RRB JE

RAILWAY RECRUITMENT BOARD

CIVIL

ENGINEERING

HIGHWAY ENGINEERING

SELF STUDY MATERIAL

CIVIL ENGINEERING FOR ALL

HIGHWAY ENGINEERING

ROAD ENGINEERING :

The road Pavements are generally constructed on small empankments, slightly above the general ground level wherever possible, in order to avoid the difficult drainage and maintenance problems. The term road or roadway thus constructed is therefore termed 'highway' and the science and technology dealing with road engineering is generally called 'Highway Engineering'.

In nutshell, it may be said that the highway engineering deals with various phase like development, planning, alignment, highway geometric design and location, highway traffic operation and its control, materials, Pavement design, construction and maintenance, economic considerations, finance and administration.

Scope of Highway Engineering

PHASES

Development, Planning and Locations Highway Design, Geometrics and Structures Traffic performance and its control Materials, construction and maintenance Economics, Finance and Administration

DETAILS

Historical background; Basic for planning, master plan; engineering survey Road Geometrics and their Design; Rigid and Flexible pavements; Design factor.

Traffic Studies analysis; Need for new road links; Traffic regulation and contral. Highway Materials and mix design. Highway construction; Earth work, Earthen Road user coast and economic analysis of highway projects; pavements types and maintance measures;

CLASSIFICATION OF ROADS :-

The different types of roads are classified into two categories, depending on whether they can be used different searons of the year.

(i) All weather roads and

(ii) Fair weather roads :- All weather roads are those which are negotiable during all. Weather, except at major river crossing where interruption to traffic is permissible upto a certain extent, the roads pavement should be negotiable during all weathers. Roads which are called fair weatehr roads; on there roads the traffic may be interrupted during monsoon season at caureways where streams may overflow across the roads.

Road Patterns :

The various road patterns may be classified as follows.

(a) Rectangular or block pattern

(b) Radial or star and block pattern

(c) Radial or star and circular pattern

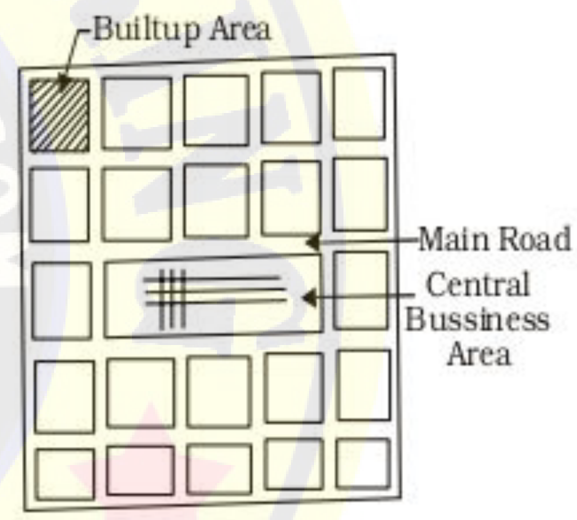
(d) Radial or star and grid pattern

(e) Hexagonal pattern

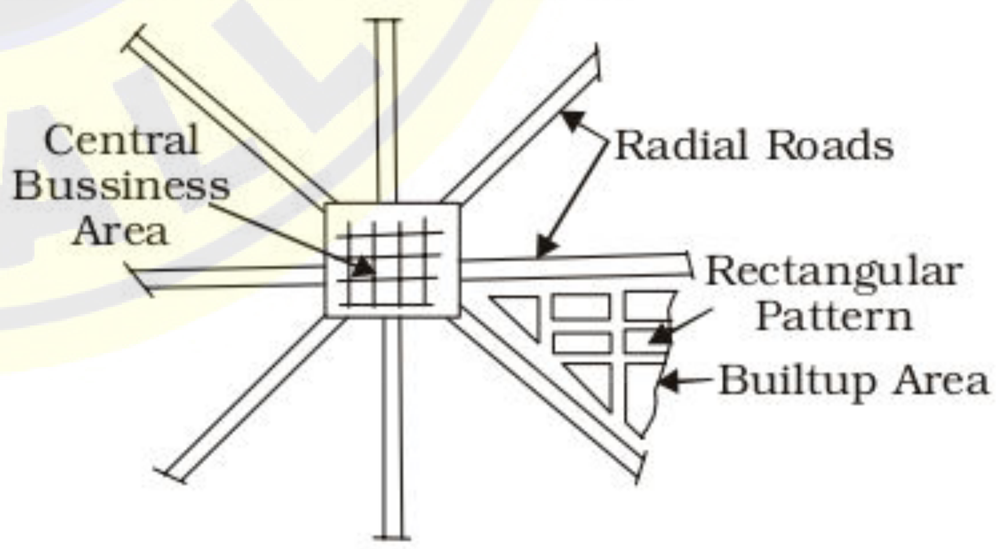
(f) Minimum travel pattern

Each of these patterns have their advantages and limitations. There can be a number of other gemoetric pattern also. The choice of the pattern are very much depends upon the locality, the layout of different towns, villages, industrial and production centres and on the choice of the planning engineer.

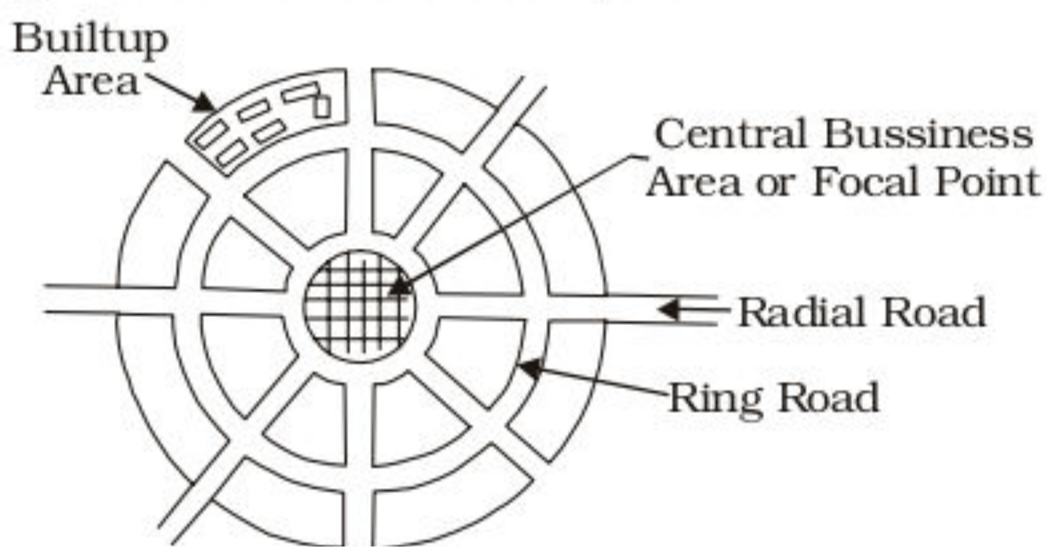
These have been shown in Figure. f.



