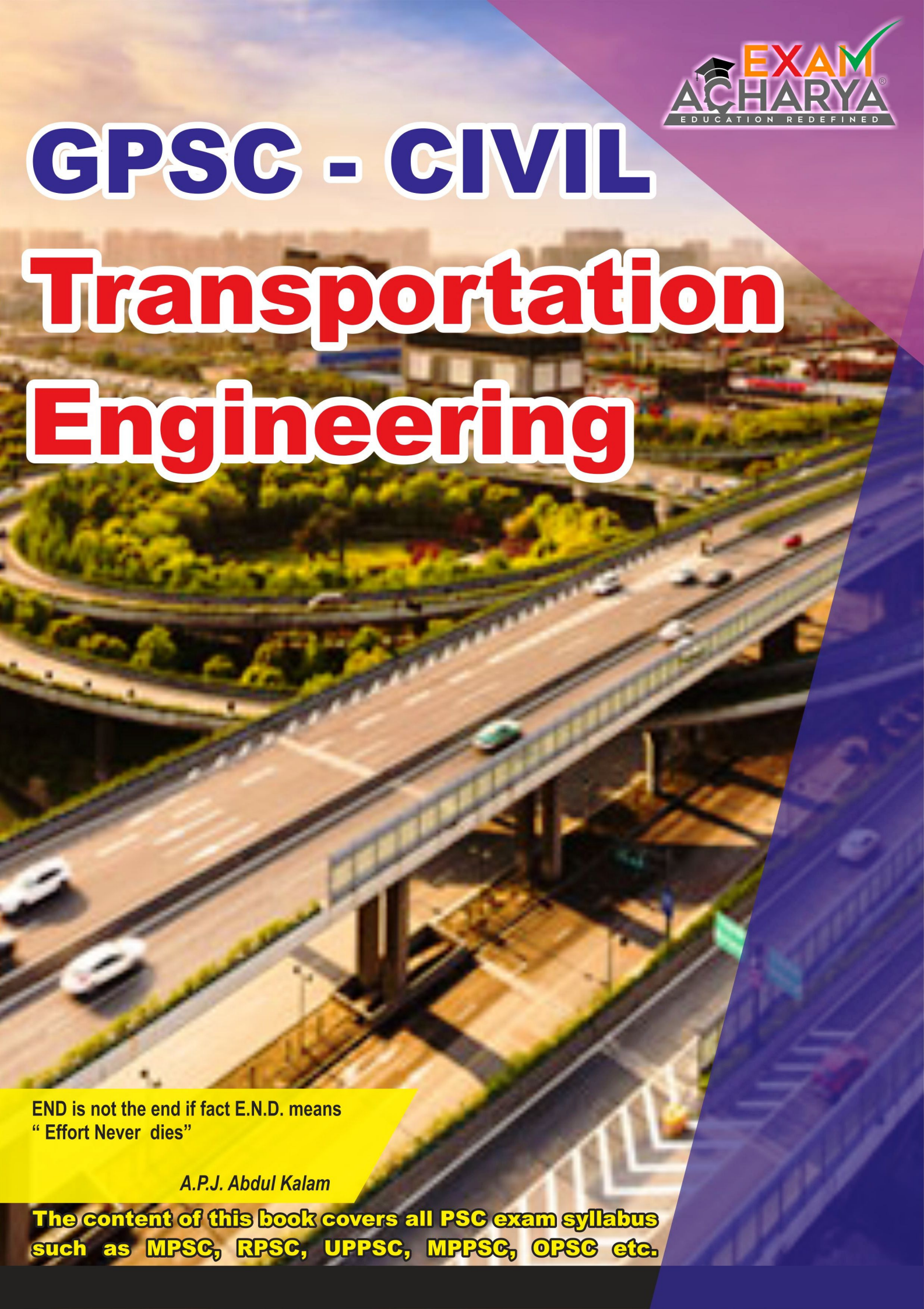
EXAM ACHARYA
EDUCATION REDEFINED

GPSC - CIVIL

Transportation Engineering



END is not the end if fact E.N.D. means
" Effort Never dies"

A.P.J. Abdul Kalam

The content of this book covers all PSC exam syllabus such as MPSC, RPSC, UPPSC, MPPSC, OPSC etc.

PREFACE

Transportation Engineering, a comprehensive refresher for GPSC, is designed for aspirants who are targeting GPSC and definitely useful for other job oriented technical exams such as RPSC, MPSC, MPPSC, UPSC, RRB JE, SSC JE etc by Exam Acharya. This book provides knowledge of the field and also helpful hints to make the study and understanding easier to the aspirants. Each chapter in this book has been meticulously designed by the state PSC's toppers and experienced faculties with the idea of maximizing the potential of an individual in a limited time. Every chapter in the book is logically divided to various sections while ensuring that the content in the book is self-sufficient and requires no cross referencing. Extra efforts have been made to simplify and summarize the theoretical aspects of the subject. Over all the whole content of the book furnishes the students with the knowledge of the subject and paves a confident path for the aspirants to accomplish success in state PSC's.

Key Features:

- Conforms to the latest syllabus prescribed by GPSC.
- Presents each topic in a lucid manner for a quick recap.
- Facilitates quick revision of concepts.

Prepared by

Mukesh Rai

Guidelines for the Aspirants

How to use this book?

- While preparing a subject, first cover all the theoretical topics of each chapter so that you will get a basic idea about particular topic.
- After covering the theoretical portion, solve the questions under “CLEAR YOUR CONCEPT” title.
- After covering the questions under “CLEAR YOUR CONCEPT” move towards the next set of questions under “TEST YOUR SELF” title.
- After finishing the theory and numerical portion of this book for each chapter, solve previous year GPSC questions which is provided in GPSC – CIVIL ENGINEERING book.
- After solving the previous year GPSC questions, for getting best results give the weekly, mid subject and full-length test prepared by Exam Acharya.

TRANSPORTATION ENGINEERING

Highways - Planning & construction methodology, Alignment and geometric design; Traffic Surveys and Controls; Principles of Flexible and Rigid pavements design.

Tunnelling - Alignment, methods of construction, disposal of muck, drainage, lighting and ventilation.

Bridges - Fundamentals of Bridge Engineering, Bridge Site Investigations and Planning, Bridge Hydrology, Standards of Loadings for Bridge Design, Different Types of Bridges, Bridge Superstructure, Bearings and Substructure Design, Design of Bridge Foundations, Bridge Approaches, River Training Work & Protection Work, Methods of Bridge Construction, Inspection, maintenance & Repair of Bridges, Testing of Bridges, Bridge Architecture.

INDEX

CHAPTER – 1

HIGHWAY PLANNING

Nowadays roads are constructed over the embankment just to ensure safety against drainage and HFL. The roads for which embankment are constructed are called highways.

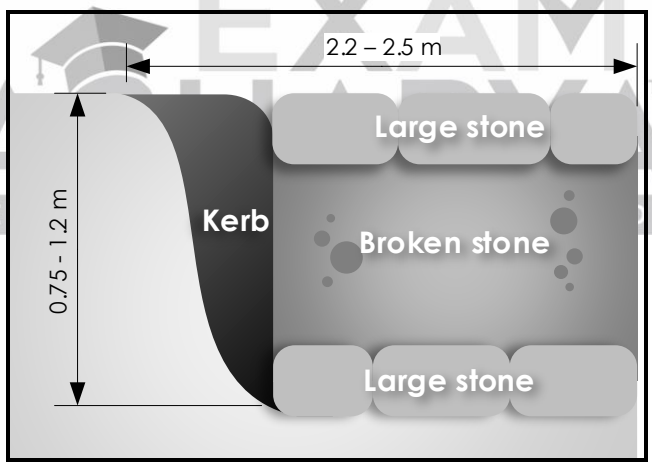
DESIGN LIFE OF HIGHWAY

Express Highway: 25 years

National and State Highway: 15 years

CHRONOLOGICAL ORDER OF ROAD DEVELOPMENT

Roman Development



Features

i. Straight regardless of gradient

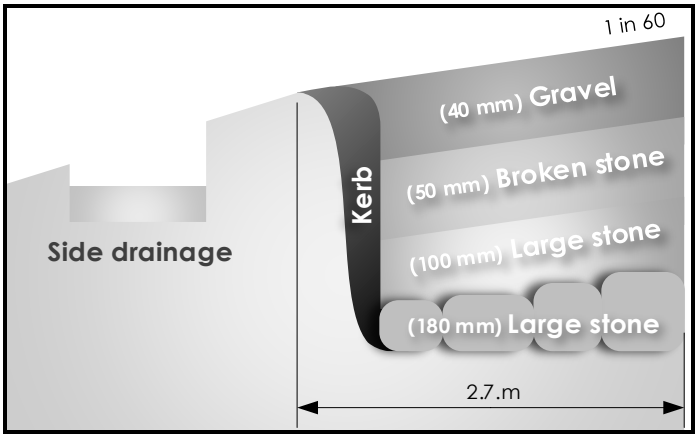
ii. Soft soil was removed, and a hard stratum was reached

iii. Kerb provided

iv. Pavement constructed in no. of layers

v. Top surface is hardened

Telford Construction



Modification

Cross slope to all the layers.

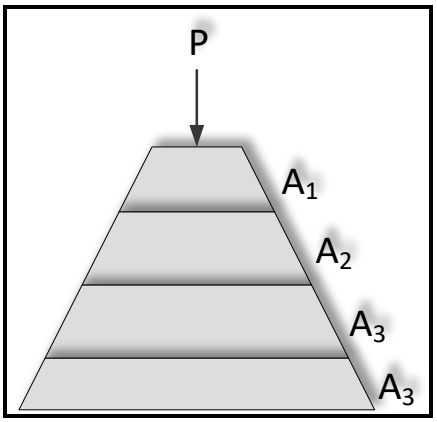
Drawback

Large foundation stone at bottom.

Macadam Construction

This is developed by John Macadam (1756 – 1836).

Macadam was the first person who suggested that large foundation stone is not required at bottom layer. He suggested the type of material as per stress distribution in different layers.



2. An extra tax should be charge on petrol and diesel for road development.

Result

Central Road Fund 1929

Note

- Currently extra tax on petrol and diesel is Rs. 2 per lit. out of which 0.5 Rs/lit. kept aside for construction development and maintenance of NH and remaining 1.5 Rs/lit. distributed to the state according to their collection.

3. A semiofficial technical body should be established for specification and design.

Result

IRC established in 1934.

4. Research and development organization should be established.

Result

Central Road Research Institute (CRRI) established in 1950 which had done following works

i. Optimum use of fly ash in M20 grade concrete.

ii. Developed bump integrator for calculation of unevenness index.

5. Long term planning

Various 20-year road plan and following act.

i. Motor vehicle act. (1939).

ii. National highway act. (1956).

iii. NHAI (National highway authority of India. 1988) It was under MORTH (Ministry Of Road Transport And Highway)

iv. NHDP (National Highway Development Programme, 1998), Golden quadrilateral is done under this programme. In golden quadrilateral 4 major cities from 4 different directions are connected by road (Delhi (N), Calcutta (E), Mumbai (W), Chennai (S))

New Batches are going to start.....

Contact:

7622050066

Test Series Available..

