93.98} \\ &= 45.175 + 44.95 \\ &= 90.12 \text{ m} \end{aligned}$$

$$ISD = 2 \times HSD$$

$$= 2 \times 90.12$$

$$= 180.24 \text{ m}$$

For ascending & descending :-

$$SSD = vt + \frac{v^2}{2g(f \pm n)}$$

(+ve) ascending

(-ve) descending

Q. Calculate the stopping sight distance on a highway at a descending gradient of 2% for a design speed of 80 km/hr. Assume other data as per IRC recommendation.

sol:-
~~t = 2.5 sec~~
~~f = 0.35~~

$$\begin{aligned} SSD &= vt + \frac{v^2}{2g(f \pm n)} \\ &= \frac{80}{3.6} \times 2.5 + \frac{(80/3.6)^2}{2 \times 9.81(0.35 - 0.02)} \\ &= 22.23 \times 2.5 + \frac{(22.23)^2}{6.47} \\ &= 131.45 \text{ m} \\ &= 132 \text{ m} \end{aligned}$$

Overtaking sight distance :-

The min^m distance open to the vision of the driver of a vehicle intending to overtake slow vehicle ahead with safety against the traffic of opp. direction is known as the min^m overtaking sight

distance on the safe passing sight distance.

→ Over taking sight distance is the distance measured along the centre of the road which a driver with his eye level 1.2 m above the road surface can see the top of an object 1.2 m above the road surface.

Factors affecting overtaking sight distance

- (a) (i) Speed of the overtaking vehicle.
- (ii) Over-taken vehicle.
- (iii) The vehicle coming from opposite direction.
- (b) Distance betⁿ the overtaking & over-taken vehicles the min^m spacing depends on the speed.
- (c) Skill & reaction time of the driver.
- (d) Rate of acceleration of overtaking vehicle.
- (e) Gradient of the road.

Analysis of overtaking sight distance :-

$$OSD = d_1 + d_2 + d_3$$

$$d_1 = V_b \times t$$

V_b = Speed of overtaking vehicle (km/h)

t = reaction time of driver (2 sec).

$$d_2 = V_b T + \frac{1}{2} a T^2$$

$$\text{or } d_2 = V_b T + 2s$$

$$T = \sqrt{\frac{4s}{a}}$$

$$s = 0.7 V_b + 6$$

s = spacing of vehicle.

$$d_3 = V T$$

V = design speed.

Q: The speed of overtaking & over-taken vehicle 70 & 40 km/hr respectively on a two way traffic road if the acceleration of vehicle is 0.99 m/sec^2 .

(i) Calculate the safe overtaking sight distance.

(ii) Mention the min^m length of overtaking zone.

Sol:- $s = 0.7 V_b + 6$

$$V = 70 \text{ km/hr} = \frac{70}{3.6} = 19.45 \text{ m/sec}$$

$$V_b = 40 \text{ km/hr} = \frac{40}{3.6} = 11.12 \text{ m/sec}$$

$$a = 0.99 \text{ m/sec}^2$$

$$s = 0.7 V_b + 6$$

$$= 0.7 \times 11.12 + 6$$

$$= 13.7$$

$$d_1 = V_b \times t$$

$$= 11.12 \times 2$$

$$= 22.2 \text{ m}$$

$$T = \sqrt{\frac{4s}{a}}$$

$$= \sqrt{\frac{4 \times 13.7}{0.99}}$$

$$= 7.45$$

$$d_2 = V_b T + 2s$$

$$= 11.12 \times 7.45 + 2 \times 13.7$$

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$$= 82.7 + 27.9$$

$$= 110.1 \text{ m}$$

$$d_3 = V \times T$$

$$= 19.45 \times 7.46$$

$$= 144.9 \text{ m}$$

$$\text{OSD} = d_1 + d_2 + d_3$$

$$= 22.2 + 110.1 + 144.9$$

$$= 277.2 \text{ m}$$

$\therefore$ min. length of overtaking zone

$$= 3 \times \text{OSD}$$

$$= 3 \times 277.2$$

$$= 831.6 \text{ m}$$

$\therefore$ desirable length of OSD

$$= 5 \times \text{OSD}$$

$$= 5 \times 277.2$$

$$= 1386 \text{ m}$$

— 0 —

→ Defn: —

A highway pavement is a structure consisting of superimposed layers of processed materials above the soil sub-grade, whose primary function is to distribute the applied vehicle loads to the sub-grade. The pavement structure should be able to provide a surface of acceptable riding quality, adequate skid resistance, favorable light reflecting characteristic & low noise pollution.

→ Types of pavement structure: —

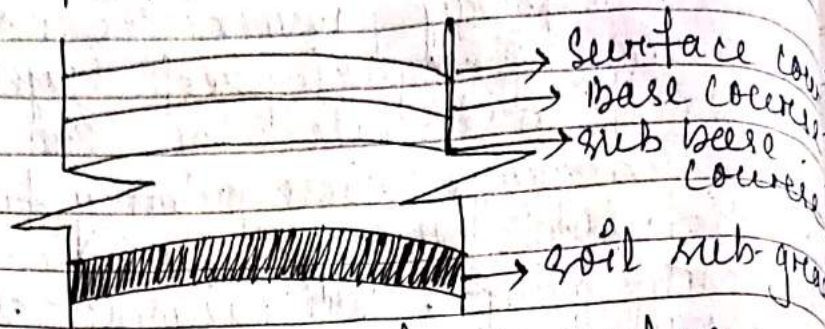
Pavements are generally classified into 2 types on the basis of structural behaviour: —

- (i) Flexible Pavement
- (ii) Rigid Pavement

(i) Flexible Pavement: —

- The pavement which have very less flexural strength are called flexible pavement.
- This type of pavement transmit the load to the lower layer by giving to giving transfer.
- A flexible pavement consists of the following 4 components: —
 - (i) Soil subgrade.
 - (ii) Sub-base course.
 - (iii) Base course.