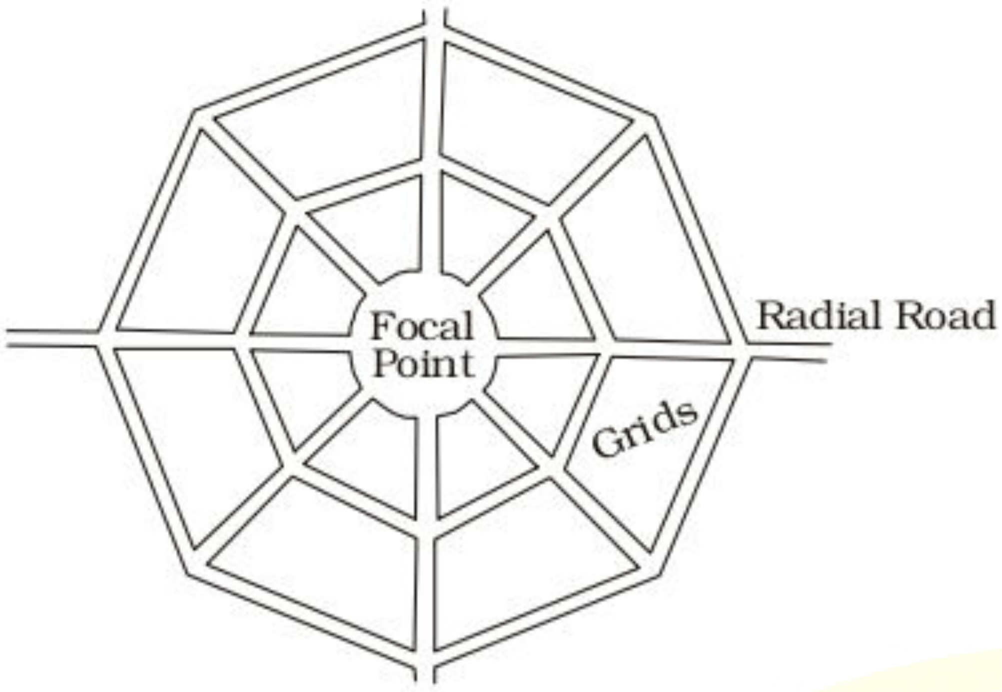
(a) Rectangular or block pattern



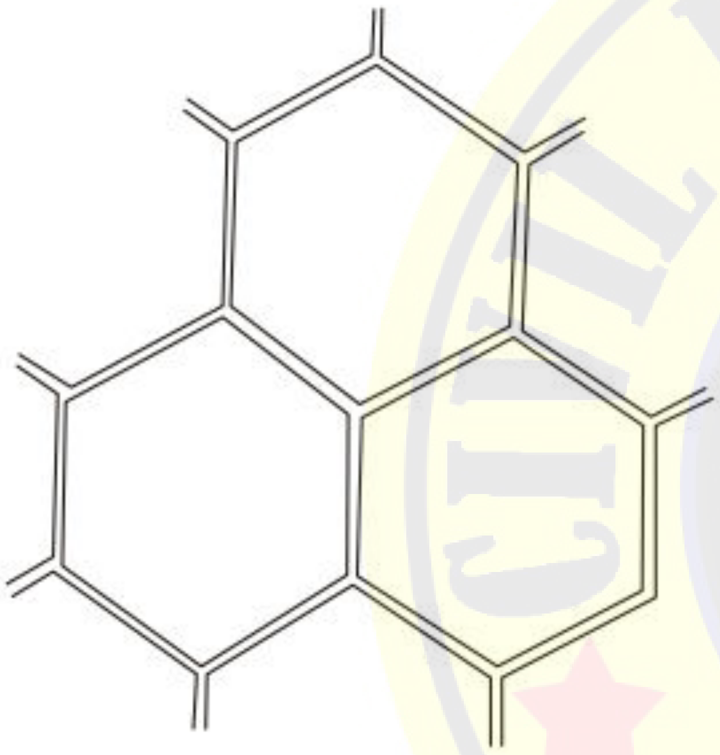
(b) Radial or star and block pattern



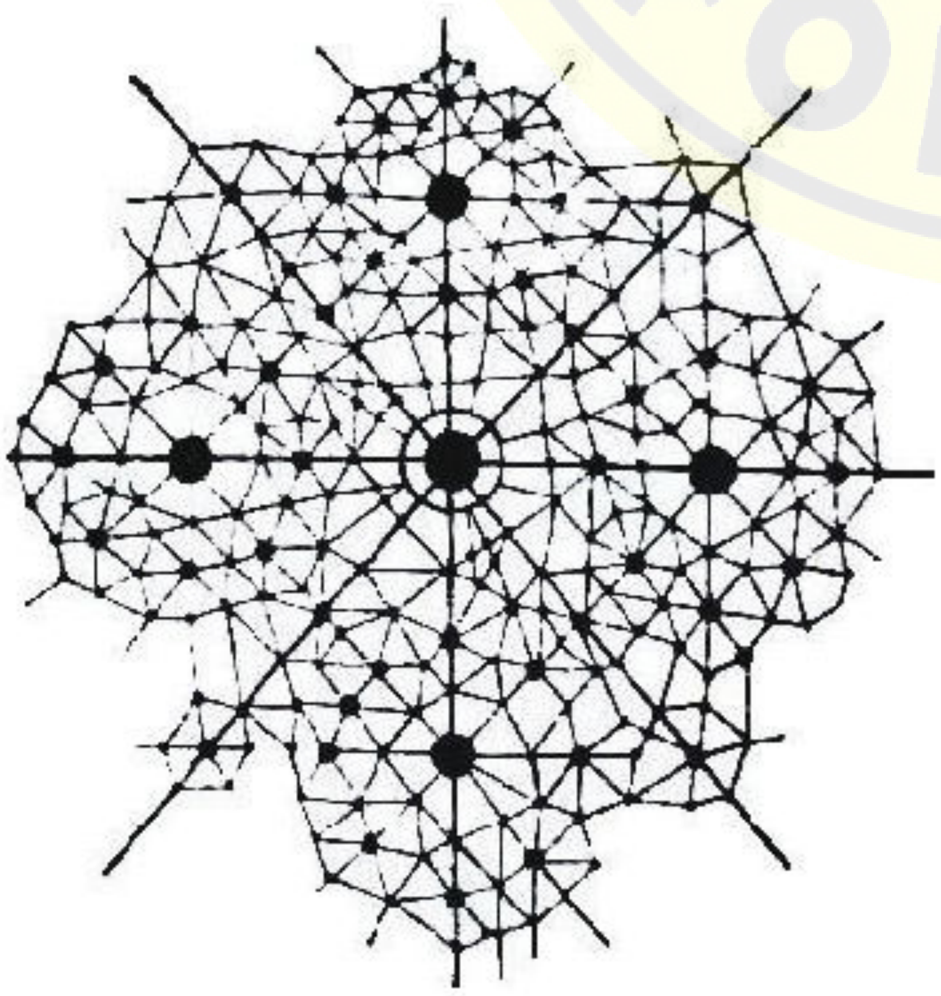
(c) Radial or star and circular pattern



(d) radial or star and grid pattern



(e) hexagonal pattern



(f) Minimum travel pattern

PLANNING SURVEYS :-

Highway planning phase includes

(i) Asseesment of road length requirement form area (it may be a district, state or the whole country).

(ii) Preparation of master plan showing the phasing of plan in annual and or five year plans.

Thus for arressing the road length requirements, field surveys are to be carried out to collect the data required for determining the length of the road system. The field surveys thus required for collecting the factual data may be called as planning surveys or fact finding surveys.

The factual studies poin t to an intelligent approach for planning and there studies should be carried out if the high way programme is to be protected from inconsistent and short sighted policies.

The planning surveys consist of the following studies;

(a) Economical studies : the various details to be collected are useful in estimating the economics involved in the highway development programme. Hence it is desirable to find the service give by each road system to the population and products of the area. All details of the existing facilities should be available before estimating the requirements such the economic justification can be made for each plan.

(b) Financial studies : The financial studies are essential to study the various financial aspects like sources of income and the manner in which funds for the project may be mobilized.

(c) Traffic or road use studies : All details of the existing traffic their volume and pattern of flow should be knows before any improvement could be planned. Traffic survey should be carried out in the whole area and on selected routes and locations in order to collect the different information regarding traffic.

(d) Engineering studies : All details of the topography, soil and other problems such as drainage, construction and maintenance problems should be irvestigated before a scientific plan or programme is suggested. This includes :-

(i) Topographic surveys.

(ii) Soil surveys.

(iii) Location and classification of existing roads

(iv) Estimation of possible development in all aspects due to the proposed highway development

(v) Road life studies

(vi) Traffic studies - Origin and Destination Studies

(vii) Special problems in drainage, construction and maintenance of roads.

PREPARATION OF PLANS :-

Before finalising the alignment and other details of the road development programme, the information collected during the fact finding surveys should be presented in the form of plans usually four drawings are prepared showing the various details of the area as listed below.

PLAN I : General area plan showing almost all existing details; viz topography, existing road network and drainage structure, rivers canals, nallah etc. towns and villages with the population; commercial industrial or agricultural activities are also shown in this map.