Total weekly test : 35

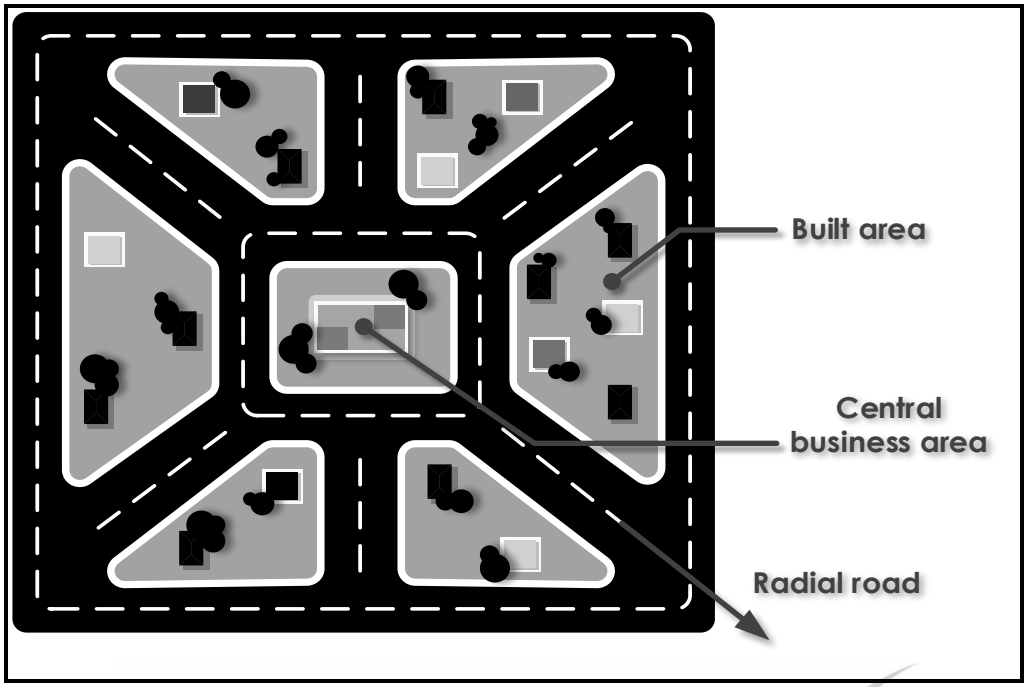
Total mid subject test : 16

Total full length test : 13

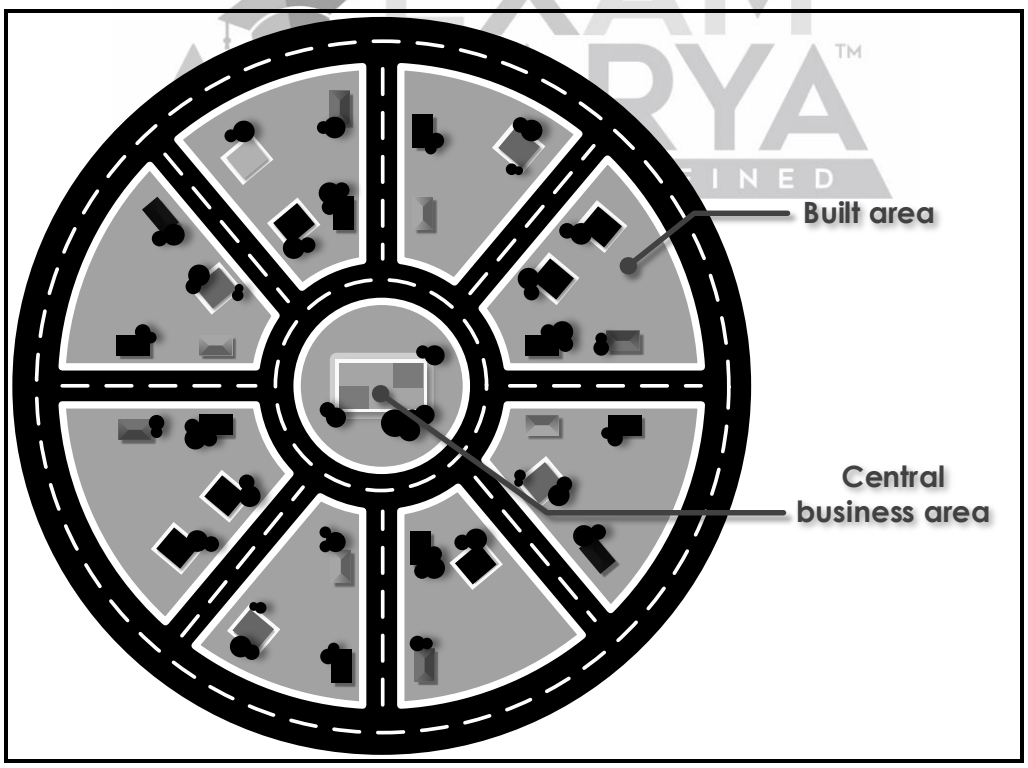
Mock test : 16

Total test : 80

Star and Block Pattern



Star and Circular Pattern



Length of Road

As per 1st 20-year road plan i.e., Nagpur Road Plan

$$\text{NH + SH+ MDR} = \frac{A}{5} + \frac{B}{20} + \text{N} + 5\text{T} + \text{D} - \text{R (in miles)}$$

$$= \frac{1.6A}{1.6^2 x 5} + \frac{1.6B}{1.6^2 x 20} + 1.6\text{N} + (1.6 \text{ x } 5\text{T}) + \text{D} - \text{R (in km)}$$

Where,

A = Agricultural area of province in km^2

B = Non- agricultural area of province in km^2

N = No. of town and village having a population of 2000- 5000.

T = No. of town and village having a population more than 5000.

D = Allowance for agriculture and industrial development (i.e., 15%)

R = Existing railway length in the area under consideration.

$$\text{ODR + VR} = \frac{1.6V}{5} + \frac{1.6Q}{2} + 1.6\text{R} + (1.6 \text{ x } 2\text{S}) + \text{D (in km)}$$

Where,

V = No. of villages with population less than 500

Q = No. of villages with population 501 - 1000

R = No. of villages with population 1001 - 2000

S = No. of villages with population 2001 – 5000

D = Allowance for agricultural development and industrial development (i.e. 15%)

Geometric Design

It may be necessary to make adjustment in the horizontal alignment of roads keeping in view the minimum radius of curve and the transition curves. Alignment should be finalized in such a way that the obstructions to visibility do not cause restrictions to the sight distance requirements.

Economy

The alignment finalized based on the above factors should also be economical. The initial cost of construction can be decreased of high embankments and deep cuttings are avoided the alignment is chosen in manner to balance to cutting and filling.

Other Consideration

Various factors which may govern the alignment are drainage considerations, hydrological factors, political consideration and monotony.

Engineering Surveys for Highway Locations

Before a highway alignment is finalized in highway project, the engineering survey are to be carried out. The stages of the engineering surveys are

Map Study

By careful study of maps, it is possible to have an idea of several possible alternate routes so that further details of these may be studies later at the site. The probable alignment can be located on the map from the following details available on the map.

i. Alignment avoiding valleys, ponds or lakes.

ii. When the roads has to cross a new of hills, possibility of crossing through a mountain pass.

iii. Approximate location of bridge site for crossing rivers, avoiding bend of the river if any.

iii. To estimate quantity of earth work and to work out the cost of alternate proposals.

iv. To finalized the best alignment from all considerations.

The procedure of all preliminary survey is given in following steps.

i. Primary traverse

ii. Topographical features

iii. Levelling work

iv. Drainage studies and hydrological data

v. Soil survey

vi. Material survey

vii. Traffic survey

viii. Determination of final centre line

Final Location and Detailed Survey

The alignment finalized at the design office after the preliminary survey is to be located on the field by establishing the centre line. Next detailed survey should be carried out for collecting the information necessary for the preparation of plans and construction details for the highway project.

Location

The centre line of the road finalized in the drawing is to be translated on the ground during the location survey.

Detailed Survey

Temporary bachmarks are fixed at intervals of about 250m and at all drainage and under pass structure. Levels along the final centre line should be taken earthwork calculation and drainage details are to be worked out from the level notes. The cross-section levels are taken up to the desired width at interval of

CLEAR YOUR CONCEPT

Qu1 The Nagpur plan classified the roads based on

a) Location

b) Function

c) Location and function

d) Annual daily traffic

Qu2 The first 20 years development plan is also called as

a) Nagpur road plan

b) Lucknow road plan

c) Bombay road plan

d) Delhi road plan

Qu3 The Nagpur plan formulae assumed which type of pattern?

a) Star and grid

b) Star and circular

c) Hexagonal

d) Circular

Qu4 As per 2nd 20 year plan the length of express highway is

a) 200 km

b) 1600 km

c) 2000 km

d) 1200 km

CHAPTER – 2

GEOMETRIC DESIGN

INTRODUCTION

A highway has visible dimensions both in the horizontal plane and in the vertical plane. The art of design of the visible dimensions is known as Geometric Design. Proper geometric design will help in the reduction of accidents and their severity. Therefore, the objective of geometric design in the provide optimum efficiency in traffic operation and maximum safety at reasonable cost. Highway geometric design covers elements such as design vehicle dimensions, user characteristics, terrain, highway classification, design speed, horizontal curves, vertical curves, gradient, sight distances, cross sectional features, junctions, interchange etc.

FACTORS CONTROLLING GEOMETRIC DESIGN

Geometric design is influenced by a number of factors such as

- Road user characteristics
- Vehicle characteristics
- Safety requirements
- Environmental considerations
- Economy in construction, maintenance, and operation of vehicles
- Topography
- Functional classification of roads
- Traffic volume and composition
- Design speed

Safety, environmental needs, and economy are built into various elements of design.

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Building Material and Construction

Dream is not that which you see while sleeping it is something that does not let you sleep.

A.P.J. Abdul Kalam

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Width	
Motor vehicle other than transport vehicle	2.5 m
Transport vehicle	2.7 m
Length	
Motor vehicle other than transport having not more than two axles	9.5 m
Transport vehicles with rigid frame with two or more axles	11.25 m
Articulated vehicle with more than two axles	16 m
Truck / trailer or tractor / trailer combination	18 m
Height	
Double decker buses	4.75 m
Other for normal application	3.8 m
Other for carrying ISO containers	4.2 m

Since there is large variation in the dimensions of different types of vehicle that use a road, it is necessary to specify certain "Design vehicles". A design vehicle is one whose dimensions and weight arc adopted for determining the elements of a highway design.

Functional Classification of Roads

In India non – urban roads are classified into the following classes:

Expressways

These are superior types facilities, generally with a divided carriageway, grade separations at cross – roads and fencing. The permit only fast vehicle.

National Highway (NH)

These are main highways running through the length and breadth of the country, connecting major parts, foreign highways and capitals of state of union territories and large industrial and tourist centers and including roads required for strategic movements for the defence of the country.

Sub – Arterial Streets

These are streets of lower order of mobility than arterial streets and are spaced at 0.5 km in highly developed areas and 3 – 5 km in urban fringes.

Collector Streets

These are intended for collecting and distribution traffic to and from local streets and feeding the arterial streets.

Local Streets

These are primarily intended for access to residence, business or abutting property.

Topography

The topography of the land, through which the road passes, also known as the terrain, control the geometric design. The following terrain types are identifying as control for in India.

S. No.	Terrain	Percentage Cross Slope of Country
1	Plain	0 – 10
2	Rolling	10 – 25
3	Mountainous	25 – 60
4	Steep	> 60

If cross slope is large, increase in radius of curvature of road will lead to increase in construction cost. Hence, design speed is reduced so that radius of curve reduces leading in reduction in cost of construction.

Design Speed

The maximum speed at which vehicles can continuously travel safely under condition is known as design speed. It may also be though of as the maximum approximate speed that will be adopted by most drivers. Choice of design speed has to be made carefully,

For urban streets the design speeds adopted in India (IRC) are given in table below,

Design speed for Urban road

Classification of roads	Design speed (km/h)
Arterial road	80
Sub-arterial road	60
Collector road	50
Local road	30

ELEMENTS OF GEOMETRICAL DESIGN

CROSS SECTIONAL ELEMENT

Pavement Characteristics

1. ***Friction***

Longitudinal or rolling friction

Rolling friction act in the direction of movement of vehicle or longitudinal direction. It supports movement of vehicle. It is generated as the resistive force to the traction force.