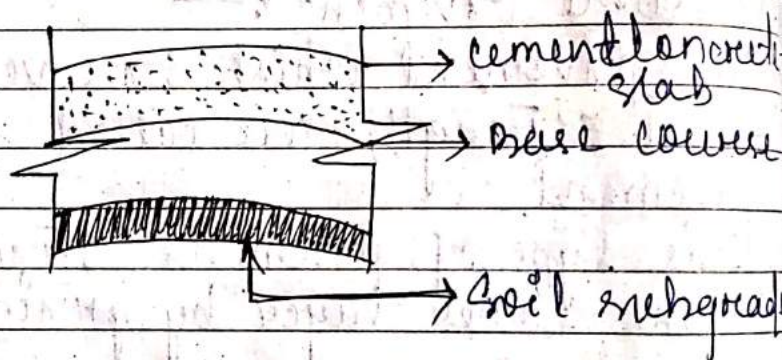
(iv) Surface course.



- It is Bituminous concrete, granular material with or without bituminous binder water bound macadam are common examples of flexible pavement.
- IRC 37: 2012 is the design code for design of flexible pavement.

(v) Rigid Pavement :-

- It has sufficient flexural strength to transmit the whole load stress to a wider area below.
- The rigid pavements are made up of portland cement concrete.



- IRC 58: 2012 is the design code of rigid pavement.

→ Functions of pavement components :-

(i) Soil subgrade :-

It is a layer of natural soil & the loads on pavement are ultimately received by the soil subgrade.

The soil subgrade layer should be about 50cm.

(ii) Sub-base & Base course :-

They are made up broken stone & aggregate.

Base & sub-base course are used under flexible pavements to improve load supporting capacity by the distribution of load.

Base course are used under rigid pavement for preventing pumping.

(iii) Wearing course / surface course :-

Its purpose is to provide smooth riding surface.

It is also called surface course.

→ Factors affecting mechanical stability :-

The stability of mechanical stabilized soil mass depend on the following factors:

i) Mechanical strength of aggregates.

ii) Gradation.

iii) Properties of soil.

iv) Presence of salts, mica etc.

v) Compaction.

→ Construction Procedure :-

i) Materials :-

The construction materials are collected

PAGE NO.
DATE: / /

from the selected borrow pits & stacked along the sides of the road in the specified proportions.

(iii) Equipment :-

The equipment needed are for excavation upto shallow depth, haulage for short distance & for compaction. Machinery or manual labour may be used for excavation & haulage. For compaction roller of the suitable type & weight is necessary depending on the material to be compacted.

→ Construction steps:-

- (i) The subgrade is prepared.
- (ii) The materials are mixed to the specified proportions as per design. Generally the ~~proportion~~ proportions are converted on volume basis.
- (iii) The existing moisture content is checked by a rapid method & additional water required is spread & the material is re-mixed.
- (iv) The wet mix spread to the desired grade & compacted by rollers. Rolling is started from the edges & with adequate longitudinal overlap, it is continued up to centre. Rolling is continued till adequate compaction is achieved.

when two layers such as base course & surface course are to be constructed, the process is repeated with appropriate proportions is achieved of mixed.

(v) field control tests :— Two field control tests necessary are :—

(a) determination of moisture content of the mix before compaction.

(b) determination of density, during & just after compaction layers hardens by drying.

~~→ Materials for concrete & base is~~
~~→ cement & flyash~~
~~→ cement~~

→ Types of Rigid pavement :—

Rigid pavements can be classified into four types :—

- (i) Jointed plain concrete pavement (JPCP)
- (ii) Jointed reinforced concrete pavement (JRCP)
- (iii) continuous reinforced concrete pavement (CRCP).
- (iv) Pre-stressed concrete pavement (PCP).

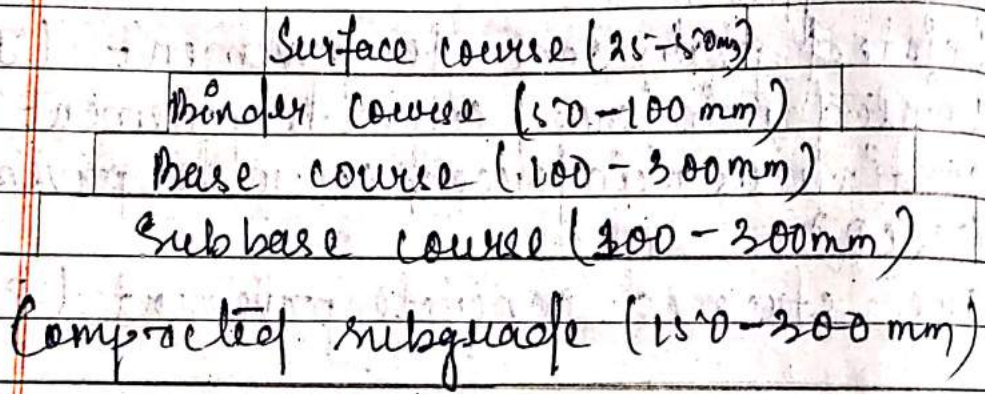
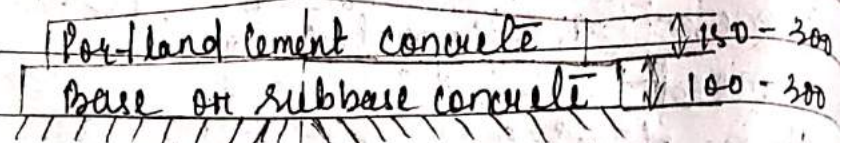
→ Failure criteria of rigid pavement :—

Traditionally fatigue cracking has been considered as the major, or only criterion for rigid pavement design.