PLAN II : This plan includes the distribution of population groups in accordance with the categories made in the appropriate plan.

PLAN III : This plan shows the locations of places with their respective quantities of Productivity.

PLAN IV : This plan shows the existing road network with traffic flows and desire lines obtained from origin and Destination studies of traffic. Proposals received from different sources may also be shown in this plan.

The various details collected from the planning survay and presented in the form of plans should be intepreted in a scientific way before arriving at the final road development programme.

the data collected should he interpreted and used for following importent purposes : -

(i) To arrive at the road network, out of several alternate possible systems, which has the maximum utility.

(ii) To fix up priority of the construction projects so as to phase the road development plan of an area in different periods of time such as five years plan and annual plans.

(iii) To axes the actual road use by studying the traffic flow patterns. This data may therefore shows areas of congestion which need immediate relief.

(iv) Based on traffic type and intensity and the performance of existing types of pavement and cross drainage structures a new structures may be desisgned using the data and past experience.

HIGHWAY ENGINEERING

Transporation contributes to the economic, industrial, social and cultural development of any country. Transportation is vital for the economic developement of any region since every commodity produced needs means of transportation at all stages from production to distribution.

HIGHWAY GEOMETRIC DESIGN:-

(i) Cross-section elements
(ii) Sight distance consideration
(iii) Horizontal alignment details
(iv) Vertical alignment details
(v) Intersection details.

Under cross section elements, the consideration for the width of pavements formation and land, the surface characteristics and cross-slope of pavment are included. The sight distance or clear distance visible ahead of a driver at horizontal and vertical curves and at intersections governs the safe movements of vehicle.

The change in read directions are made possible by introducing horizontal curves. Super-elevation is provided by raising the outer edge of pavement to counteract the centrifugal force developed on a vehicle traversing a horizontal curve, extra pavment width is also provided on horizontal curves.

DESIGN CONTROLS AND CRITERIA :-

The geometric design of highways depends on several design factors. The important of these factors which control the geometric elements are:-

(i) Designed speed
(ii) Topography
(iii) Traffic factors
(iv) Designed hourly volume and capacity
(v) Enviroment and other factors.

HIGHWAY CROSS SECTION ELEMENTS:-

(a) Pavement surface characteristics:- The pavement surface depends on the pavement type which is decided based on the availability of material and funds, volume and compositon of traffic subgrade and climatic conditions, construction facilities and consideration. The important surface characteristics of the pavment are the friction unevenness, light reflecting characteristics and drainage of surface water.

(b) Friction:- When a vehicle negotiates a horizontal curve, the lateral friction developed counteracts the centrifugal force. Thus, It governs the safe operating speed.Frictional force is an important factor in the acceleration and retardation abilities of vehicle. The maximum coefficent of friction comes into play only when the braking efficiency is high enough to partially arrest the rotation of the wheels on application of brakes at low speed.

Skid occurs when the side without revolving or when wheels partially revolve,i.e when the path, travelled along the road surface is more than the circumferential movements of the wheel due to rotation.

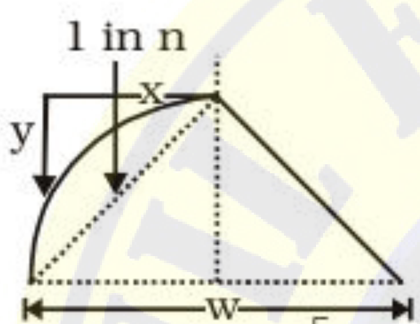
(c) Pavement unevenness:- Higher operating speed are possible on even pavement surfaces with less undulations than on uneven and poor surfaces, pavement surface should hence be maintained with minimum possible unevenness such that the desired speed can be maintained in comformity with other geometric standards.

(d) Light reflecting characteristics:- Night visibility very much depends upon the light reflecting characteristics of pavement surface. The glare caused by the reflection of headlights is considerably high on wet pavement surface than on the dry pavement.

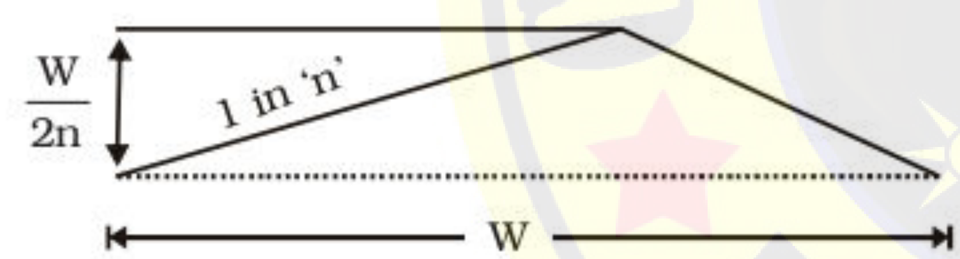
Cross Slope or Chamber:-

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

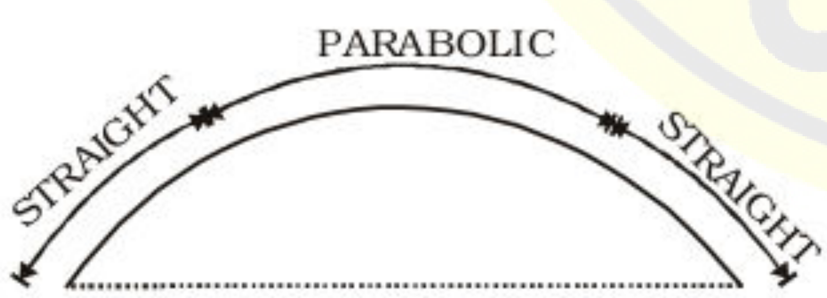
(a) Shape of cross slope:- The chamber is given a parabolic elliptic or straight line shape in the cross section. Parabolic or elliptic shape is given so that the profile is flat at the middle and steeper towards the edges. It is preferred by fast moving vehicales as they have to frequently cross the crown line during overtaking operation on a two lane highway.



(a) Parabolic shape $\left[y = \dfrac{2x^2}{nW}\right]$



(b) Straight line



(c)Combination of straight and parabolic shape.

(b) Providing Chamber in the filed:- Forming a straight line chamber is very simple. In case of parabolic chamber the general equation-

$y = \dfrac{x^2}{a}$ may be adopted.

Here, $a = \dfrac{nW}{2}$ for a pavement of width 'w' and cross slope 1 in n.

Hence, $y = \dfrac{2x^2}{nW}$

SIGHT DISTANCE:-

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 object.

Three sight distance situations are considered in the design.

(i) Stopping or absolute minimum sight distance.

(ii) Safe overtaking or passing sight distance, and

(iii) Safe sight distance for entering into uncontrolled intersections.

(a) 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 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.

(b) Braking Distance :- If 'F' is the maximum frictional force developed and the braking distance is 'l' then work done against frictional force in stopping the vehicle is F×l = fwl ,

Where 'W' is the total weight of the vehicle.

The kinetic energy at the design speed of v m/s will be :

$$\frac{1}{2}mV^2 = \frac{Wv^2}{2g}$$

$$\text{Hence, } fwl = \frac{Wv^2}{2g} \quad \text{or} \quad l = \frac{V^2}{2gf}$$

Where, l = braking distance, m

v = speed of vehicle, m/sec

f = design coefficent of friction.

= 0.4 to 0.35, depending on speed, from 30 to 80 kmph.

g = acceleration due to gravity = 9.8 m/sec^2.

Stopping distance = lag distance + braking distance.

$$\text{i.e, } SD, m = vt + \frac{v^2}{2gf}$$

If speed is 'V' kmph, stopping distance,

$$SD, m = \left[0.278\,vt + \frac{v^2}{254f}\right]$$

Above both eqations are general equations for stopping distance at level.

Stopping distance at slopes = SD, m= 0.278

$$0.278\ v.t + \frac{v^2}{254(f \pm 0.01)n}$$

DESIGN OF HORIZONTAL ALIGNMENT:-

Often changes in the direction are necessitated in highway alignment due to obligatory points various design factors to be considered in the horizontal alignment are design speed, radius of circular curves, type and length of transition curves, superelevation and widening of pavement on curves.