As per IRC 73 : 1980, $f_{longitudinal}$ = 0.35 – 0.4

Note:

- Coefficient of longitudinal friction depends upon speed of vehicle. As speed of vehicle increases the contact area between tyres and surface decreases. Hence coefficient of friction decreases.

$$f_{longitudinal} \propto \frac{1}{speed\ of\ vehicle}$$

- Smooth tyres offers higher friction factor then the new tyres on the dry pavement due to large area of contact, whereas on wet pavement condition is reversed because water act as lubricating agent.

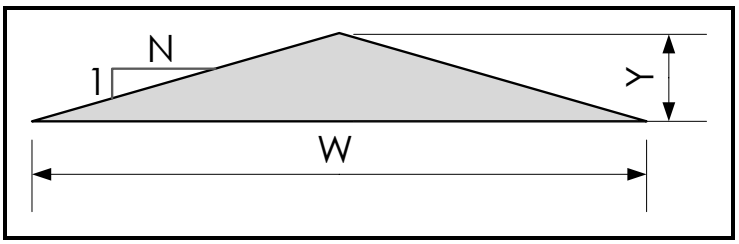
Lateral friction

Lateral friction comes in picture only when these lateral force on the vehicle.

As per IRC 73 : 1980, $f_{lateral} = 0.15$

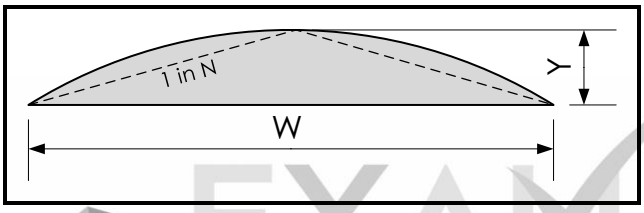
The following types of cambers are available,

a. Straight line camber



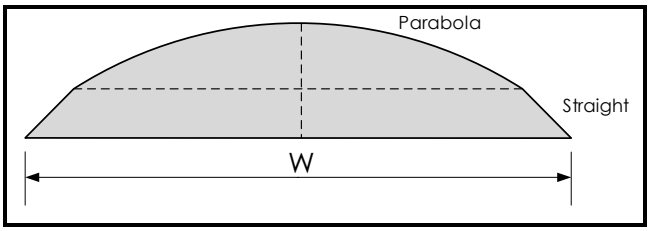
$$y = \frac{W}{2N}$$

b. Parabolic camber



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

c. Combination



Note

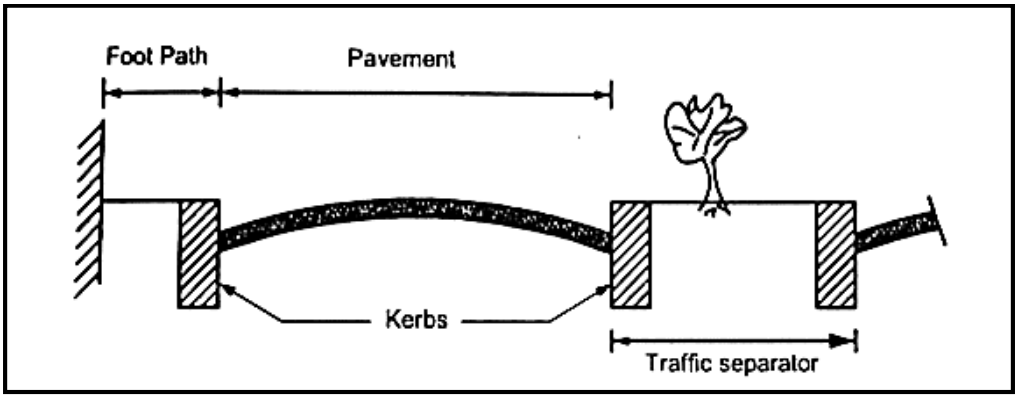
- Straight line chamber is preferred for cement concrete pavement because camber is very less and to provide less camber straight line camber is best profile.
- For high speed vehicle movement parabolic camber is preferred because central portion is flat.
- Combination camber is used generally for express highway

Generally, **Gradient = 2 x camber**

7. *Kerb*

The boundaries between pavement and shoulders or footpaths are known as **kerbs**.

The kerb may also be provided between the pavement and traffic separator.



Kerb and traffic separator

Functionally they could be of three types.

i. Low or mountable kerbs - Height 10 cm

- Vehice can cross it without any difficulty.

ii. Semi – barrier kerbs - Height 15 to 20 cm

- In emergency vehicles can climb over it.

iii. Barrier types kerbs - Height 23 to 45 cm

- Provided for hill roads.

- Maximum width of vehicle as per IRC is 2.44 m.
- As per IRC minimum width of traffic separator or median is 5.0 m for highway and 1.2 m for bridge.

8. *Divider*

It separates the road traffic moving in opposite direction so that chance of head on accident can be reduced. It also reduces the glare effect due to head light of

12. Control line (C.L)

At the locations like bank, hospital, factory, theatre etc, on the road, where more people gather disturbance to the traffic will be more.

The distance from the centre line of road to such building is called control line.

TYPE OF ROAD	FOR OPEN AREA	
	B.L.(m)	C.L.(m)
NH, SH	40	75
MDR	30	55
ODR	20	35
V.R.	12	24

13. Spoil Bank

The bank constructed from surplus excavated earth on the side of road cutting parallel to its alignment are known as spoil banks.

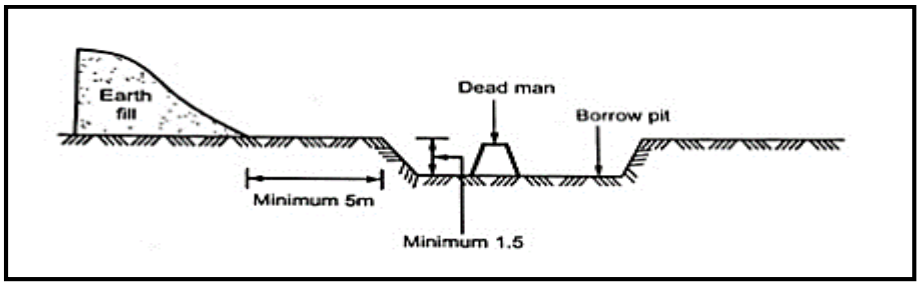
This soil from spoil bank can be used for the repair of shoulders.

14. Borrow Pit

The pits dug along the road alignment for using excavated earth in the construction of embankment are known as borrow pits.

Borrow pits should be dug at least 5 m from the toe of embankment.

The small portion of earth left undug in a borrow pit to measure the depth of excavation is known as deadman.



Assumption

1. Height of observation is 0.15 m.
2. Height of driver eye is 1.2 m
3. Break efficiency is 100%.

Lag distance

It is the distance travelled by the vehicle in reaction time.

$$L_g = Vt_r$$

$$= 0.278Vt_r$$

Where,

L_g = Lag distance (m)

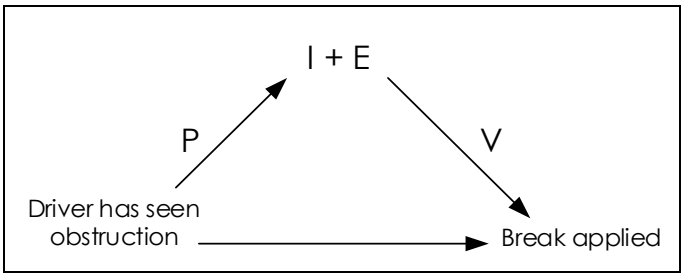
V = Speed of vehicle (km/hr)

t_r = Reaction time (sec.)

Reaction time

Reaction time is the total time taken by the driver for the application of break.

$$t_r = P + I + E + V$$



Where,

P = Perception (Time loss in perceiving any object)

I = Intellection (Time loss in understanding situation)

E = Emotion (Time loss due to anger or fear)

V = Volition (Time loss in final action i.e. application of brake)

New Batches are going to start.....

Contact:

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Test Series Available..

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Total test : 80

Total resisitive force = mg(f + S)

As we know,

$\Delta K.E.$ = work done

$$\frac{1}{2}mV^2 - 0 = L_B[mg(f+S)]$$

$$L_B = \frac{V^2}{2g(f+s)}$$

As per IRC,

$$L_B = \frac{(0.278V)^2}{2X9.81X(f+S)}$$

$$= \frac{V^2}{254(f+S)}$$

$$\boldsymbol{L_B = \frac{V^2}{254(f+S)}}$$

Case 2 : Vehicle moving down the gradient:

Gradient considered as negative,

$$\boldsymbol{L_B = \frac{V^2}{254(f-S)}}$$

Case 3 : Vehicle moving on flat road:

$$\boldsymbol{L_B = \frac{V^2}{254f}}$$

$$d_1 = V_B t_r$$

$$= 0.278 V_B t_r$$

$$\mathbf{d_1 = 0.278 V_B t_r}$$

As per IRC , t_r = 2 sec.

Distance d_2

In this distance vehicle A will overtake vehicle B safely against traffic of opposite direction.

$$d_2 = B + 2S$$

$$= V_B T + \frac{1}{2} a T^2 \text{ [where a = acceleration]}$$

Now,

$$B + 2S = V_B T + \frac{1}{2} a T^2$$

$$V_B T + 2S = V_B T + \frac{1}{2} a T^2$$

$$2S = \frac{1}{2} a T^2$$

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

$$\mathbf{T = \sqrt{\frac{4S}{a}}}$$

Where,

S = space headway

Space headway

The distance maintain between two consecutive vehicle travelling in same direction is known as space headway.

S = Gap + Length of vehicle

= (lag + breaking distance) + length of vehicle

HORIZONTAL ALIGNMENT

Horizontal alignment is one of the most important features influencing the efficiency and safety of a highway. A poor design will result in lower speeds and resultant reduction in highway performance in terms of safety and comfort. In addition, it may increase the cost of vehicle operation and lower the highway capacity. The horizontal alignment design elements include radius of circular curve, design of super elevation extra widening, horizontal curves, design of transition curve and set back distance.

Design Speed

The design speed is the single most important factor in the design of horizontal alignment. The design speed depends on the type of the road, type of terrain. Indian road congress (IRC) has classified the terrains into four categories namely plain, rolling, mountainous and steep based on the cross slope. The recommended design speed for various terrains and type of roads are given in the table below.