The pumping is identified as an important failure criterion. Pumping

is the ejection of soil slurry through the joints and cracks of cement concrete pavement caused during the downward movement of slab under the heavy wheel load.

- iii Other major types of distress in rigid pavement include faulting, spalling & deterioration.



Natural subgrade in
Typical cross section of a flexible
pavement.

map

→ MECHANICAL SOIL STABILIZATION: —

Principal Application: —

→ Defn: —
Correctly proportioned materials (aggregates & soils) when adequately compacted to get a mechanically stable layer, the method is called mechanical stabilization.

→ Thus the two basic principles in this method of stabilization are: —

- Proportioning
- Compaction

→ Factors affecting mechanical stability: —
The stability of mechanical stabilized soil mass depends on the following factors: —

- (i) Mechanical strength of aggregate.
- (ii) Gradation
- (iii) Properties of soil
- (iv) Presence of salts, mica, etc.
- (v) Compaction

→ Construction Procedure: —

Materials: —

The construction materials are collected from the selected borrow pits & are stacked along the sides of the road in the desired proportion.

Equipment: —

The equipment needed are for excav-

vation upto shallow depth, haulage for short distance & for compaction machinery or manual labour may be used for excavation & haulage. Compaction roller of the suitable type & weight is necessary depending on the materials to be compacted.

→ Construction steps:-

- (i) The subgrade is prepared.
- (ii) The materials are mixed to the desired proportion as per design. Generally the proportions are constant on vol. basis.
- (iii) The existing moisture content is checked by nuclear method & additional water required is spread & the material is re-mixed.
- (iv) The wet mix spread to the desired grade & compacted by rollers. Rolling is started from the edges & with adequate longitudinal overlap it is continued up to centre. Rolling is continued till adequate compaction is achieved.

When two layers such as base course & surface course are to be constructed the process is repeated with appropriate proportions & achieved of mixed.

(v) Field control tests:- Two field

- control tests necessary are:-
- (a) determination of moisture content of the mix before compaction.
 - (b) determination of density, density & just after compacted layers hardens by drying.

→ PORTLAND CEMENT STABILIZATION:-

→ Nature of soil:-

- All inorganic soils which can be pulverised can be stabilised using cement. Soil should be low in organic matter for successful stabilization since this constituent tends to reduce the strength of soil cement. About 2% of organic matter is considered to be the safe upper limit.
- In general the best results are obtained with well-graded soil having less than 50% of it particle finer than 0.075 mm & plasticity index less than 20%.

→ Amount of cement:-

- Soil-cement has been made with cement content varying from 5% to 20% for satisfactory of cement are usually required (Lambe, 1962).
- For gravels, cement level of 5% to 10% by weight.
- For sands, cement level of 7% to 12%.

- by weight.
- For silts, a cement level of 12% to 15% by weight.
 - For clays, a cement level of 12% to 20% by weight.
 - When the cement is hydrating satisfactorily in a mixture, an increase in strength is obtained with increasing cement content. The cement content required is usually determined by measuring the compressive strength of specimens made with different proportions of cement.

Soil No.	Soil type	Cement content	compressive strength (days)	Dry Density
1	Silty clay	7	2415	17.413
		10	2760	17.413
		13	3105	17.413
2	Sandy clay	7	1794	18.37
		10	2622	18.53
		13	3657	18.53
3	Clayey sand	7	1656	17.43
		10	1932	17.74
		13	2340	18.06
4	clean sand (uniformly graded)	7	1449	17.43
		10	2829	18.06
		13	5934	18.53
5	Gravel (poorly graded)	7	1104	19.47
		10	2484	19.63
		13	3864	19.64

- Mixing :-
 → make uniform soil-cement water mixture, provides strong & durable soil-cement.
 → The intimacy of the mixture is not directly proportional to the mixing energy. As a matter of fact, increase in continuous mixing causes a decrease in the degree of mixing & may lead to segregation of components. Thus continued mixing should be only upto the optimal level.
 → Soil-cement made by mix-in-place method & rotary miller hence shown about 50% & 70% of the strength of a laboratory mixture.

- Moisture content :-
 → The moisture content plays two roles in soil-cement :-
 (i) it influences the compaction characteristics as with natural soil.
 (ii) it furnishes water for cement hydration.

- Of these two, the effect of moisture cement on the quality of soil cement largely arises from its influence on the compaction.

- Compaction conditions :-
 → In order to obtain satisfactory soil-cement adequate compaction is essential.

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→ As in natural soil it has been observed that for specimens having the same cement content & given the same out of compaction but having different moisture content the greatest strength is obtained for the one compacted at approximately the optimum moisture content.

→ Age & curing :-

As with concrete, the compressive strength of a soil-cement increases with age. In practice soil-cement is cured after compaction under conditions that prevents drying of the surface.

→ Admixtures for soil-cement :-

→ In order to accelerate the set & to improve the properties of soil-cement, lime or calcium chloride is added.