(i) **Design speed:-** The overall design of geometrics of any highway is a function of the design speed.

The design speed is the main factor on which geometric design elements depends. The recommended design speeds for different classes of urban roads are:-

(a) Arterial roads, 80 kmph.
(b) Sub-arterial roads, 60 kmph.
(c) Collector streets, 50 kmph and
(d) Local streets, 30 kmph.

(ii) **Horizontal curves:-** A horizontal highway curve is a curve in a plan to provide change in direction to the central line of a road. When a vehicle traverses a horizontal curve, the centrifugal force acts horizontally through the centre of gravity of the vehicle.

Centrifugal force 'p' is given by the equation:-

$$P = \frac{Wv^2}{gR}$$

Here, P = Centrifugal force
W = Weight of the vehicle, kg
R = radius of the circular curve,m
v = Speed of vehicle, m/s
g = acceleration due to gravity = 9.8 m/s^2

The ratio of the centrifugal force to the weight of vehicle (P/W) is known as the centrifugal ratio or the impact factor.

The centrifugal ratio is equal to v^2/gR.

(iii) **Superelevation**:- In order to counteract the effect of centrifugal force and to reduce the tendency of the vehicle to overturn or skid, the outer edge of the pavement is raised with respect to the inner edge, thus providing a transverse slope throughout the length of horizontal curve. This transverse inclination to the pavement suface is known as superelevation.

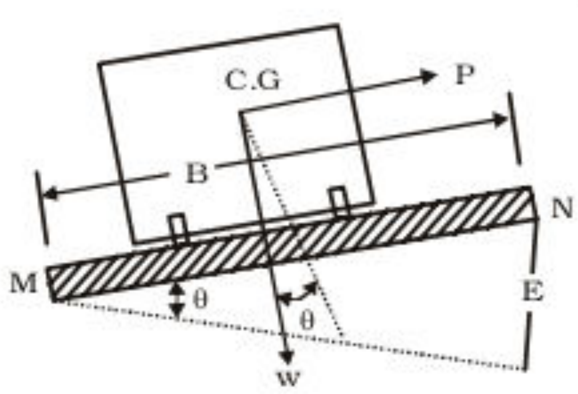


Fig:- **Superelevated pavement section.**

From fig, it may be seen that superelevation,

$$e = \frac{NL}{ML} = \tan\theta$$

$$\text{or } e = \frac{V^2}{gR}\ \frac{V^2}{127R} \quad \text{or} \quad e + f = \frac{V^2}{127R}$$

$$\text{or } f = \frac{V^2}{gR} = \frac{V^2}{127R} \quad \text{or} \quad V\sqrt{127fR}$$

(iv) **Radius of horizontal curve**

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

DESIGN OF VERTICAL ALIGNMENT:-

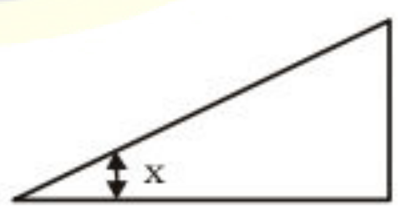
While aligning a highway, it is the general practice of follow the general topography or profile of the land. In order to have smooth vehicle movements on the roads, the changes in the grade should be smoothened out by the vertical curves. The vertical alignment is the elevation or profile of the centre line of the road. The vertical alignment consists of grades and vertical curves, and it influences the vehicle speed, acceleration, retardation, stopping distance, sight distance and comfort in vehicle movements at high speeds.

(i) **Gradient:-** Gradient is the rate of rise or fall along the length of the road with respect to the horizontal. It is expressed as a ratio of 1 in x (1 vertical unit to x horizontal units). Sometimes the gradient is also expressed as a percentage, i.e, n in 100. An angle that measures the change of direction at the intersection of two grade is called the deviation angle 'N' which is equal to the algebraic difference between the two grades. In fig. the deviation angle,

$$N = \angle DBC = \angle BAC + \angle BCA$$

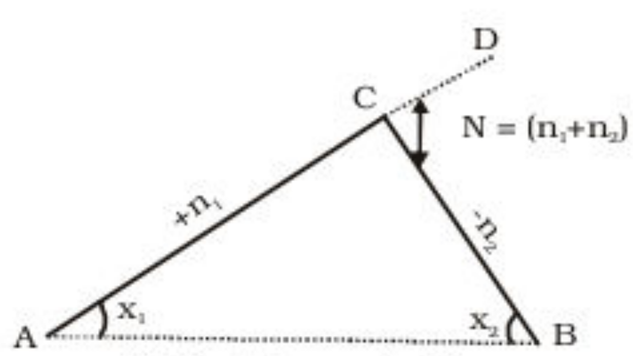
$$= +n_1 - (-n_2) = n_1 + n_2$$

Where 'n' is ascending gradient of AB and -n_2 is the descending gradient of BC.



(a) Gradient = 1 in x

$$\tan x = \frac{100}{x} \text{percent}$$



(b) Deviation angle, N

Fig :- **Measure of gradient.**

Gradients are divided into the following categories:-

Ruling gradient limiting gradient,Exceptional gradient, minimum gradient.

(ii) **Vertical curves:-** Due to changes in grade in the vertical alignment of highway, it is necessary to introduce vertical curve at the intersections of different grades to smoothen out the vertical profile and thus ease off the changes in the gradients for the fast moving vehicles.

The vertical curves used in highway may be classfied into two categories:-

(a) Summit curves or crest curves with convexity upwards.

(b) Valley or sag curves with concavity upwards.

Length of summit curve for stopping sight distance(SSD):-

Two case are to be considered in deciding the length:-

(i) When the length of the curve is greater than the sight distance (L > SSD)

(ii) When the length of curve is less than sight distance (L < SSD)

(i) When L > SSD.

$$\text{Then}, L = \frac{NS^2}{\left(\sqrt{2H} + \sqrt{2h}\right)^2}$$

Where, L = length of summit curve, m

S = Stopping sight distance,(SSD), m

N = deviation angle, equal to algebraic difference in grades radions or tangent of the diviation angle.

H = Height of eye level of driver above roadway surface,m

h = height of subject above the pavement surface,m.

The value of H, the height of driver's eye above roadway surface is taken as 1.2m in India. The height of object 'h' above the pavement surface for the purpose of safe stopping distance is taken as 0.15m as per IRC standard.

$$\text{So}, L = \frac{NS^2}{4.4}$$

(ii) When L < SSD

$$\text{Then}, \; L = 2S - \frac{\left(\sqrt{2H} + \sqrt{2h}\right)^2}{N}$$

if we substitute, H = 1.2 & h = 0.15m then length of the curve obtained as : - L = 2s - 4.4/N.

TYPES OF PAVEMENT:-

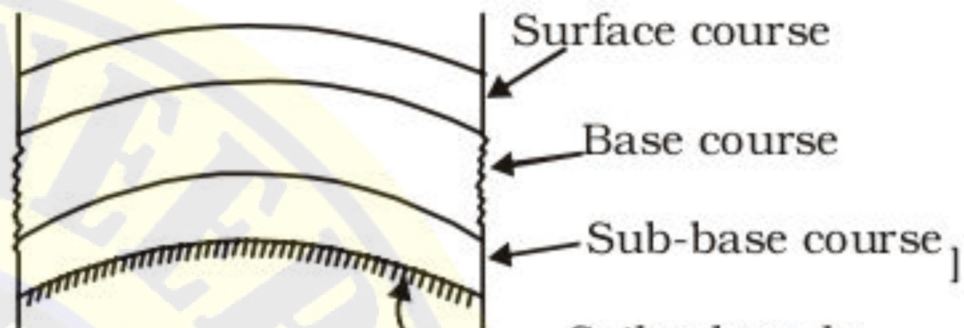
The surface of the roadway should be stable and non-yielding, to allow the heavy wheel loads of road traffic to move with least possible ralling resistance.