Terrain classification

Terrain	Cross Slope (%)
Plain	0 – 10
Rolling	10 – 25
Mountainous	25 – 60
Steep	> 60

Design speeds in India for rural highways

Road classification	Design speed km/h							
	Plain terrain		Rolling terrain		Mountainous terrain		Steep terrain	
	Ruling design speed	Minimum design speed	Ruling design speed	Minimum design speed	Ruling design speed	Minimum design speed	Ruling design speed	Minimum design speed
National and State highway	100	80	80	65	50	10	40	30
Major district roads	80	65	65	50	40	30	30	30
Other district roads	65	50	50	40	30	25	25	20

Case 1 : To avoid overturning of vehicle

$$M_o < M_R$$

$$P \times h < w \times \frac{b}{2}$$

$$\mathbf{I = \frac{P}{W} < \frac{b}{2h}}$$

Case 2 : Unsafe condition

$$M_o > M_R$$

$$P \times h > w \times \frac{b}{2}$$

$$\mathbf{I = \frac{P}{W} > \frac{b}{2h}}$$

Case 3 : On the verge of overturning

$$M_o = M_R$$

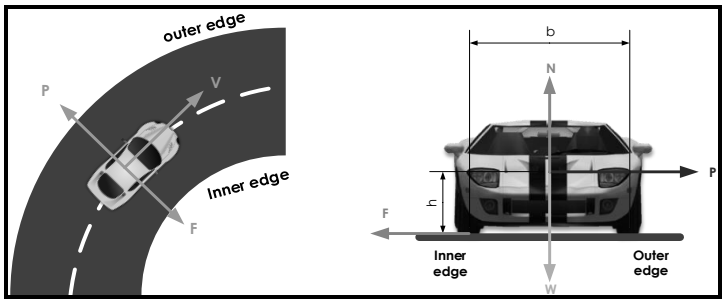
$$P \times h = w \times \frac{b}{2}$$

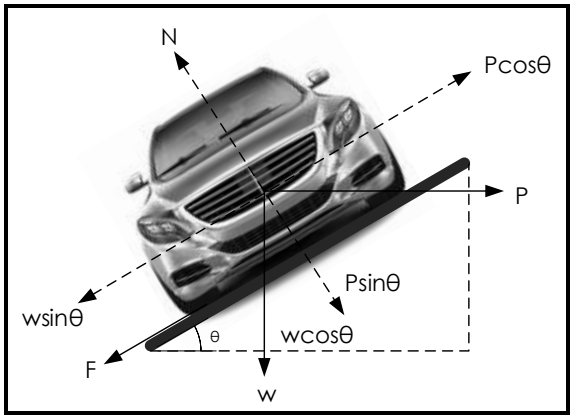
$$\mathbf{I = \frac{P}{W} = \frac{b}{2h}}$$

Note

- If there is no super elevation on horizontal curve then for a vehicle negotiating the horizontal curve, pressure at outer wheels is more than pressure at inner wheel.
- At the time of overturning (Case – 1 & case – 3) total pressure is carried by outer wheel only because inner wheel just lost the contact with road surface ($R_{inner} \approx 0$).
- Due to increase of pressure on outer wheel, it more pressure on outer edges of pavement due to which consolidation occurs at one or more than one layer of pavement which is called as " ruts".

Lateral Skidding





Normal reaction, N = wcos$\theta + Psin\theta$

Frictional force, F = fN = f (wcos$\theta + Psin\theta$)

Total resistive force = wsinθ + F

$$= \text{wsin } \theta + \text{f (cos } \theta + Psin\theta)$$

Balancing force along slope

$$\text{Pcos } \theta = \text{wsin } \theta + \text{f (wcos } \theta + Psin\theta)$$

$$\text{P} = \text{wtan } \theta + fw + fPtan\theta$$

$$\text{P} = \text{we} + \text{fw} + \text{fpe [tan } \theta = \text{e (super elevation)]}$$

$$\text{P(1- ef)} = \text{w(e + f)}$$

$$\frac{P}{w} = \frac{e+f}{1-ef}$$

$$\frac{\frac{mv^2}{R}}{mg} = \frac{e+f}{1-ef}$$

$$\frac{v^2}{Rg} = \frac{e+f}{1-ef}$$

$$\frac{v^2}{Rg} = e + f [\because ef \ll 1, \therefore (1-ef) \approx 1]$$

$$\text{e + f} = \frac{(0.278V)^2}{R \times 9.81}$$

$$\text{e + f} = \frac{V^2}{126.93R}$$

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

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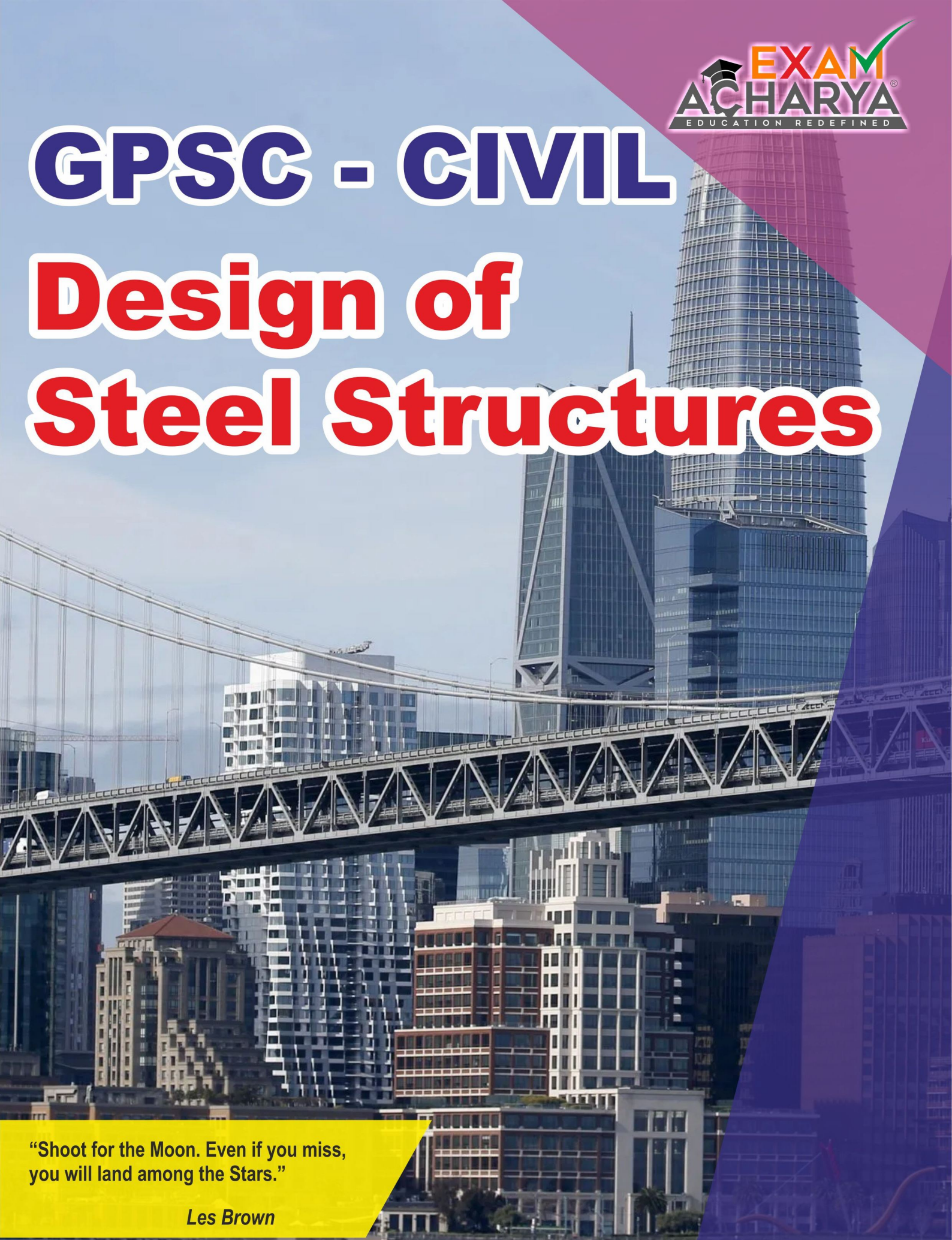
Design of Steel Structures



"Shoot for the Moon. Even if you miss, you will land among the Stars."

Les Brown

The content of this book covers all PSC exam syllabus such as MPSC, RPSC, UPPSC, MPPSC, OPSC etc.

Step 2: if e > e_{max} provide e = e_{max} and check 'f ' for 100% design speed.

$$f = \frac{V^2}{127R} - e_{max} \leq 0.15$$

If f > 0.15 then move to step 3.

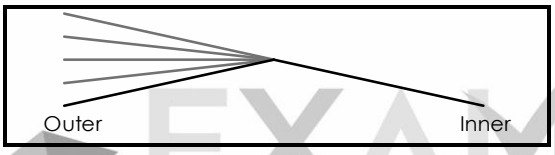
Step 3: if f > 0.15 Restrict speed.

Maximum speed limit , $V_{max} = \sqrt{127R(e_{max} + 0.15)}$

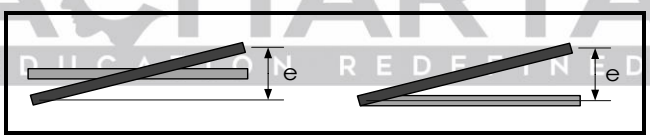
Ruling min radius, $R_{ruling} = \frac{V^2}{127(e_{max}+0.15)}$

Alignment of Super Elevation

i. Elimination of the crown of the cambered section.



ii. Rotation of pavement to attain full super elevation.



EXTRA WIDENING

Increased in width of pavement by increasing the lane is called widening. This is done just to resolve the problem of increase in traffic volume.

PURPOSE OF EXTRA WIDENING

i. To account off tracking due to rigidity of wheel base.

ii. To encounter psychological tendency of driver negotiating the curve.

iii. To account lateral skidding.

iv. To increase visibility at curve.

Psychological Widening (W_P)

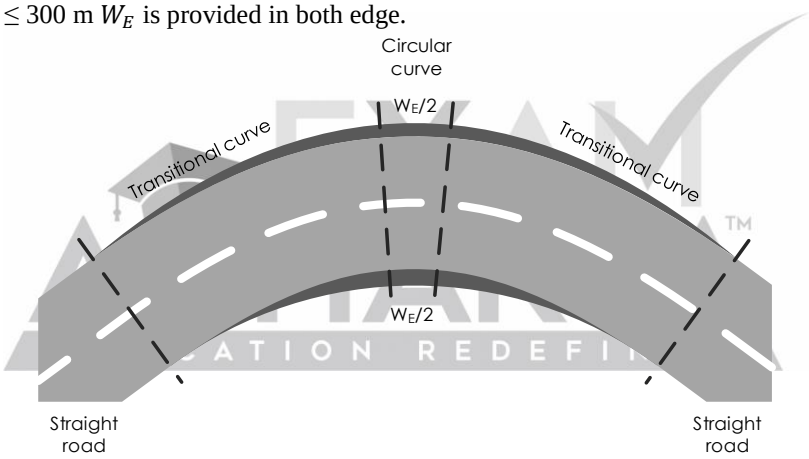
There is tendency for vehicle close to the edge of pavement on curve and maintain more side gap between another vehicle. The empirical equation is.

$$W_P = \frac{V}{9.5\sqrt{R}}$$

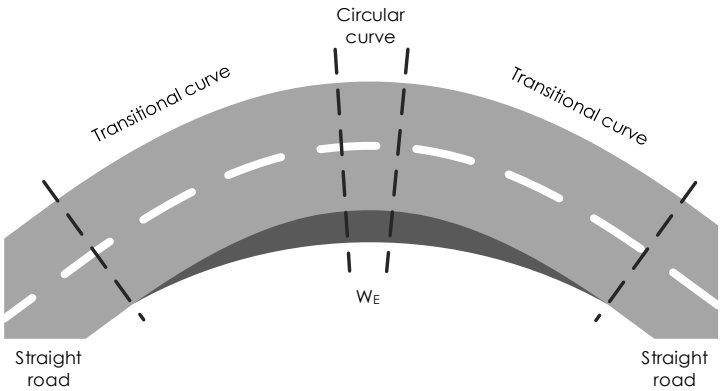
∴Total extra widening , $W_E = W_M + W_P$

$$W_E = \frac{nl^2}{2R} + \frac{V}{9.5\sqrt{R}}$$

Note:
As per IRC
For single lane road, $W_P = 0$
If R > 300 m, $W_E = 0$
If 50 m ≤ R ≤ 300 m W_E is provided in both edge.



If R < 50 m, W_E is provided in inner edge.



Nature of Transition Curve

1. Spiral
2. Cubic parabola
3. Clothoid
4. Lemniscate

Note

- The rate of change of acceleration is not constant in Clothoid and Lemniscate transition curve.
- IRC recommends spiral nature transition curve for horizontal alignment and cubic parabola for vertical alignment (valley curve only)

For a spiral transition curve.