→ These chemicals, by increasing the effectiveness of cement as a stabilizer permit.

→ Lambe, 1962 :-

(i) A reduction in the amount of cement required to treat a soil responsive to cement.

iii) stabilisation of some of the soils (e.g. certain organic soils) which are not responsive to cement above.

→ Construction of soil-cement :-

→ construction of soil-cement involves the following operations :-

ci) shaping the soil to be treated.

cii) Pulverising the soil.

ciii) adding water & cement.

civ) mixing.

cv) Compacting.

cvi) finishing.

cvi) Curing.

→ It is in-place method, Travelling & plant method & stationary plant method are suitable to produce soil-cement mixtures in the field. The optimum sequence for adding water & cement & mixing depends on the soil & site conditions.

→ Clayey soils are easy to handle compared to plastic soils.

→ Handling of plastic soils can be ~~reduced~~ reduced by adding lime (1 to 3%).

→ The field control of soil-cement stabilisation is done by experienced person based on the site visual inspection.

→ Moisture content & dry density hence be checked as per ~~standards~~ standards.

→ Cement is the most successful & excellent results are guaranteed if used properly.

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→ Materials for concrete Base:-

→ Cement & Flyash:-

- M Cement shall be Type GP Portland cement complying with IS 3972. when submitting details of the nominated mix in accordance with clause 5.03.3 the contractor shall nominate the branch & source of the cement. On approval of a nominated mix by superintendent the contractor shall use only the nominated cement in the work.
- M Documentary evidence of the quality & source of the cement shall be furnished by the contractor to the superintendent upon request at any stage of the work.
- M The cost of re-testing the cement shall be borne by the contractor & results of the testing forwarded to the superintendent.
- M Cement shall be transported in waterlight containers & shall be protected from moisture until used. Caked or lumpy cement shall not be used.
- M Documentary evidence of the quality & source of the flyash shall be furnished by the contractor to the superintendent.

→ Aggregate :—

(i) General :—

- In addition to properties specified in IS 2758:1, the max^m soluble sulphate salt content of aggregates expressed as percentage SO_3 by mass, shall not exceed 0.1%.
- Aggregates containing more than the max^m permissible amount of sulphates or with visible encrustations of salts shall be washed & drained before being used in concrete.
- At least 40% by mass of the total aggregates in the concrete mix shall be quartz sand. Gravelly sand is aggregate having a nominal size of less than 5mm and shall contain at least 70% quartz by mass.

(ii) Fine aggregate :—

- Fine aggregates shall consist of clean, hard, tough, durable, uncoated grains uniform in quality. Fine aggregate shall comply with IS 2758:1 in respect of bulk density ($1200 kg/m^3$ min^m), water absorption (max^m 5%), material finer than 2 micrometers, & impurities & deleterious materials.
- When submitting details of the ~~data~~ ^{agg} nominated mix the contractor shall submit to the superintendent —

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NATA Certified Laboratory Test Report.

(iii) Coarse Aggregate :-

- iii Coarse aggregate shall consist of clean, washed, hard durable non-metallic furnace slag or gravel. Coarse aggregate shall comply with IS 2758.
- iv In respect of particle density, bulk density, water absorption, mineral filler than 75 micrometers weak particles, light particles or dusting impurities.

→ Admixtures :-

- ii Chemical admixtures & their use shall comply with IS 1478. Admixtures shall not contain calcium chloride, calcium formate or triethanolamine or any other accelerator.
- iii An air-entraining agent shall be included in the mix & the air content of concrete shall comply with clause 5.03.4.
- iv During the warm season a lignin or lignin based ('ligzol') set-retarding mixture approved by the superintendent may be used to control slump within the limits stated in clause 5.03.4.

y Test

- iii During the cool season a light or light based set - retarding admixture containing not more than 6% reducing sugar may be used in the mix.

→ concrete :-

- iii mix design, manufacture, placing, compaction & finishing of concrete for concrete base shall be the responsibility of the contractor.

- iv where concrete is to be cast betⁿ fixed forms the nominal max^m size of the mix shall be 40mm.

- iv where the superintendent has approved of the placement of concrete by means of a self-propelled slip-form paving machine, the mix design & workability shall be the machine proposed for use.

→ concrete subbase :-

→ Materials for concrete subbase :-

Materials for concrete subbase shall conform to the requirements of clause 5.03 except that.

- (a) Cement shall be Type GP Portland cement or Type GB blended cement complying with IS 3972.

- (b) The combined grading of aggregate used in the work shall not deviate from

from the proposed grading by more than the amounts.

→ Subbase concrete construction:
The production, transport, placement, finishing, curing & conformity of concrete for subbase shall conform with clauses 5.06, 5.07, 5.10, 5.12 & 5.13 except.

→ Subgrade Beams:-

(i) General:-

Subgrade beams shall be provided below the subbase at expansion or contraction joints & isolation joints in the concrete base as shown in the drawings.

(ii) Excavation:-

Excavation for subgrade beams shall be to the dimensions shown on the drawings. All loose materials shall be removed & the vertical faces trimmed to neat lines.

(iii) Concrete:-

Concrete in subgrade beams shall comply with the requirements of the specification volume 2 - concrete works. The min^m compressive strength at 28 days shall be

32 M²

(iv) Steel Reinforcement :-

steel reinforcement shall be of the type & size shown on the drawings & shall be supplied & installed in accordance with this specification part.

(v) Curing :-

The top surface of the subgrade beam shall be cured in accordance with clause 5.11 before placing the subbase.