Based on the structural behaviour, pavements are generaly classified into two categories:-

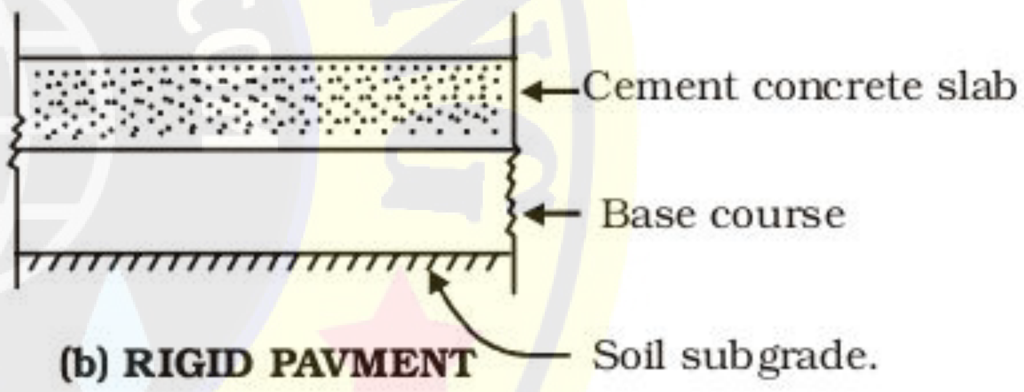
(i) Flexible pavements

(ii) Rigid pavement

(i) Flexible pavements are those, which on the whole have low or negligible flexural strength and are rates flexible in their structural action under load. A typical flexible pavement consists of four components i.e, soil subgrade, sub-base course, base course and surface course.



(a) FLEXIBLE PAVMENT.



(b) RIGID PAVMENT

Fig :- **Components of flexible and Rigid Pavements.**

The flexible pavement layers transmit the vertical or compressive stresses to the lower layers by grain to grain transfer through the points of contact in the granular structure.

(ii) **Rigid Pavment:-** Rigid pavments are those which possess note worthy flexural strength or flexural rigidity. The stresses are not transferred from grain to grain to the lower layers as in case of flexible pavment layers.

The rigid pavements are made of Portland cement concrete either plain, reinforced or prestressed concrete. The plain cement concrete slab are expected to take-up about 40 kg/cm² flexural stress.

(iii) **Semi-rigid pavement:-** When bonded material like the pozzolanic concrete (lime-flyash-aggregate mix) lean cement concrete or soil cement are used in the base course or sub-base course layer the pavment layer has considerably higher flexural strength than the common flexible pavment layer.

PAVEMENT MATERIALS:-

(i) **AGGREGATES:-**

Aggregates form the major portion of pavement structure and they form the prime materials used in pavement construction. Most of the road aggregate are prepared from natural rock. the aggregates are specified based on their grain size, shape, texture and its gradation.

Based on the strength property, the coarse aggregates may be divided as hard aggregates and soft aggregates.

The soft aggregates include moorum, kankar, laterite, brick aggregates and slag.

Desirable properties of road aggregates:-

(a) **Strength:-** The aggregate which are to be used in top layers of pavement, particularly in the wearing course have to be capable of withstanding high stresses in addition to wear and tear, hence they should possess sufficient strength resistance to crushing.

(b) **Hardness :-** The aggregates used in the surface course are subjected to constant rubbing or abrasion due to moving traffic. they should be hard enough to resist the wear and tear due to abrasive action of traffic.

(c) **Toughness:-** Aggregates in the pavements are also subjected to impact due to moving wheel loads.

(d) **Durability:-** The stone used in pavement construction should be durable and should resist disintegration. The property of the stones to withstand the adverse action of weather may be called soundness.

(e) **Adhesion with bitumen:-** The aggregates used in bituminous pavements should have less affinity with water when compared with bituminous materials, otherwise the bituminous coating on aggregate will be stripped off in presence of water.

(ii) **BITUMINOUS MATERIALS:-**

Bituminous binders used in pavement construction works include both bitumen and tar. Bitumen is a petroleum product obtained by the distillation of petroleum crude whereas road tar is obtained by the destructive distillation of coal or wood.

Bitumen is hydrocarbon material of either natural or pyrogenous origin, found in gaseous, liquid, semi-solid or solid form and is completely soluble in carbon disulphide and in carbon tetra chloride.

When the bitumen contains some inert material or minerals, it is some times called asphalt . Asphalt is found as deposits in the form of natural asphalt or rock asphalt.

The bitumen should possess the following desirable properties:-

(a) The viscosity of the bitumen at the time of mixing and compaction should be adequate. This is achieved by heating the bitumen and aggregate prior to mixing or by use of cutbacks or emulsions of suitable grade.

(b) The bituminous material should not be highly temperature susceptible. The material should be durable.

(c) In presence of water the bitumen should not strip off from the aggregate. There has to be adequate affinity and adhesion between the bitumen and aggregate used in the mix.

TESTS FOR MEASURTING THE STRENGTH PROPERTIES OF MATERIAL:-

Many tests are known for measuring the strength properties of the subgrades. Mostly the test are empirical and are useful for their correlation in the design. Some of the tests have been standardised for the use.

The common strength test for the evaluation of soil subgrade are:-

California bearing ratio test:- CBR test is a penetration test, evolved for the empirical method of flexible pavment design. The CBR test is carried out either in the laboratory on prepared specimen or in the field by taking in -situ measurements. This test is also carried out to evaluate the strength of other flexible pavement component materials.

California resistance value test:- The California resistance value is found by using Hveem stabilometer.

This test is used in an empirical method of flexible pavement design based on soil's strength.

Triaxial Compression test:- Altough triaxial test is considered as the most important soil strength test, get the test is not very commonly used in structural design of pavements. This is because only a few theoretical methods make use of this triaxial test results.

Plate bearing test:- Plate bearing test is carried out using a relatively larger diameter plate to evaluate the load supporting capacity of supporting power of the pavement layers. The plate bearing test is used for determining the elastic modulus of subgrade and other pavement layers. The results of the plate bearing tests are used in flexible pavement design method.

DESIGN OF FLEXIBLE PAVEMENTS:-

The maximum intensity of stresses occurs in the top layer of the pavement. The magnitude of load stresses reduces at lower layers. Hence, the superior pavement materials used in top layers of flexible pavements.

(i) **California bearing ratio method:-**

$$t = \sqrt{P}\left[\frac{1.75}{CBR} - \frac{1}{P\Pi}\right]^{1/2}$$

$$\text{or} \quad t = \left[\frac{1.75P}{CBR} - \frac{A}{\Pi}\right]^{1/2}$$

Here, t = pavment thickness, cm
P = Wheel load, kg
CBR = California bearing ratio, percent
P = Tyre pressure, kg/cm²
A = area of contact, cm²

(ii) **Triaxial method:-** This design method is based on Boussinesq displacement equation for homogeneous elastic single layer:-

$$\Delta = \frac{3pa^2}{2E\left(a^2 + z^2\right)^{1/2}}$$

$$p = p / \pi a^2$$

$$\therefore \Delta = \frac{3P}{2\pi E\left(a^2 + z^2\right)^{1/2}}$$

$$Z = \sqrt{\left(\frac{3P}{2\pi E\Delta}\right)^2 - a^2}$$

Assuming that the pavement is incompressible, Z become T, the thickness of pavement:-

$$T = \sqrt{\left(\frac{3P}{2\pi E_{s\Delta}}\right)^2 - a^2}$$

Here, T = pavement thickness, cm
A = area of contact, cm²
P = wheel load
E_s = Modulus of Elasticity of subgrade from triaxial test result, kg/cm²
a = radius of contact area, cm
Δ = design deflection (0.125 cm).

(iii) Burmister's (Layered system) method:-

for flexible plate, $\Delta = 1.5 \frac{pa}{E_s}.F_2$

for rigid plate, $\Delta = 1.18 \frac{pa}{Ep}.F_2$

For single layer, h = 0 and $\frac{Es}{Ep} = 1$ therefore

$F_2 = 1$ and these equations get reduced to Boussinesq's settlement equation.

i.e $\mu_s = \mu_p = 0.5$

DESIGN OF RIGID PAVEMENTS:-

Here, it is assumed that the upward reaction is proportional to the deflection,i.e, $P = K\Delta_2$.