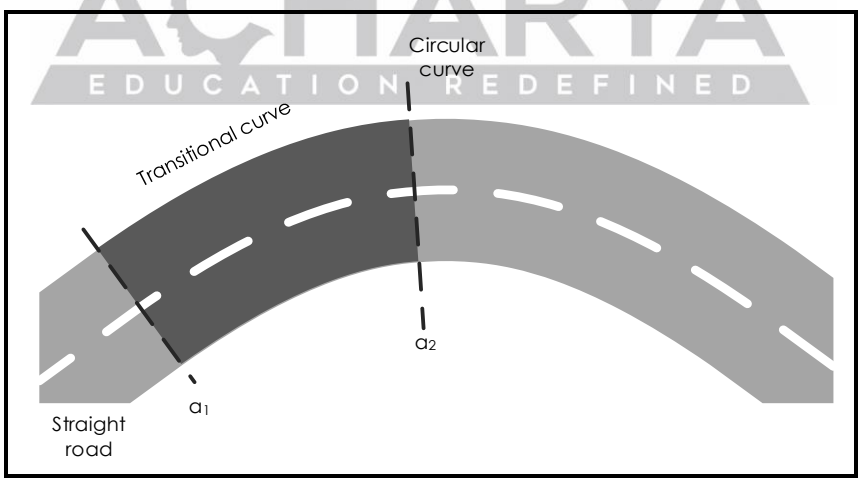
a. Rate of change of centrifugal acceleration is constant

b. Length of transition curve is inversely proportional to the radius of curve. $L_R \propto \frac{1}{R}$.

Length of Transition Curve

Length of transition curve should be determined as maximum of following three criteria.

Criteria 1 : As per rate of change of centrifugal acceleration

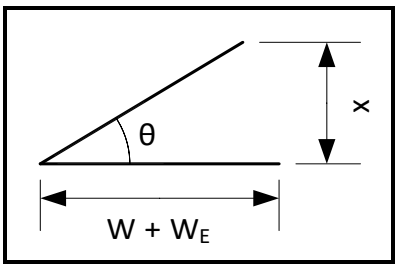


$$P = ma = \frac{mv^2}{R}$$

$$\therefore a = \frac{V^2}{R}$$

$$\therefore \text{Initial acceleration} = \frac{V^2}{R} = \frac{V^2}{\infty} = 0$$

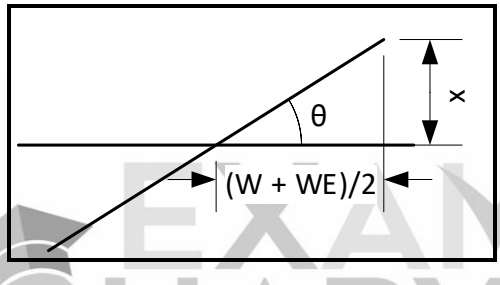
If rotation is about inner edge.



$$\therefore tan\theta = \frac{X}{W + W_E}$$

$$X = e(W+W_E)[\therefore tan\theta = e]$$

If rotation is about centre of the road.



$$\therefore tan\theta = \frac{X}{\frac{(W + W_E)}{2}}$$

$$X = \frac{e(W+W_E)}{2}[\therefore tan\theta = e]$$

Note

- As per IRC rate of introduction of super elevation is1 in 150 for plane and rolling terrain and 1 in 60 for mountainous terrain.

Criteria 3: As per IRC minimum length of transition curve

$$L_T = \frac{2.7V^2}{R}$$ **(**for plain and rolling **t**errain)

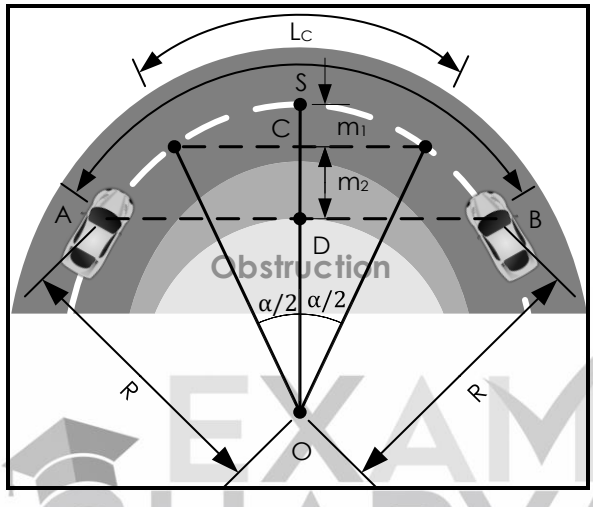
$$= \frac{V^2}{R}$$ (for mountainous terrain)

for $\frac{\alpha}{2}$

$$\frac{\alpha}{360} = \frac{S}{2\pi R}$$

$$\frac{\alpha}{2} = \frac{180 \cdot S}{2\pi R}$$

Length of curve is less than sight distance (SSD or OSD or ISD)

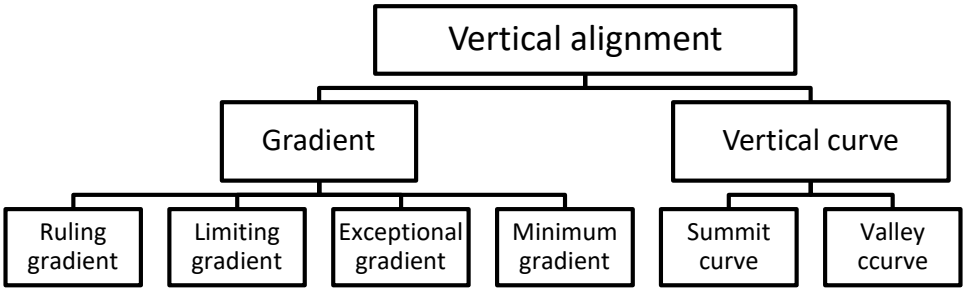


Set back distance (m)

$$m = m_1 + m_2$$

$$\mathbf{m = R(1 - \cos\frac{\alpha}{2}) + [\frac{(S - L_C)}{2} X \sin\frac{\alpha}{2})}$$

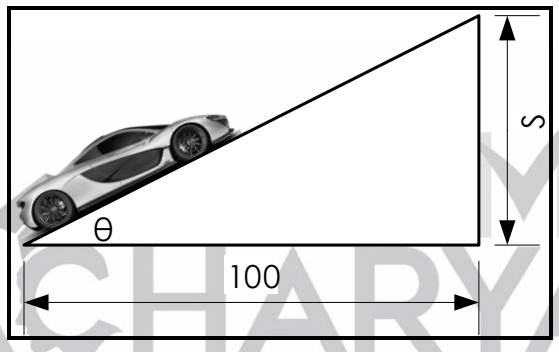
VERTICAL ALIGNMENT



Gradient

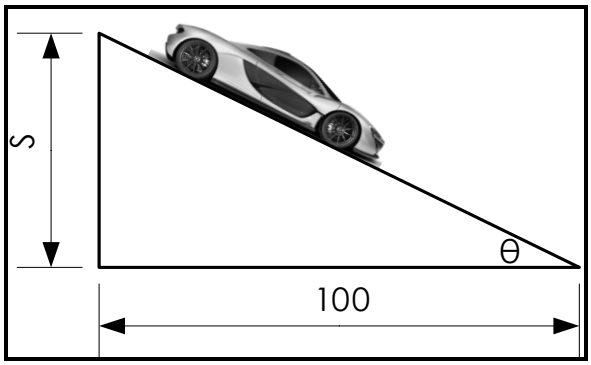
Gradient is the rise or fall of road along longitudinal direction.

a. Rising or ascending or positive gradient:



$$\text{Gradient} = \tan\theta = \frac{S}{100} = S\%$$

b. Falling or descending or negative gradient:



$$\text{Gradient} = \tan\theta = \frac{S}{100} = S\%$$

Note
- At higher elevation lesser gradient is provided because availability of oxygen is less due to which less fuel bum and it reduces the pulling power of vehicle.

Grade Compensation

When there is horizontal curve is additional to the gradient there will be increased in resistance to tractive force due to curve and gradient. In this case IRC suggested to compensate the grade so that, pulling power of vehicle should not be compromised.

Grade compensation = $\frac{30+R}{R}$%

Maximum grade compensation =$\frac{75}{R}$%

Compensated gradient = Gradient – grade compensate

Grade compensate is the minimum between grade compensation and maximum grade compensation.

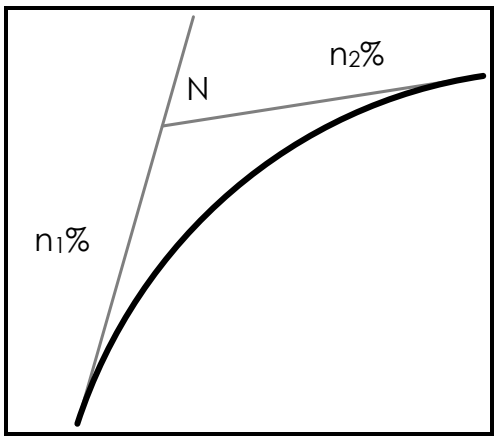
Note
- As per IRC grade compensation is not required for gradient flatter than 4% and compensated gradient should not be less than 4%.

CURVE

Summit Curve

Summit curve are vertical curve with convexity upward and concavity downward. It is formed by two gradient in following ways.

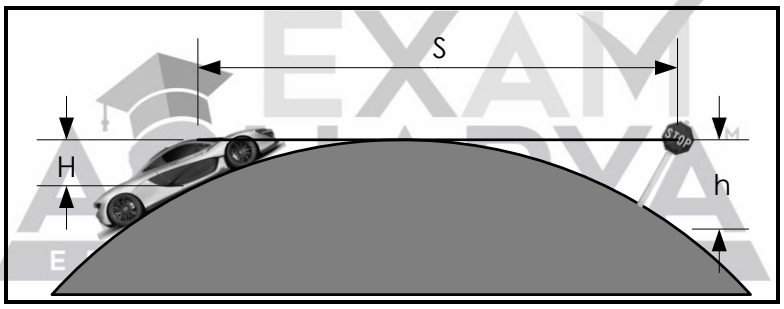
a. When an Ascending Gradient Meet Another Ascending Gradient



Properties of Summit Curve

1. Convexity upward and concavity downward.
2. Vertical point of intersection always lie above the curve.
3. Square parabola is generally preferred for summit curve due to best riding quality and simplicity of calculation.
4. Ideal shape for summit curve is circular because sight distance available throughout the curve is constant
5. Summit curve is design only for sight distance criteria (SSD or OSD or ISD)
6. Generally there is no problem of discomfort because weight acts in downward direction and centrifugal force act in upward direction. A apart of pressure on tyre and spring of vehicle get released.

Length of Summit Curve



Case 1: when L_S > SD.

Length of summit curve, $L_S = \frac{NS^2}{2(\sqrt{H}+\sqrt{h})^2}$

Where,

H = height of driver eyes

h = height of obstruction

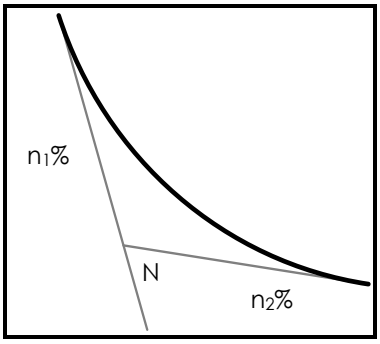
N = change in gradient

S = Sight distance

Valley Curve

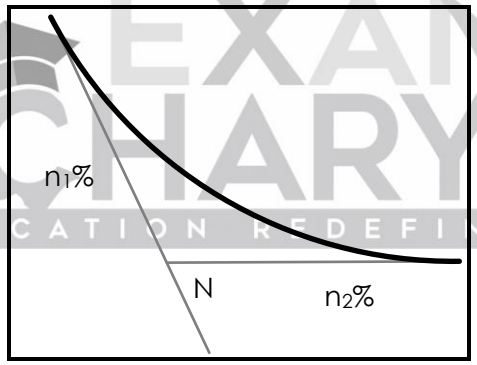
Valley curve are vertical curve with concavity upward and convexity downward. Valley curve are found by two gradients in following ways.