→ Placing & Finishing :-

- At least four weeks before commencing work under this specification, the contractor shall submit as part of the quality plan, for the information of the superintendent, full details of the equipment & methods proposed for placing & finishing the concrete base & sub-base together with a paving plan.
- When placing concrete subbase the subgrade shall be wetted down sufficiently in advance of placing to ensure a firm, uniformly moist surface at the time of placing.
- Construction equipment shall not operate on the prepared subbase after approval to place concrete has been given.
- Unless otherwise approved, placement

- at each placing location shall proceed at a rate of not less than 25 linear metres per hour.
- Deposit concrete in such a manner as to require a min^m of rehandling. The placing of concrete shall be rapid & continuous betⁿ haulage & construction joints.

→ Placing in fixed forms - Hand placing :-

(i) Spreading :-

Place concrete so that face is generally vertical & normal to the direction of placing. Concrete shall be placed uniformly over the width of the slab or lane & in such manner as to min^m segregation.

(ii) Vibration :-

- All concrete, including that adjacent to forms or existing concrete, shall be compacted by internal mechanical vibration.
- The vibrator shall be inserted into the concrete to such depth as will provide the best compaction, but not deeper than 50mm above the surface of the subbase.

iii. The vibrator shall be capable of emitting atleast 5000 impulses per minute when under load & the vibration shall be of sufficient amplitude to produce noticeable vibrations in at least 300mm in radius.

iii. Vibrators shall not be used for distributing & spreading concrete.

iv) Finishing :-

(a) General :-

iii. Finishing operations shall be started immediately after placement, spreading & compaction of the plastic concrete.

iii. Finishing operations shall comprise transverse finishing, longitudinal straight edge finishing & texturing of the surface.

(b) Transverse finishing :-

iii. Transverse finishing shall be by mechanical screed. Vibrating screeds shall have twin beams, be atleast 300mm longer than the width of lane being finished & be equipped with handles.

iii. Strike off concrete & screed to form levels as soon as possible after vibration. Atleast two passes shall be made with the screed over each section of pavement.

(c) Straight edge finishing :-

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After the transverse finishing is completed, but while the concrete is still plastic, minor irregularities & some marks in the pavement surface, particularly around formed contractor joints, shall be eliminated means of hand-operated long-handled aluminium floats.

(d) Surface Texturing :-

- When most of the water glass has disappeared & before the concrete becomes non-plastic the whole surface of the pavement shall be textured by use of a fine button or hessian - drag. Contractor shall submit to the superintendent details of the proposed texturing method & equipment.
- The average texture depth of the finished surface shall be in the range 2.0 - 2.5 mm.

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—: ROAD MATERIALS:—

→ SOIL :-

- Soil consists mainly of mineral matter formed by the disintegration of rocks, by the action of water, frost, temp^{re}, pressure or by plant or animal life.
- The individual grain size of soil particles, soils have been classified as gravel, sand, silt & clay.
- The characteristic of soil grains depend on the size, shape, surface texture, chemical composition & electrical surface charges.
- Moisture & dry density influence the engineering behaviour of a soil mass.

→ DESIRABLE PROPERTIES :-

- (i) Stability
- (ii) Incompressibility
- (iii) Permanency of strength
- (iv) Good drainage
- (v) Ease of compaction

→ SIGNIFICATION OF SUBGRADE SOIL :-

- Subgrade soil is an integral part of the road pavement structure as it provides the supports to the pavement structure from beneath.

The main function of the subgrade is to give adequate support to the pavement & for this the subgrade should possess sufficient stability under adverse climate & loading conditions.

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iii The foundation of waves, corrugations, melting & shoving in black top pavements & phenomenon of pumping, blowing & consequent cracking due to the poor subgrade conditions.

iv Soil is used in embankment construction in addition to stabilization incompressibility is also important as differential settlement may cause failure.

v Compacted soil & stabilized soil are often used in sub-base or base course of highway pavements.

→ CALIFORNIA BEARING RATIO (CBR) TEST

iv This is a penetration test developed by the California division of highway as a method for evaluating the stability of soil subgrade & other flexible pavement materials.

iii The test results have been correlated with flexible pavement thickness requirements for highways & air fields.

iii The laboratory CBR apparatus consists of a mould 150 mm diameter with a base plate & a collar, a loading frame with the cylindrical plunger of 50 mm diameter & dial gauges for measuring the expansion on soaking & the penetration values.

iii The penetrant cylindrical plunger penetrates material &

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- iii The penetration test consists of causing a cylindrical plunger of 50mm diameter to penetrate values of a pavement component material at 1.25 mm/minute.
- iii The load values to cause 2.5mm & 50mm penetration are recorded.
- iii These loads are to be expressed as percentages of standard load values at respective deformation levels to obtain CBR value.
- iii The average of a large number of tests on crushed stones are 1370 & 2055 kg (70 & 105 kg/cm²) respectively at 2.5 & 50mm penetration.
- iii The mould is subjected to four days soaking & the swelling & water absorption values are noted.
- iii The surcharge weight is placed on the top of the specimen in the mould & the assembly is placed under the plunger of the loading frame.
- iii Value are noted corresponding to penetration values of 0.0, 0.5, 1.0, 1.5, 2.0, 3.0, 4.0, 5.0, 7.5, 10.0 & 12.5 mm.
- iii The load values may be converted to pressure values & plotted against the penetration values.
- iii The load values corresponding to 2.5 & 5.0 mm penetration values from the corrected origin C are noted.