The modulus of subgrade reaction 'k' is given by :-

$$K = \frac{p}{\Delta} = \frac{p}{0.125} \ \text{kg / cm}^3$$

Radius of relative stiffness:-

$$l = \left[\frac{Eh^3}{12K\left(1-\mu^2\right)}\right]^{1/4}$$

Here, l = radius of relative stiffness, cm
E = Modulus of elasticity of cement concrete kg/cm²
μ = Poisson's ratio for concrte = 0.15
h = Slab thickness, cm
k = Subgrade modulus or modulus of subgrade reaction, kg/cm³

RIGID PAVEMENT JOINT :-

Various types of joints provided in cement concrete pavements to reduce the temperature stresses. These are expansion joint, contraction joints and warping joints. If expansion and contraction joints are properly designed and constructed , these is no need of providing warping joints. Expansion joint spacing is designed based on the maximum temperature variations expected and the width of joint. The contraction joint spacing design is governed by the anticipated frictional resistance and allowable tensile stress in concrete during the initial curing period. The spacing between the expansion joint are so adjusted that the contraction joints have equal spacing. Dowel bars are provided at expansion joints and some times at contraction joint also.

(i) **Spacing of Expansion Joint:-** If 's' is the maximum expansion in a slab of length Le with a temperature rise from T_1 to T_2.

S^1 = Le. C (T_2 - T_1), where 'C' is thermal explansion of concrete per degree rise in temperature.

From the relation given above, if S^1 is half the joint width the spacing of expansion then joint Le is given by the equation :

$$Le = \frac{S^1}{100C(T_2 - T_1)} \qquad \ldots(i)$$

(ii) **Spacing of contraction joint:-**

Total frictional resistance up distance

$$Lc / 2 = w \times b \times \left(\frac{Lc}{2}\right) \times \frac{h}{100} \times f \qquad \ldots(ii)$$

Allowable tension in cement concrete = Sc × h × b × 100

Equating the above two values,(i) and (ii)

$$\frac{bLchf}{200} = 100Sehb$$

$$Lc = \frac{2Sc}{wf} \times 10^4$$

Here, Lc = Spacing between contraction joints,m

h = Slab thickness, cm

f = Coefficient of friction (maximum value is about 1.5)

W = Unit weight of cement concrete, kg/m^3(2400 kg/m^3)

Sc = Allowable stress in tension in cement concrete, kg/cm^2 (0.8 kg/ cm^2).

WATER BOUND MACADAM ROADS :

The term macadam in the present day means the pavement base course made of crushed or broken aggregate mechanically interlocked by ralling and the voids filled with screening and binding material with assistance of water. The WBM may be used as a sub-base, base-course or surfacing course. The thickness of each compacted layer of WBM ranges from 10.0 cm to 7.5 cm depending on size and gradation of the aggregates used. The number of layers and total thickness of WBM construction depends on the design details of the pavement.

GRAVEL ROADS:- Gravel roads are considered superior to earth roads as they can carry heavier traffic. The road consists of a carriageway constructed using the gravels. The chamber may between 1 in 25 and 1 in 30.

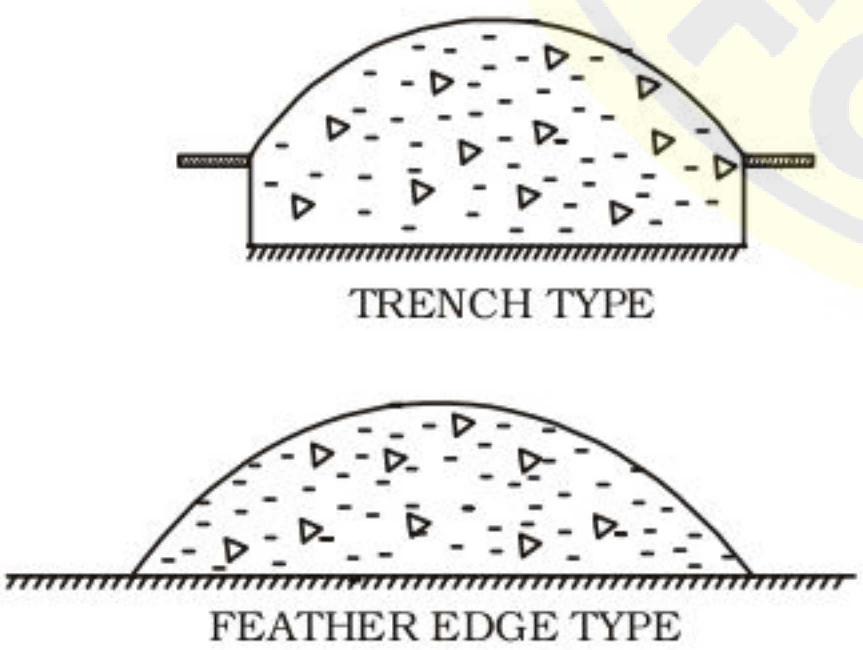


Fig:- **Types of gravel road Section.**

BITUMINOUS PAVEMENTS CONSTRUCTION:-

The following construction techniques are in use:-

(i) **Interface treatments like prime coat and tack coat :-**

Bituminous prime coat is the first application of a low viscosity liquid bituminous material over an existing porous or absorbent pavement surface like the WBM base course.

Bituminous black coat is the application of bituminous material over an existing pavement surface which is relatively impervious like an existing bituminous suface or a cement concrete pavement.

(ii) **Surface dressing and Seal coat:-**

Bituminous surface dressing is provided over an existing pavement to serve as thin wearing coat. Seal coat is usually recommended as a top coat over certain bituminous pavements which are not impervious, such as open graded bituminous, construction like premixed carpet and grounded macadam .

Bituminous macadam (BM) is a premix laid immediately after mixing and then compacted. It is an open graded construction suitable only as a base or binder course. When this layer is exposed as a surface course, at least a seal course is necessary.

HIGHWAY MAINTENANCE:-

Various maintenance operations are :-

(i) Routine maintenance

(ii) Periodic maintenance.

(iii) Special repairs .

Routine and periodic maintenances are needed for any type of road whether it is designed and constructed with scientific bias or not. The longitudinal and cross drains would need attention under the routine maintanance work. One of the common items of maintanence work is the removal of silt, rubbish and weeds from the longitudinal and cross-drains.

Special repairs and strengthening of pavement with overlays are needed to prevent pavement failure.

Improvement of highway geometry may also be included under special repair.

HIGHWAY DRAINAGE:-

Highway drainage is the process of removing and controlling excess surface and sub-soil water within the right of way. This includes interception and diversion of water from the road surface and subgrade.

Rational formula is widely used to estimate the peak run-off water for highway drainage. The rational formula, in its simplest form is given by:-

$$Q = CiA_d$$

Where,Q = run-off,m^3/sec

C = run - off coefficient

i = intensity of rainfall, mm/sec.

A_d = drainage area in 1000 m^3 .

TRAFFIC ENGINEERING

General:- The road traffic is composed of various categories of vehicular traffic and the pedestrain traffic, Each category of vehicular traffic has two components, the human element the driver and his machine as vehicle.

TRAFFIC CHARACTERISTICS:-

(i) **Road user characteristics :-** The various factors which affect road user characteristics may broadly be classified under four heads i.e, physica, mental, psychological and environental.

(ii) **Vehicular characteristics:-** The various vehicular charactersitics affecting the road design may be classified as static and dynamic characteristics of the vehicle.

Static characteristics of vehicles affecting road, design, are the dimensions, weight and maximum turning angle.

Dynamic characteristics of vehicles affecting road design are speed, acceleration and braking characteristics and some aspects of vehicle's body design.

TRAFFIC STUDIES:-

Traffic studies or surveys are carried out to analyse the traffic characteristics.

The various traffic studies generally carried out are:-

(a) Traffic volume study
(b) Speed studies
 (i) Spot speed study
 (ii) Speed and delay study.
(c) Origin and destination (O & D) study.
(d) Traffic flow characteristics
(e) Traffic capacity study
(f) Parking study
(g) Accident studies or the traffic flop.

Traffic volume study:-Traffic volume is the number of vehicles crossing a section of road per unit time at any selected period. Traffic volume is used as a quantity measure of flow, the commonly used units are vehicles per day and vehicles per hour.