A. When a Descending Gradient Meet Another Descending Gradient



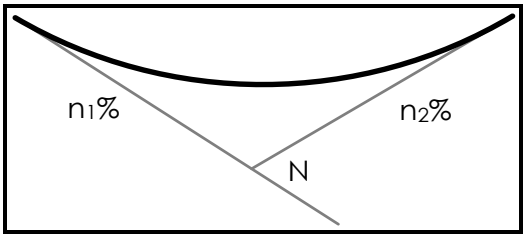
$$N = |n_2 - n_1|$$

b. When a Descending Meet Flat Gradient



$$N = n_1$$

c. When a Descending Meet an Ascending Gradient



$$N = |n_2 + n_1|$$

Length of Valley Curve

Length of valley curve is a designed on the basis of two criteria.

Criteria 1: on the basis of HSD

Case 1 : when Lv > HSD

$$L_v = \frac{NS^2}{2h + 2Stan\beta}$$

N = change in gradient

h = height of head light

S = HSD (≈ SSD)

β = Beam angle.

As per IRC, h = 0.75 m, β= 1°

$$\mathbf{L_v = \frac{NS^2}{1.5+0.035\,S}}$$

Case 2: when L_v < HSD.

$$L_v = 2S - \frac{2h + 2\,S\,tan\beta}{N}$$

Where

N = change in gradient

h = height of head light

S = HSD (≈ SSD)

β = Beam angle.

As per IRC, h = 0.75 m, β= 1°.

$$\boldsymbol{L_v = 2S - \frac{1.5+0.035S}{N}}$$

CLEAR YOUR CONCEPT

Qu1 The most raised portion of the pavement is called

a) Super elevation

b) Camber

c) Crown

d) Kerb

Qu2 Transition curve is introduced in

a) Horizontal curve

b) Circular curve

c) Between horizontal curve and circular curve

d) Vertical curve

Qu3 The main purpose of providing camber is

a) To collect storm water

b) To maintain equilibrium

c) To follow IRC specifications

d) To follow geometric specifications

Qu4 The extra width of pavement is provided on

a) Horizontal curve

b) Width of pavement

c) Length of pavement

d) Super elevation

CHAPTER – 3

HIGHWAY MATERIAL

SUB GRADE SOIL

Soil is an accumulation or deposit of earth material, derived naturally from the disintegration of rocks or decay of vegetation that can be excavated readily with power equipment in the field or disintegrated by gentle mechanical means in the laboratory. The supporting soil beneath pavement and its special under courses is called sub grade. Compacted sub grade is the soil compacted by controlled movement of heavy compactors.

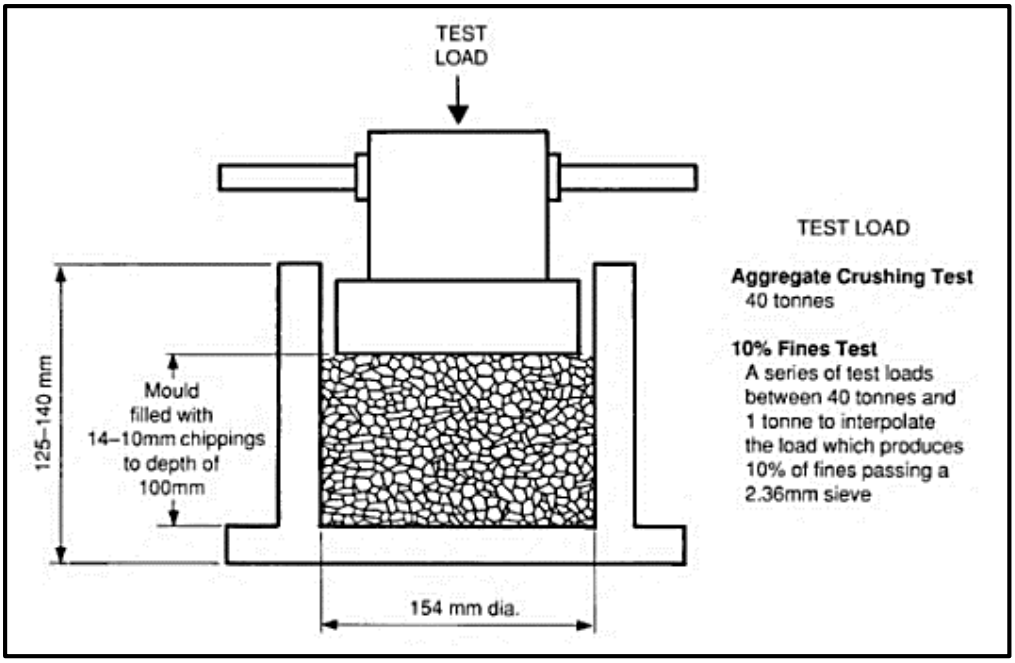
Desirable Properties of Sub Grade Soil

i. Stability
ii. Incompressibility
iii. Permanency of strength
iv. Minimum changes in volume and stability under adverse conditions of weather and ground water
v. Good drainage
vi. Ease of compaction.

EVALUATION OF SOIL STRENGTH

Shear Test

Shear test are usually carried out on relatively small soil samples in the laboratory. In order to find out the strength properties of soil, a number of representative samples from different locations are tested. Some of the commonly known shear tests are direct shear test, triaxial compression test and unconfined compression test.



Objective

i. Determine the aggregate crushing value of coarse aggregate.

ii. Assess suitability of coarse aggregates for use in different types of road.

Apparatus

i. A steel cylinder 15 cm diameter with plunger and base plate.

ii. A straight metal tamping rod 16 mm diameter and 45 to 60 cm long rounded at one end.

iii. A balance of capacity 3 kg readable an accurate to one gram.

iv. IS sieves of sizes 12.5 mm, 10mm and 2.36 mm.

v. A compression testing machine.

vi. Cylindrical metal measure of sufficient rigidity to retain its from under rough usage and of 11.5 cm diameter and 18 cm height.

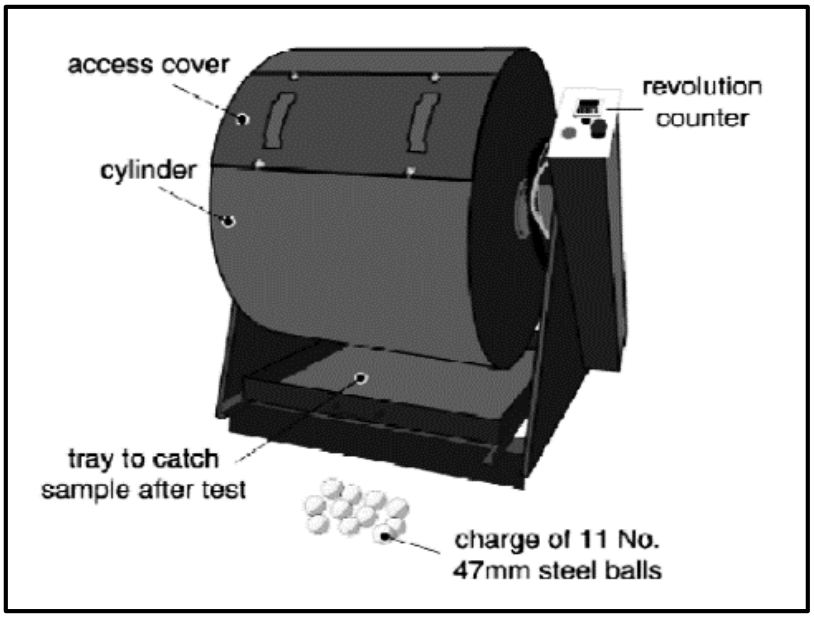
vii. Dial gauge.

Crushing test value for different types of pavement

Pavement type	Aggregate crushing value limit
Flexible pavement	
Soling	50
Water bound macadam	40
Bituminous macadam	40
Bituminous surface dressing or thin premix carpet	30
Dense mix carpet	30
Rigid pavement	
Other than wearing course	45
Surface or wearing course	30

Abrasion Test

Abrasion test is carried out to test the hardness property of aggregates and to decide whether they are suitable for different pavement construction works. The principal of Los Angeles abrasion test is to find the percentage wear due to relative rubbing action between the aggregate and steel balls used as abrasive charge.



New Batches are going to start.....

Contact:

7622050066

Test Series Available..

Total weekly test : 35

Total mid subject test : 16

Total full length test : 13

Mock test : 16

Total test : 80

Procedure of Los Angeles Abrasion test:

i. The test sample shall consist of clean aggregate which has been dried in an oven at 105 to 110˚C to substantially constant weight (A) and shall conform to one of the gradings. The grading or gradings used shall be those most nearly representing the aggregate furnished for the work.

ii. The test sample and the abrasive charge shall be placed in the Los Angeles abrasion testing machine and the machine rotated at a speed of 20 to 33 rev/min. for gradings A, B, C and D the machine shall be rotated for 500 revolutions for gradings E, F and G, it shall be rotated for 1000 revolutions as mentioned in table.

Grading	Number of Spheres	Weight of Charge (gm)
A	12	5000 ± 25
B	11	4584 ± 25
C	8	3330 ± 20
D	6	2500 ± 15
E	12	5000 ± 25
F	12	5000 ± 25
G	12	5000 ± 25

iii. The machine shall be so driven and so counter – balanced as to maintain a substantially uniform peripheral speed. If an angle it used as the shelf, the machine shall be rotated in such a directed that the charge is caught on outside surface of the angle.

iv. At the completion of the test the material shall be discharged from the machine and a preliminary separation of the sample made on a sieve coarser than the 1.70 mm IS sieve.

v. The material coarser than the 1.70 mm IS sieve shall be washed dried in an oven at 105 to 110˚C to a substantially constant weight and accurately weighted to the nearest gram (B).

Apparatus

i. **Balance:** It should be accurate up to 1 gm

ii. Sieve: Sieves required are 12.5, 10 and 2.36 mm

iii. Impact testing machine: weight of hammer is 13.5 – 14 kg and height of fall is 380 $\pm$ 5mm

Procedure

i. The test sample shall consist of aggregate the whole of which passes a 12.5 mm IS sieve and its retained on a 10 mm IS sieve. The aggregate comprising the test sample shall be dried in an oven for a period of 4 hours at a temperature of 100 to 110˚C and cooled.

ii. The measure shall be filled about one – third with the aggregate and temped with 25stokes of the rounded end of the tamping rod. Further similar quantity of aggregate shall be added and a further tamping of 25 strokes given. The measure shall finally be filled to overflowing, tamped 25 times and the surplus aggregate struck off using the tamping rod as a straight edge. The net weight of aggregate in the measure shall be determined to the nearest gram (weight A).

iii. The impact machine shall rest without wedging or packing upon the level plate, block or floor so that it is rigid and the hammer guide columns are vertical.

iv. The cups shall be fixed firmly in position on the base of the machine and the whole of the test sample placed in it and compacted by a single tamping of 25 strokes of the tamping rod.

v. The hammer shall be raised until its lower face is 380 mm above the upper surface of the aggregate in the cup and allowed to fall freely on to the aggregate. The test sample shall be subjected to a total of 15 such blows each being delivered at an interval of not less than one second.

vi. The crushed aggregate shall then be removed from the cup and the whole of its sieved on the 2.36 mm IS sieve until no further significant amount

Theory of Flakiness Index and Elongation Index Tests


VC: HIGHWAY GUIDE

The particle shape of aggregates is determined by the percentages of flaky and elongated particle contained in it. For base course and construction of bituminous and cement concrete types the presence of flaky and elongated particles are considered undesirable as these cause inherent weakness with possibilities of breaking down under heavy loads. Thus evaluation of shape of the particles, particularly with reference to flakiness and elongation is necessary. The flakiness index of aggregates is the percentage by weight of particles whose least dimension (thickness) is less then three – fifths (0.6times) of their mean dimension. This test is not applicable to sizes smaller than 6.3 mm. the elongation index of an aggregate is the percentage by weight of particles whose greatest dimension (length) is greater than nine – fifths (1.8 times) their mean dimension. This test is not applicable for sizes smaller than 6.3 mm.