→ SOUNDNESS TEST :-

- # Soundness test is intended to study the resistance of aggregates to weathering action, by conducting accelerated weathering test cycle.
- # The resistance to disintegration of aggregate is determined by using saturated solution of sodium sulphate or magnesium sulphate.
- # Dry aggregate specimen of specified size range is weighed & counted.
- # It is immersed in the saturated solution of sodium sulphate or magnesium sulphate for 16 to 18 hrs.
- # The specimen is dried in an oven at 105°C to a constant weight making one cycle of immersion & drying.
- # After completing the first cycle, the sample is dried & each fraction of the aggregate is examined visually to see if there is any evidence of excessive splitting, crumbling or disintegration of the grain.
- # Sieve analysis is carried out to note the variation in gradation of the original. The coarse aggregate fractions of each size or range is sieved on specified sieve sizes.
- # The average loss in weight of aggregate to be used in pavement construction after 10 cycles should not exceed

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12% when tested with sodium sulphate
18% when tested with magnesium sulphate

→ ABRASION TEST :-

- iii To determine the abrasion value of given aggregate sample by conducting Los Angeles abrasion test
 - iv Abrasion is a measure of resistance to wear or hardness.
 - v It is essentially properties for road aggregate especially when in wearing course.
 - vi When traffic moves on the road the soil particle (sand) are comes betⁿ the wheel & road surface causes abrasion on the road stones.
 - vii Abrasion test on aggregate are generally carried out by any one of the following methods :-
1. Los Angeles abrasion test
 2. Deval abrasion test
 3. Derry abrasion test

→ LOS Angeles abrasion test :-

- iii The principle of Los Angeles abrasion test is to find the percentage wear due to relative rubbing action betⁿ the aggregate & steel balls used as abrasion^{ve} charge. Pounding action of these balls also exist while conducting the test.
- iv Max^m allowable Los Angeles abrasion values of aggregates in different types of

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pavement layers as per Indian Road Congress (IRC).

-III for sub-base course or value of for base course such as WBM, Bituminous Macadam (B.M). Built - Spray grout base course & etc values of 50%.

-III If aggregate is used in surface ~~or~~ course as a bituminous surface dressing, single or two ~~and~~ coats, cement concrete surface course etc. the abrasion value should be less than 35%.

-III If aggregate is used for bituminous or concrete cement concrete pavement as surface course then max^m aggregate abrasion value should be 30%.

→ Procedure :-

(1) Clean & dry aggregate sample conforming to one of the grading A to G will be used for the test.

(2) Aggregate weighing 5 kg for grading A, B, C, D & 10 kg for grading E, F or G may be taken as test specimen & placed in the cylinder.

(3) The abrasion^{ve} change was also done in accordance with the cylinder & the machine, & cover is fixed to

make dust light.

(4) The machine was rotated at a speed of 30 to 33 revolutions per minute.

(5) The machine was rotated for 500 revolutions for grading A, B, C & D for grading E, F & G. It shall be rotated for 1000 revolutions.

(6) After the desired no. of revolutions, the machine was stopped & the material was discharged from the machine taking care to take out entire stone dust.

(7) Using the sieve of size larger than 1.75 mm I.S. sieve, the material was first separated into two parts & the finer portion was taken out & further on a 1.75 mm I.S. sieve.

→ IMPACT TEST :-

1. A test design to evaluate the toughness of stone or the resistance of the aggregates to fracture under repeated impacts is called impact test.

2. The aggregate impact test is commonly carried out to evaluate the resistance to impact of aggregates & has been standardized by IS.

3. The aggregate impact value indicates a relative measure of resistance of agg-

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- ale to impact, which has a different effect than the resistance to gradual increasing compressive stress.
- The testing machine consists of a metal base & a cylindrical steel cup of internal diameter 10.2 cm & depth 5 cm, in which the aggregate specimen is placed.
 - A metal hammer of weight of 13.5 kg having a free fall from a height 38 cm is arranged to drop through vertical guides.
 - Aggregate specimen passing 12.5 mm sieve & retained on 10 mm sieve is filled in the cylindrical measure 3 layers by tamping each layer 25 blows.
 - The measure to the cup of the aggregate in the cup & is allowed to fall freely on the specimen.
 - The test specimen to 15 blows, the crushed aggregate is sieved on 2.36 mm sieve.
 - The aggregate impact value should not normally exceed 30% for aggregate to be used in wearing course of pavements. The maxⁿ permissible value is 35% for bituminous macadam & 40% for water bound macadam base courses.

→ WATER ABSORPTION TEST :-

- ii To determine water absorption of given coarse aggregate.
- iii stones having higher water absorption value are porous & thus weak. They are generally unsuitable unless found acceptable based on crushing & hardness test.

-vi The materials are used.

(i) Balance.

(ii) Hot air oven.

(iii) Containers.

-iv The coarse aggregate passing through 10mm sieve is taken about 200gm.

-v They are dried in an oven at a tempⁿ of $110 \pm 5^\circ\text{C}$ for 24 hrs.

-vi The coarse aggregate is cooled to room tempⁿ.

-vii It's weight is taken as (w_1).

-viii The dried coarse aggregate is immersed in clean & water at a tempⁿ $27 \pm 2^\circ\text{C}$.

-ix The coarse aggregate is removed from water & wiped out of trace of water with a cloth.

-x Within three minutes from the removal of water, the weight of coarse aggregate w_2 is found that.

-xi The above procedure is repeated for various samples.