Speed studies:- The actual speed of vehicles over a particular route may fluctuate widely depending on several factors such as geometric features, traffic conditions, time, place, enviroment and driver.

Spot speed is the instantanesous speed of a vehicle at a specified section or location.

Average speed is the average of the spot speeds of all vehicle passing a given point on the highway.

Space mean speed, $$V_s = \frac{3.6dn}{\sum_{i=1}^{n} t_1}$$

Where, V_s = Space-mean speed,kmph
d = length of road, in metres
n = number of individual vehicle observations
t_1 = observed travel time (Sec) for nth vehicle to travel distance d,m

Time mean speed, $$V_t = \frac{\sum_{i=1}^{n} Vi}{n}$$

Origin and Destination Studies (O&D) :- The origin and destination studies are carried out mainly to (i) Plan the road netwrok and other facilities for vehicular traffic and (ii) plan the schedule of different modes of transporation for the trip demand of commuters.

ANALYSIS OF SPEED FROM SKID DISTANCE:-

The basic equation for finding the braking distance or skid distance 's' for a vehicle of weight 'w' to slow down from speed v_1 and to v_2 m/sec is obtained by equating the reduction in kinetic energy with the work done against the frictional force i.e,

$$\frac{w}{2g}\left(V_1^2 - V_2^2\right) = w.f.s$$

Where 'f' is the average friction factor or skid resistance developed. $S = \frac{V_1^2 - V_2^2}{2gf}$

Substituting the values of g = 9.8 m/s² and the speed in V_1 adn V_2 kmph.

$$S = \frac{V_1^2 - V_2^2}{254f}$$

If the skid distance 's' is measured from the skid marks, the initial speed V_1 may be calculated from the relation:- $V_1 = \sqrt{V_2^2 + 2gfs}$

in km/h units,

$$V_1 = \sqrt{V_2^2 + 254fs}$$

If the vehicle comes to a stop after the skid distance S, then V_2 would be zero.

INTERSECTIONS AND INTERCHANGES:-

At the intersection these are through, turning and corssing traffic and these traffic movements may be handled in different ways depending on the type of intersection and its design.

Intersection may be classified into two broad groups:-

(i) **Intersection at grade:-**This include all roads which meet at more or less the same level. The traffic manoeuvers like merging, diverging and crossing are involved in the intersection at grade.

(ii) **Grade separated intersection:-** The intersecting roads are separated by difference in level, thus eliminating the crossing manoeuvres.

Radius of rotary roadway:-

$$R = \frac{V^2}{127f}$$

RELATIONSHIP BETWEEN SPEED TRAVEL TIME VOLUME DENSITY AND CAPACITY:-

The travel time per unit length of road is inversly proportional to the speed. If 'T' is travel time and 'V' is the speed (km/h).

$$T(\text{min / km}) = \frac{60}{V}$$

$$\text{or } T\,(\text{sec / km}) = \frac{3600}{V}$$

$$q = kV_s$$

TRAFFIC SIGNS:-

The traffic signs should be backed by law in order to make them useful and effective. Traffic sign have been divided into three categories according to Indian motor vehicles Act. These are

(i) Regulatory signs (ii) Warning sings and

(iii) Informatory signs.

HILL ROADS : A hill road is one which passes through a terrian with a cross slope of 25 per cent or more. A hilly or mountainous area is characterised by a highly broken relief with widely differing elevations steep slopes, deep gorges and a great number of water courses. Owing to complete topography, the route length has to be inefectively increased.

Type of terrian	cross slope, per cent
(i) Level (L) or plain	0 to 9.9
(ii) Rolling (R)	10 to 24.9
(iii) Mountainous (M)	25 to 60
(iv) Steep (S)	Above 60

It is the object of engineer to establish the shortest, most economical and sofe route between the obligatory points. This should be done keeping the expenditure of transportation, the wear and tear of the vehicle and the annual maintenance cost to the minimum.

ALLIGNMENT OF HILL ROADS :

The hill road alignment should link up the obligatory and control points fitting well in the landscape and satisfying the geometric requirements. The best allignment for a hilll road is one whereen the total sum of the ascands and descends between extreme points is the least. It is permissible to increase the length as mush as 50 times the highest saved by a detour.

The various steps necessary in an alignment of a hill road include map study, reconnausance, trace cut or preliminary survey and detailed survey. It may be advantageous to start the survey from the higher obligatory point.

Some particulars of special significane are discussed blow :-

Resisting length : The resisting length of a road is its effective length taking into consideration the total work done against the resistances. Suppose two stations 'A' and 'B' with difference in elevation 'h' and straight line distance L_0 are to be connected by means of road. The longituding sections of four alternate route are shown below in fig.

In hill stations the difference in elevation 'h' is likely to be high when compared to the shortest distance L_0 resulting in a gradient stipper than the rulling gradient as in fig(a). Hence, it becomes necessary to increase the length of atleast to L_1, (L_0 + l) so as to have the desired ruling gradient.

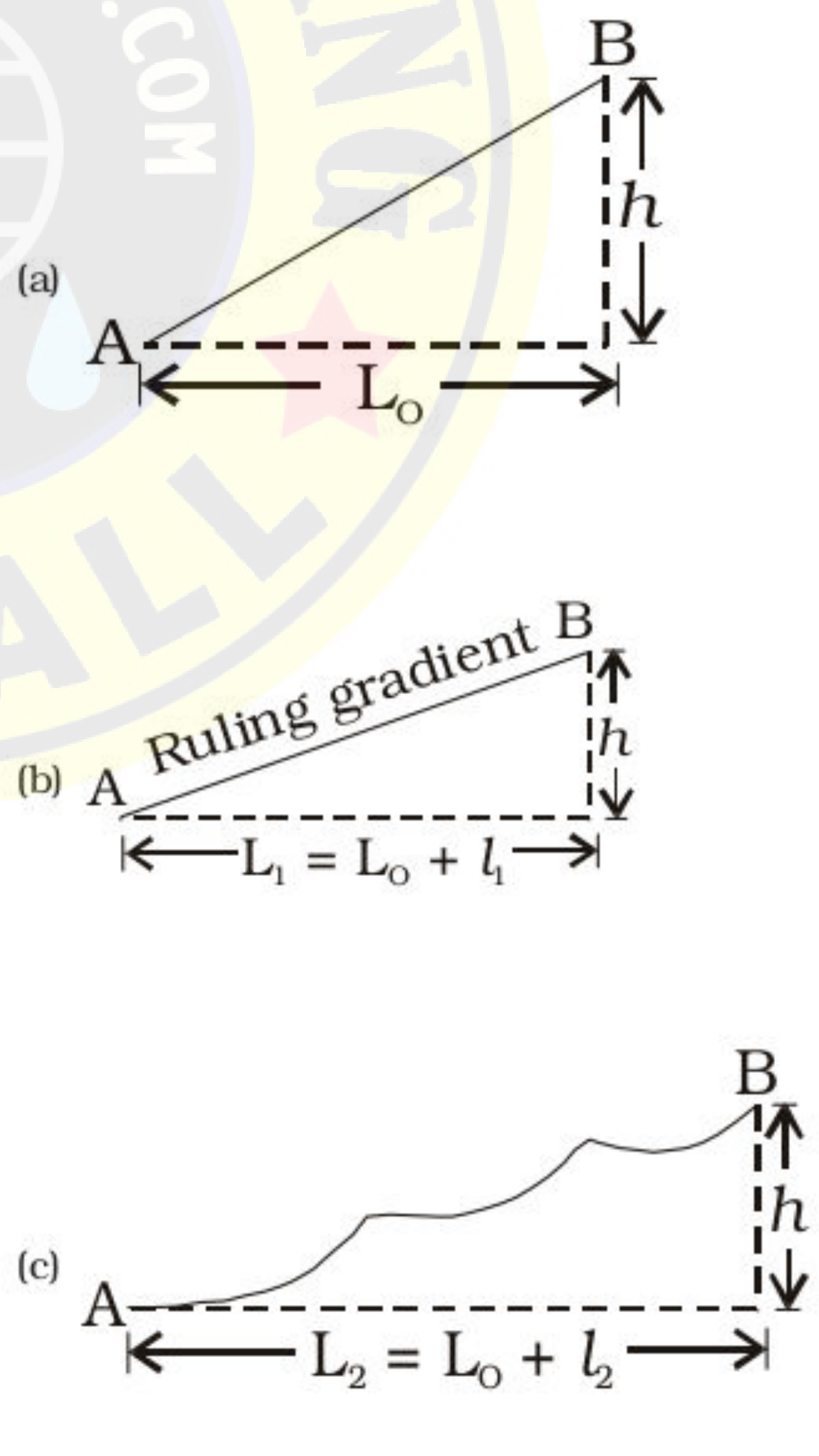


Fig- Longitudinal Sections of Alternate Routes.