Procedure of Shape Tests on Coarse Aggregate

i. Sieve the sample through the IS sieves (as specified in the table)

ii. Take a minimum of 200 pieces of each fraction to be tested and weight them.

iii. To separate the flaky materials, gauge each fraction for thickness on a thickness gauge. The width of the slot used should be of the dimensions specified in column (4) of the table for the appropriate size of the material.

iv. Weight the flaky material passing the gauge to an accuracy of at least 0.1 percent of the test sample.

v. To separate the elongated materials, gauge each fraction for length on a length gauge the width of the slot used should be of the dimensions specified in column (6) of the table for the appropriate size of the material.

vi. Weight the elongated material retained on the gauge to an accuracy of at least 0.1 percent of the test sample.

Soundness Test

Soundness test is intended to study the resistance of aggregates to weathering action, by conducting accelerated weathering test cycles, the porous aggregates subjected to freezing and thawing are likely to disintegrate prematurely. To ascertain the durability of such aggregates, they are subjected to an accelerated soundness test as specified in IS: 2386 part V. Aggregate of specified size are subjected to cycles of alternate wetting in a saturated solution of either sodium sulphate or magnesium suphate for 16 - 18 hours and then dried in oven at 105 - 110˚C to a constant weight. After five cycles, the loss in weight of aggregates is determined by sieving out all under sized particles and weighing and the loss in weight should not exceed 12 percent when tested with sodium sulphate and 18 percent with magnesium sulphate solution.

Specific Gravity of Aggregate

Objective

Specific gravity is defined as the ratio of Weight of Aggregate to the weight of equal volume of water. The specific gravity of an aggregate is considered to be a measure of strength or quality of the material. Aggregates having low specific gravity are generally weaker than those with high specific gravity. This property helps in a general identification of aggregates.

Apparatus required

i. Wire mesh bucket: wire basket of not more than 6.3mm mesh or a perforated container of convenient size with thin wire hangers for suspending it from the balance.

ii. Setup of specific gravity test (>6.3mm): The setup consists of container for filing water or suspending the wire basket in it and an airtight container of capacity similar to that a basket, a shallow tray and two dry absorbent clothes.

iii. Pycnometer: pycnometer of 1000 ml for aggregates finer than 6.3 mm.

GPSC - CIVIL

Construction, Planning and Management

"All Birds find shelter during a rain.
But Eagle avoids rain by flying above
the Clouds."

A.P.J. Abdul Kalam

The content of this book covers all PSC exam syllabus such as MPSC, RPSC, UPPSC, MPPSC, OPSC etc.

6. The contests of the pycnomeer are discharged and it is cleaned.
7. Water is filled up to the top of the pycnometer without any entrapped air it is then weighed.
8. For mineral filler, specific gravity bottleis used and the material is filled up to one – third of the capacity of bottle. The rest of the process of determining specific gravity is similar to the one described for aggregate finer than 6.3 mm.

Observation and Recording

Observation table for specific gravity of aggregate coarser than 6.3mm.

Description	Observed values
Weight of saturated aggregate and basket in water (W_1 g)	
Weight of basket in water (W_2 g)	
Weight of saturated aggregates in air (W_3 g)	
Weight of oven dry aggregates in air (W_4 g)	
Apparent specific gravity $\frac{W_4}{[W_4-(W_1-W_2)]}$	
Bulk specific gravity $\frac{W_4}{[W_3-(W_1-W_2)]}$	

Observation table for specific gravity of aggregate finer than 6.3 mm.

Description	Observed values
Weight of pycnometer in water (W_1 g)	
Weight of aggregate and pycnometer (W_2 g)	
Weight of aggregates, pycnometer, and water (W_3 g)	
Weight of water and pycnometer in air (W_4 g)	
Apparent specific gravity $\frac{W_2-W_1}{[(W_4-W_1)-(W_3-W_2)]}$	

7. The aggregate is placed in a shallow tray and heated to 100ºC - 110ºC in the oven for 24 ± 0.5 hours. Later, it is cooled in an air tight container and weighed.

Calculation

If weight of saturated aggregates in air = W_1 g

Weight of oven dry aggregates in air = W_2 g

$$\textbf{Water absorption (\%)} = \frac{(W_1 - W_2)X100}{W_2}$$

BITUMINOUS MATERIAL

Bituminous materials are widely used in a road construction and maintenance, after gaining experience from their use in obtaining smooth riding surface. Bituminous mixtures are being used as structural layers. These materials are considered to be flexible from structural point of view.

DESIRABLE PROPERTIES OF BITUMEN

Bitumen should have good affinity to aggregates. Bitumen should be fluid enough to coat all particles of the aggregates in a premix process. This is achieved by heating the bitumen and the aggregates too. In spraying work, bitumen should be susceptible of being sprayed to a thin film. This is achieved either by heating it or by fluxing it or by emulsifying it, when the binder cools down to atmospheric temperature it should harden to hold the aggregates together. Its susceptibility to change its viscosity when temperature varies should be low. In particular, its viscosity characteristics should be reasonably constant within the range of temperatures the road experiences. The bitumen should retain its properties over a long period. In other words, it should be durable binder and should not lose its properties too soon.

Bitumen Emulsion

Bitumen emulsion is a liquid product in which bitumen is suspended in a finely divided condition in an aqueous medium and stabilized by suitable material. Normally cationic type emulsions are used in India. The bitumen content in the emulsion is around 60 and the remaining is water. When the emulsion is applied on the road it breaks down resulting in release of water and the mix starts to set. The time of settings is depends upon the grade of bitumen. The viscosity of bituminous emulsions can be measured as per IS : 8887 – 1995. Three types of bituminous emulsions are available, which are Rapid Setting (RS), Medium Setting (MS) and Slow Setting (SS). Bitumen emulsions are ideal binders for hill road construction, where heating of bitumen or aggregates are difficult. Rapid setting emulsions are used for surface dressing work. Medium setting emulsions are preferred for premix jobs and patch repairs work. Slow setting emulsions are preferred in rainy season.

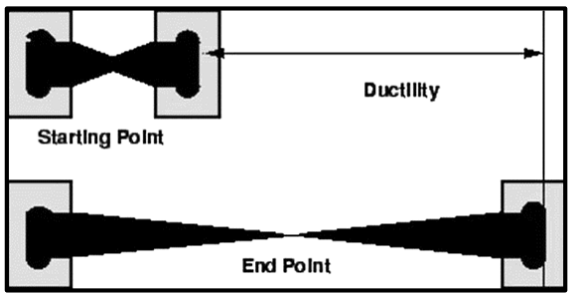
Bituminous Primers

In bituminous primer the distillate is absorbed by the road surface on which it is spread. The absorption therefore depends on the porosity of the surface. Bitumen primers are useful on the stabilized surfaces and water bound macadam base courses. Bituminous primers are generally prepared on road sites by mixing penetration bitumen with petroleum distillate.

Modified Bitumen

Certain additives or blend of additives called as bitumen modifiers can improve properties of bitumen and bituminous mixes. Bitumen treated with these modifiers is known as modified bitumen. Polymer modifies bitumen (PMB)/ crumb rubber modified bitumen (CRMB) should be used only in wearing course depending upon the requirements of extreme climatic variations. The detailed specifications for modified bitumen have been issued by IRC SP 53 : 1999. It must be noted that the performance of PMB and CRMB is dependent on strict control on temperature during construction.

DUCTILITY TEST



Ductility is the property of bitumen that permits it to undergo great deformation or elongation. Ductility is defined as the distance in cm to which a standard sample or briquette of the material will be elongated without breaking. Dimension of the briquette thus formed is exactly 1 cm square. The bitumen sample is heated and poured in the mould assembly placed on a plate. These samples with molds are cooled in the air and then in water bath at 27˚C temperature. The excess bitumen is cut, and the surface is leveled using a hot knife. Then the mold with assembly containing sample is kept in water bath of the ductility machine for about 90 minutes. The sides of the moulds are removed, the clips are hooked on the machine and the machine is operated. The distance up to the point of breaking of thread is the ductility value which is reported in cm. The ductility value gets affected by factors such as pouring temperature, test temperature, rate of pulling etc. A minimum ductility value of 75 cm has been specified by the BIS, figure shows ductility molds to be filled with bitumen.

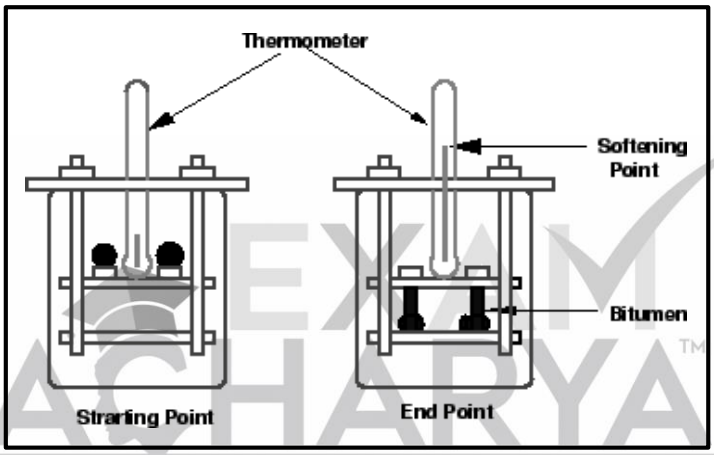
VISCOSITY TEST

Viscosity denotes the fluid property of bituminous material and it is a measure of resistance to flow. At the application temperature, this characteristic greatly influences the strength of resulting paving mixes. Low or high viscosity during compaction or mixing has been observed to result in lower stability values. At high viscosity, it resist the compactive effort and thereby resulting mix is heterogeneous, hence low stability values. And at low viscosity instead of providing a uniform film over aggregates, it will lubricate the aggregate particles. Orifice type viscometers are used to indirectly find the viscosity of liquid binders like cutbacks and emulsions. The viscosity expressed in seconds is the time taken by the 50 ml bitumen material to pass through the orifice of a

SOFTENING POINT TEST

VC: HIGHWAY GUIDE

Softening point denotes the temperature at which the bitumen attains a particular degree of softening under the specifications of test. The test is conducted by using Ring and Ball apparatus. A brass ring containing test sample of bitumen is suspended in liquid like water or glycerin at a given temperature. A steel ball is placed upon the bitumen sample and the liquid medium is heated at a rate of 5˚C per minute. Temperature is noted when the softened bitumen touches the metal plate which it at a specified distance below. Generally, higher softening point indicates lower temperature susceptibility and is preferred in hot climates. Figure shows softening point test setup.



FLASH AND FIRE POINT TEST

At high temperatures depending upon the grades of bitumen materials leave out volatiles and these volatiles catches fire which is very hazardous and therefore it is essential to qualify this temperature for each bitumen grade. BIS defined the flash point as the temperature at which the vapor of bitumen momentarily catches fire in the form of flash under specified test conditions. The fire point is defined as the lowest temperature under specified test condition at which the bituminous material gets ignited and burns.