→ AGGREGATE CRUSHING STRENGTH TEST

- M To determine the strength of coarse aggregate may be assessed by aggregate crushing test.
- M The aggregate crushing value provides a relative measure of resistance to crushing under gradually applied compressive load.
- M To achieve a high quality of pavement aggregates possessing high resistance to crushing on low aggregate crushing values are preferred.
- M The apparatus for the standard test consist of a steel cylinder 15.2 cm diameter with a base plate & a plunger, compression testing machine, cylindrical measure of diameter 11.5 cm & height 18 cm, tamping rod & sieve.
- M Dry aggregates passing 12.5 mm IS sieve & retained on 10 mm sieve is filled in the cylindrical measure in three equal layers, each layer being tamped 25 times by the tamping.
- M The test sample is weighed (equal to W_1 g) & placed in the test cylinder in three equal layers, tamping each layer 25 times.
- M The plunger is placed on the top of specimen & a load of 40 tonnes is applied at a rate of 4 tonnes per

minute by the compressive machine.
The crushed aggregate is removed & sieved on 2.36 mm sieve.

The crushed material which passes the sieve is weighed equal to w_2 . The aggregate crushing value is the % of the crushed material passing 2.36 mm sieve in terms of original weight of the specimen.

Aggregate crushing value

$$= \frac{100 w_2}{w_1} \%$$

The aggregate crushing value for good quality aggregate to be used in base course shall not exceed 45% & value for surface course shall be less than 30%.

→ AVAILABILITY OF ROAD AGGREGATES IN INDIA : —

(1) Strength : —

The aggregates to be used in road construction should be sufficiently strong to withstand the stress due to traffic wheel load;

The aggregates which are to be used in top layers of the pavements, particularly in the wearing course have to be capable of withstanding high stresses in addition to wear & tear; hence they should possess sufficient strength resistance to crushing.

(2) Hardness : —

- The aggregates used in the surface course are subjected to constant rubbing or abrasion due to moving traffic.
- Abrasive action may be increased due to the presence of abrasive materials like sand betⁿ the types of moving vehicles & the aggregates exposed to the top surface.
- Heavy wheel loads can also cause deformations on some types of pavements resulting in relative movement of aggregates & rubbing of aggregates with each other within the pavement layer.

(3) Toughness : —

- Aggregates in the pavements are subjected to impact due to moving wheel loads.
- Severe impact like hammering is quite common when heavily loaded steel-tired vehicles move on water bound macadam roads where stones protrude out especially after the monsoons.
- Jumping of the steel tired wheels from one stone to another at different levels cause severe impact on the stones.
- The magnitude of impact would increase

with the roughness of the road surface, the speed of the vehicle & other vehicular characteristics.

(4) Durability :-

- The stone used in pavement construction should be durable & should resist disintegration due to the action of weather.
- The property of the stones to with-stand the adverse action of weather may be called soundness.
- The aggregates are subjected to the physical & chemical action of rain & ground water & the impurities there - is and that of atmosphere.
- It is desirable that the road stones used in the construction should be sound enough to withstand the weathering action.

(5) Shape of aggregates :-

- The size of the aggregate is first qualified by the size of square sieve opening through which an aggregate may pass, & not by the shape.
- Aggregates which happens to fall in a particular size range may have rounded cubical angular flaky or elongated shape of particles.
- Rounded aggregates may be preferred in cement concrete mix due to low specific surface area.
- The same proportion of cement paste &

same water cement ratio, whereas rounded particles are not preferred in granular base course, WBM concrete etc. as the stability due to interlocking of rounded particles is less.

• The voids present in a compacted aggregate depends on its shape factors. Highly angular & elongated aggregates have more voids in comparison with rounded aggregates.

→ CEMENT :-

A cement is a binder, a substance used for construction that sets, hardens, & adheres to other material to bind them together.

★ Physical Properties.

- Fineness of cement
- Soundness
- Consistency
- Strength
- Setting-time
- Heat of hydration
- Loss of ignition
- Bulk density
- Specific gravity

★ Chemical Properties.

- Tricalcium Aluminate
- Tricalcium silicate

- Dicalcium silicate.
- Ferrite.
- Magnesia.
- Sulphur trioxide.
- Iron oxide.
- Alkali.
- Free lime.
- Humina.

→ BITUMEN TEST :-

- Traditional distillation of petroleum.
- Gasolene → Petroleum → Diesel → Kerosene → Bitumen.
- Destructive distillation of wood or coal gives tar (in the absence of oxygen). Tar is always obtained in liquid state of bitumen depends on tempⁿ.

→ Penetration Test :-

- Determines hardness or softness of bitumen.
- Penetrometer app is used.
- Penetration value penetration in 1/10 mm units for 5 s.
- Grade of bitumen is decided based on penetration value.

$$\text{Penetration value} = \frac{120}{100} \text{ mm to } \frac{160}{10} \text{ mm.}$$

$$= 12 \text{ to } 16 \text{ mm.}$$

→ VISCOSITY TEST :-

- Resistance of flow.

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- iii Viscosity is general for penum for consistency.
- iv Orifice type of viscometer is used for bitumen liquid form.
- v Time in seconds for 50ml bitumen to flow standard of orifice at standard temp.

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Chapter - 07

Road Maintenance :

- Road maintenance is one of the most important component of the entire road system.
- Various types of failure in pavement ranging from minor & localized failure to major & general failure do take place on roads.
- By early detection and repair of defects at initial stages, the rapid deterioration of the pavement can be prevented.
- Such survey & evaluation should be carried out periodically so as to plan necessary preventive maintenance measures.