The resisting lengths of the different routes are compared by considering amount of work required to move a load over there routed.

The total work done in case (a) in moving a load 'W' tron station 'A' to 'B' along the shortest length Lo up to height 'h'

$$= WfL_o + Wh = Wf(L_o + \frac{h}{f}) = WfL_r$$

Here, L_r = resisting length = $L_o + \frac{h}{f}$

f = coefficient of frictional reistance.

In case (b), the reisting length , $L_{r1} = L_1 + \frac{h}{f}$

Similarly in aligments (c) the value of resisting length are given by :-

$$Lr_2 = L_2 + \frac{h+h_2}{f} + L_o + l_2 + \frac{h+h_2}{f}$$

In this equation l_2 is the additional distance to be traversed along the alternative routes, h_2 and h_3 are the total uneffective rise and fall along the routes.

Thus the concept of resisting length gives the correct idea of various alternate routes while selecting an alignments after the preliminary survey. Obviously out of the alternate alignments which fullfill the desired geometric standards, the one with the minimum resisting length should be prefered.

ALLIGNMENT SURVEY :

The aligment of hill roads is fixed in three stages :-

(i) **Reconnaissance :** The general route for the alignment is selected during the reconnaissance.

(ii) **Trace Cut :** The route selected during the reconnaissance is translated on the ground during the trace cut so as to provide an accees for subsequent detailed surveys. 1.0 to 1.2 m wide track is constructed, with easier gradients than the specified gradients. Instead of cutting into hard rock, access is achieved by means of dry rubble filling or walls.

(iii) **Detailed Survey :** During the detailed surveys, bench marksare fixed and the longitudenal and cross sections are obtained. A strip covering about 15m on either side on straight and 30m at shap curve may be surveyed.

GEOMETRICS OF HILL ROAD :

The geometric standards for gradient superelevation and radius of curves etc. On hill roads are different from those in plains. The main reason for difference are the topogrophy and other problem in alignment of hill roads.

Width of Pavement, Formation and Land :-

The recommended widths of pavement or carriagevay, formotion and land for hill roads in India are given below in table.

Table : Width of pavement, Formation and Land

Highway Classification	Pavement width, m	Roadway width, m (excluding side drains & parpets)	Right-of-way width, m	
			Normal	Exceptional
NH & SH				
Two lane	7.00	8.80	24	18
Single lane	3.75	6.25	24	18
MDR	3.75	4.75	18	15
ODR	3.75	4.75	15	12
VR	3.00	4.00	9	9

At stretch on hard rock the shoulders may be reduced by 0.4 m on either sides on two-lane roads and by 0.2 m in other cole. The minimum Set back for building line beyond the right of way should be 5 m in normal case and 3m in exceptional circumstances.

Camber or cross fall :

steeper cross slope or camber is adopted for hill roads and recommended values are given in table below when the road has longitudinal gradients greater than 1 in 20, flatter camber may be provided.

Type of surface	Camber per cent
Subgrade, earth roads & shoulders	3.0 to 4.0
Gravel and W.B.M. surface	2.5 to 3.0
Bituminous surfacing	2.5
High type bituninous surface & CC	2.0

Signt distance : The stopping signt distance is calculated from the relation :

$$SSD = 0.278\ Vt + \frac{V^2}{254f}$$

Where, V = design speed, kmph.

t = reaction time, taken as 3 seconds

f = coefficent of friction assumed as 0.4

The overtakeing sight distance is calculated from the relation :-

OSD = $0.556\ V_b + 2S + 0.78\ TV_b + 0.278\ VT$

Where, V = Speed of overtaking vehicle, kmph

V_b = Speed of overtaken vehicle = (V–16) kmph

S = spacing of mousing Vehicles = $(0.2\ V_b + 6)$ m

t = Overtaking time = $\sqrt{\dfrac{14.4}{A}}$, secs.

A = acceleration in kmph/sec.

Superelevation : The superelevation is provided at horizontal curves of hill roads is obtained by the formula :

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

IRC specifies that superelevation should not exceed 7 per cent in sections of hill roads which gets snow bound and 10 per cent in other places.

Radius of Horizontal Curve :

$$R(min) = \frac{0.008V^2}{etf}$$

the lateral friction factor 'f' is taken as 0.15.

Widening of Curves : Extrawidth of carriageway we at horizontal curves is calculated from the relation:-

$$W_e = \frac{18n}{R} + \frac{0.1V}{\sqrt{R}}$$

Where '*n*' is number of lanes

Transition Curves : The length of transition curves is to be calculated from the formula :-

$$L_s = \frac{0.0215V^4}{CR}$$

Here, $C = \dfrac{80}{Vt75}$ (maximum values of 0.76 for speeds less than 30 kmph)

L_s = length of transition metre

R = radius, metre

V = design speed, kmph

The minimum length of transition recommended by I.R.C are 10m for design speed up to 40 kmph and 20m for design speed 40 to 50 kmph.

DRAINAGE IN HILL ROADS :

Drainage of water from Hill slop :-

Surface water flowing from the hill slope towards the road way is one of the main problems in drainage of hill roads. In order to intercept and divert water from the hill slope catch water drains are provided running parallel to the roadway water from the catch water drains is diverted by sloping drains and carried across the road by means of culverts. Catch water drains if improperly constructed are liable to do more damage than good to the road.

Road side Drain : Side drain is provided only on the hill side of the roads and not on both sides. Due to limitation in the formation width, the side drains are constructed to such a shape that at emergency the vechile could utilise this space for crossing at low speed or for parking. The usual type of side drains are angle, saucer and kerb and channel drains.

Craes Drainage : As far as possible, cross drainage should be taken under the road and at right angle to it. At the head of small cross drains catch pits must he provided to collect the stones and rubbish and to prevent scores. In rocky cuts catch pits is deeper than the sill of the culvert of cross drains by at least 0.3 m. The floor of the cross drain is given a longitudinal slope of 1 in 7.

The Waterway required for cross drainage work smog be calculated by any one of the usual formulos. As far as possible single span bridges are constructed. Protective structures are provided upsteam and down stream of the Cross drainage work.

In hilly roads where rain fall is heavy, it is recommended that Culverts should be provided every 60 to 90 m to facilitate drainage of water cross the roads.

MAINTENANCE PROBLEMSIN HILL ROADS :

Maintenance of Drainage Structure :

Catch water drains, side drains, catch pits and culverts are periodically cleared off of all blockages to prevent overflowing during rains.

Planting of trees on the upper slopes in order to reduce the scouring action of unstable ground due to rains is often resorted to as a precautionary measure.

The earth for repeasing berms is taken by dressing the hill slopes into terraces, but the lowest terrace should not be more than 1.8m in height.

Snow Clearance : The total accmulation of compacted snow during winter months may be as high as 6 min the Himalayan region. At avalanche sides the depth of snow accumulation could be much more. Because of snow accumlation most of hill roads at very high altitudes are closed for traffic in winters.

The first problem in snow clearance is to correctly locate the position of the road and other structure under snow cover, for mavements. This is overcome by erecting snow markers, which are wooden poles with meter marked on it before the winter. Snow clearnace is done with machine, but care must be taken when using them on black top surfaces not to damage them. Wheel dozers, snow blasts, motor graders or manual lobours are used. If the ice crust is thick, blasting by explosive may be done without affecting structures.

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