Maintenance of highways :-

- Routine maintenance :- It includes filling up of potholes & patch repairs, maintenance of shoulders & the cross slope & repairing of cracks.
- Periodic maintenance :- This include renewal of wearing course of pavement surface.
- Special repairs :- It includes major reconstruction of the pavement through reconstruction of overlays to rectify deficiencies.

Basic Maintenance Objective :-

The basic objective of maintenance function are to ~~maintain~~ maintain & operate the highway system in a manner such that:

- Comfort, convenience & safety are afforded to the public.
- The investment in roads, bridges &

- Appropriate maintenance is preserved.
- The aesthetic & compatibility of highway system with the environment is preserved.
- The necessary expenditure of resources is accomplished with continuous emphasis on economy.

Failure in flexible pavement:-
One of the prime cause of flexible pavement failure is excessive deformation in subgrade soil. This can be noticed in the form of local modulation or waves & corrugation in the pavement surface.

→ Types of defects in flexible pavement:-

- Surface defect:- These are associated with the surfacing layers & may be due to excessive or deficient quantity of bitumen in them or these layers.
- Crack:- It contains hair line crack, alligator crack, edge crack, shrinkage crack etc.
- Deformation:- It includes creepage, heaving, corrugation, shoving, shallow, depression, settlement.

(iv) Disintegration :— It covers stripping, loss of agg, raveling, potholes & edge cracking

→ Methods of repairing the defects :—

(i) Seal coat :—

Seal coat is a single thin application of bitumen which may major, may not be covered with agg.

(ii) Patching :—

Patching is the application of bituminous material for filling potholes, shallow depression, rutting & edge irregularities

→ Special repairs in flexible pavement :—

(i) Waves & corrugation :—

Defective rolling, poor subgrade condition, poor gradation, temperature, underlying layers contribute to the formation of waves & corrugation.

(ii) Skidding of pavement surface :—

Water, clay, silt, clay sand, oil & grease in the pavement are few factors which cause skidding.

Failure in rigid pavement :—

Failure of cement concrete pavement are perceived mainly by the formation of shrink cracking. The failures are

- mainly due to two factors.
- (i) deficiency of pavement material.
 - (ii) structural inadequacy of the pavement system.

→ Typical rigid pavement failures:

- Scaling is observed in cement concrete pavement showing overall deterioration of the concrete.
- shrinkage cracks normally develop during the curing operation of cement concrete pavement immediately after the cast.

→ Special repair of rigid pavement:

- (i) Grout jacking or lifting of slabs. Once pavement starts pumping the grout for connecting it lies in providing effective drainage. If the substance is localised then the same is repaired by patching the portion of slabs which is determined.

- (ii) The mud jacking procedure consists of drilling no. of holes 4cm to 5cm dia. 1.5 to 3m apart in the cement concrete slab. Corroding is such slabs is done. Under pressure through these holes. The grout normally used is either 1:3 1/2 cement sand mix or bitumen. The mix is injected through pressure holes using the compression.

→ Strengthening of existing pavement : —
Strengthening may be done by providing additional thickness of the pavement of adequate thickness in one or more layers over the existing pavement, which is called overlay. If the existing pavement have completely deteriorated an overlay would not serve the purpose & hence we should remove the existing damaged pavements & it is residual if.

→ Type of overlay : —

- (i) Flexible overlay over flexible pavement.
- (ii) Rigid " " " " " "
- (iii) Flexible " " " " rigid " "
- (iv) Rigid " " " " " "

→ Design of Overlay : —

The overlay thickness reqd. over a flexible pavement may be determined either by one of the conventional pavement design methods or by a non-destructive testing method viz. the Benkelman beam deflection method.

→ Benkelman beam deflection method : —

Benkelman beam is a device which can be conveniently used to measure the rebound deflection of a pavement due to a dual wheel load assembly or the design wheel load.

Excavation Equipment :-

(1) Bull dozer :-

It may be used for clearing, opening up, pulling scrap, moving soil for short haul distance of about 100m.

(2) Power shovel :-

It is used to excavate earth all classes except rock & to load into wagons. It may be mounted on crawler tracks & it can move at low speeds.

(3) Scraper :-

It is considered as one of the useful earth moving equipment as it is self operating. It can dig, haul & spread the material in uniformly thick layers.

(4) Hoe :-

It is meant to excavate below the natural surface where the machine is stationed & it is capable of having precise control of depth of excavation at close range work.

(5) Dragline :-

It is used to excavate soft earth & to deposit in nearby bank or to load into wagons. It can operate on natural ground while excavating from a pit with

- the bucket.

(a) Clampshell :-

It is useful for excavation of soft to medium materials & loose material at or below existing ground surface.

→ Compacting Equipment :-

(i) Rammer :-

These are useful to compact relative small areas & where the rollers can't operate such as compaction of trenches, "found" & slopes.

(ii) Vibrator :-

They are most suited for compacting dry cohesionless granular material. There are also vibrator mounted rollers to give the combined effect of rolling & vibration.

(iii) Watering :-

This method is considered to be an efficient method of compacting cohesionless sands.

(iv) Rollers :-

The principle of rollers is the application of pressure which is slowly increased & decreased. The various rollers are as :-

-iii Smooth wheeled rollers:-

These are suitable to roll a wide range of soils, preferably granular soil.

-iii Pneumatic tyred rollers:-

They are suitable to compact non plastic silts & fine sand.

-iii Sheep foot roller:-

These type of roller are suitable to compact layer soil.

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