G_2 = Apparent specific gravity of fine aggregate

G_3 = Apparent specific gravity of filler aggregate

G_4 = Apparent specific gravity of bitumen. (i.e G_b)

$$G_m = \frac{W_m}{W_m - W_w}$$

Where,

W_m = weight of specimen in air

W_W = weight of specimen in water

$W_m - W_w$ = Volume of specimen

- Used for design of hot paving mix with maximum aggregate size 25 mm
- Stability value = maximum load carried by specimen at standard temp. of 60˚C.
- Deformation is measured in units of 0.25 mm.

Percentage Voids in Mineral Aggregate (VMA)

Benkelman Beam Test

- Flexible overlay on flexible pavement
- Overlay design
- Sample is compacted by 50 blows.

$$\mathbf{VMA = V_V + V_b}$$

Where

V_V = volume of air voids %

V_b = volume of bitumen %

Vb = volume of bitumen %

It is the % of volume of bitumen to the total volume of specimen.

The optimum bitumen content (OBC) for the mix design is found by taking the average value of the following three bitumen contents found from the graphs of the test results.

i. Bitumen content corresponding to maximum stability
ii. Bitumen content corresponding to maximum unit weight.
iii. Bitumen content corresponding to median of designed limits of percentage air voids in total mix (4%).

Marshall mix design criteria are given below:

Test Property	Specified Value
Marshall Stability, kg	340 (minimum)
Flow value, 0.25 mm units	8 to 17
Air voids in total mix, %	3 to 5
Voids filled with bitumen, VFB%	75 to 85

Mixes with very high values of Marshall stability and low flow values are not desirable as the pavements constructed with such mixes are likely to develop crackes due to heavy moving loads.

Loss on Heating Test

When the bitumen is heated it looses the volatility and gets hardened. About 50 gm of the sample is weighed and heated to a temperature of 163˚C for 5 hours in a specified oven designed for this test. The sample specimen is weighted again after the heating period and loss in weight is expressed as percentage by weight of the original sample. Bitumen used in pavement mixes should not indicate more than 1% loss in weight, but for bitumen having penetration values 150 – 200 up to 2% loss in weight is allowed.

Water Content Test

It is desirable that the bitumen contains minimum water content to prevent foaming of the bitumen when it is heated about the boiling point of water. The water in a bitumen is determined by mixing known weight of specimen in a pure petroleum distillate free

CLEAR YOUR CONCEPT

Qu1 The highest CBR number is required for

a) Pavement

b) Sub grade

c) Sub base

d) Base

Qu2 What is the most common waste material used in construction?

a) Fly ash

b) Slag

c) Pozzolona

d) Rice husk

Qu3 Which bitumen does not need heating?

a) Paving grade

b) Cut back

c) Modified

d) Bitumen emulsion

Qu4 The specified method for bitumen mix in India is

a) Hveem

b) Marshalls method

c) Hubbard method

d) Super paver mix method

Qu5 Marshall stability determines

a) Ductility

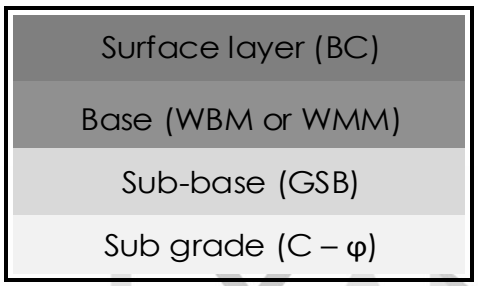
CHAPTER – 4

PAVEMENT DESIGN

TYPES OF PAVEMENT

A pavement is the load bearing and load distribution component of a road. Pavement can be classified as:

a. Flexible Pavement



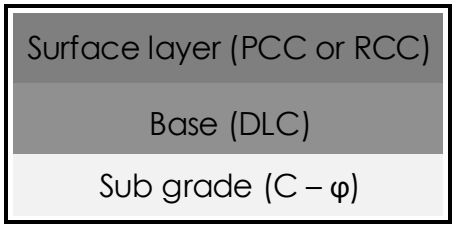
A flexible pavement is one that is made up of one or more layers of materials the highest quality material forming the top layer.

Loads are transmitted through the layers, care being taken to ensure that stress in each layer are within the permissible values and the stress on the sub – grade is within its bearing power.

The load carrying capacity of the flexible pavement is derived from the load distribution property and not form its flexural or bending strength.

The flexible pavement layers reflect the deformation of the lower layer. Thus, if the lower layer of the pavement of soil sub grade is undulated, the flexible pavement surface also gets undulated.

b. Rigid Pavement



A rigid pavement (constructed with cement concrete slabs) depends upon the flexural strength or beam action of the slab for withstanding the wheel load.

Thus, a major contributor to the load bearing capacity is the slab itself.

The stresses are not transferred from grain to grain to the layer as in case of flexible pavement layers.

The rigid pavement made of Portland cement concrete either plain reinforced, prestressed concrete. The plain cement concrete slabs are expected to take up about 40 kg/cm^2 flexural stress.

The main point of difference in the structural behavior of rigid pavement as compared to the flexible pavement is that the critical condition of stress in the rigid pavement is the maximum flexural stress occurring in the slab due to wheel load and the temperature changes whereas in the flexible pavement it is the distribution of compressive stress.

The cement concrete pavement slab can very well serve as a wearing surface as well as effective base course.

The rigid pavement are usually designed, and the stress are analyzed using the elastic theory, assuming the pavement as an elastic plate resting over elastic or viscous foundation.

Major pavement failure are fatigue cracking and plumping. Normally in India fatigue cracking is the only criteria adopted for rigid pavement design. Allowable number of load repetition to cause fatigue cracking depends on stress ratio, where stress ratio is the ratio of flexural tensile stress and concrete modulus of rupture.

DIFFERENCE BETWEEN FLEXIBLE PAVEMENT AND RIGID PAVEMENT

Flexible pavement	Rigid pavement
• Low flexural rigidity.	• Significant flexural rigidity.
• Load transferred through grain – grain contact.	• Load transferred to slab action (layer to layer).
• If there is any failure at bottom layer then failure will be appeared at top.	• If there is any failure at bottom layer then for small cavity slab will act as a bridge over it.
• No joints required.	• Contraction and expansion joint are provided.
• Less initial cost but high maintenance cost.	• High initial cost and low maintenance cost.
• IRC 37 – 2012.	• IRC 58 – 2012.

FUNCTION OF PAVEMENT COMPONENT

1. Soil Sub Grade

The pavement load is ultimately taken by soil sub grade. Hence, in no case it should be over stress and 50 cm layer of soil sub grade should be well compacted at OMC.

Common strength tests used for evaluation of soil subgrade are

i. CBR test

ii. California resistance value test

iii. Triaxial compression test

iv. Plate bearing test.

2. Sub Base and Base Course

These are composed of broken stone aggregates. It is desirable to use smaller size graded aggregates at sub base course instead of boulder stones.

Base and sub base course are used under flexible pavements primarily to improve load supporting capacity by distribution of the load through a finite thickness.

Where,

P = contact pressure

Z = Depth

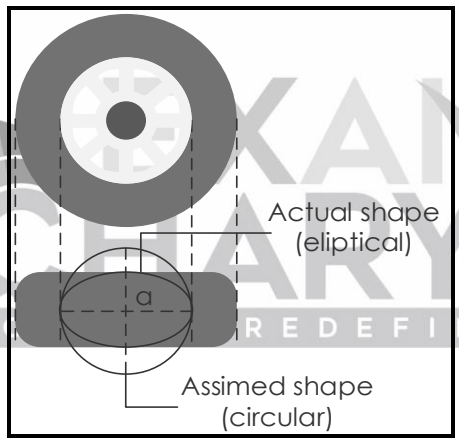
a = Radius of contact area

Actual shape of contact area is elliptical, but IRC consider as circular for calculation purposes.

$$\textbf{Contact pressure} = \frac{\boldsymbol{Load}}{\boldsymbol{Contact\ area}}$$

Contact area = πa^2

Contact pressure p = $\frac{P}{A} = \frac{P}{\pi a^2}$



Rigidity Factor (R.F)

$$\textbf{Rigidity factor} = \frac{\boldsymbol{contact\ pressure}}{\boldsymbol{tyre\ pressure}}$$

New Batches are going to start.....

Contact:

7622050066

Test Series Available..

Total weekly test : 35

Total mid subject test : 16

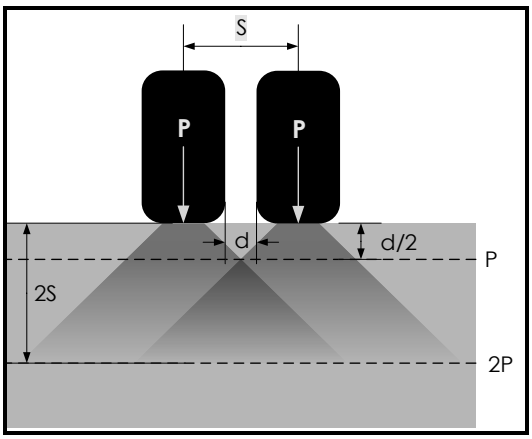
Total full length test : 13

Mock test : 16

Total test : 80

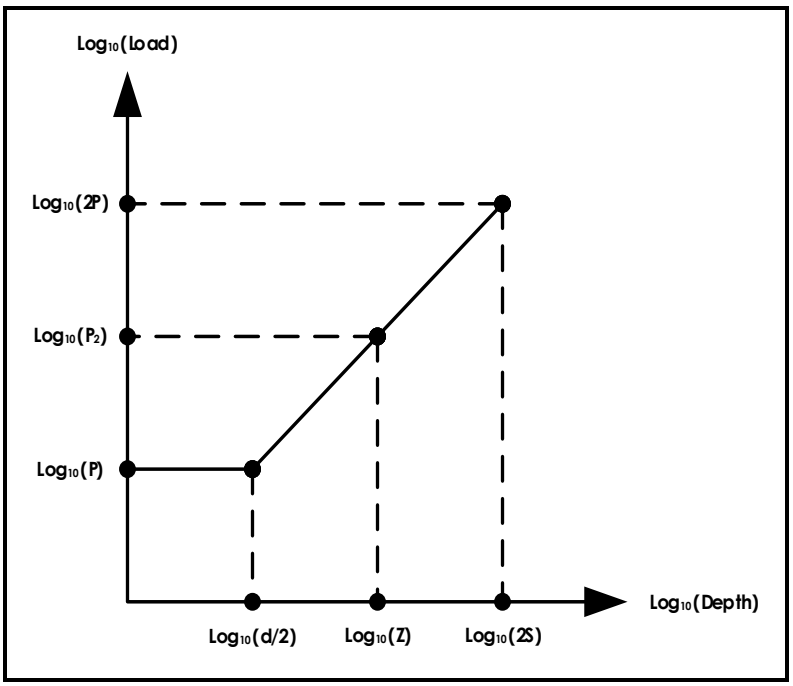
ESWL (Equivalent Single Wheel Load)

It is defined as the load on single tyre which will cause an equivalent magnitude of parameter such as stress, strain and deflection at the given location resulting from multiple wheel load at same location.



Observation

1. Up to depth $\frac{d}{2}$, ESWL = P
2. Beyond depth 2S, ESWL = 2P
3. Between $\frac{d}{2}$ to 2S, ESWL = Logarithmic variation.



c = $W_L - 40 \not> 20$ (Expressed as whole number between 0 – 20)

d = $I_p - 10 \not> 20$ (expressed as whole number between 0 – 20)

P = percentage finer (percentage of soil passing from 0.075 mm sieve)

W_L = Liquid limit

I_P = Plasticity index = W_L - W_P

To design the pavement thickness by this method first the GI value of the soil is found. The anticipated traffic is estimated and is designated as light, medium or heavy.

Traffic volume (commercial vehicle)	No. of vehicle per day (anticipated traffic)
Light	< 50
Medium	50 – 300
Heavy	> 300

Based on the anticipated traffic and group index value, thickness of pavement layer is calculated. The thickness of sub base depends only on group index value. However, the thickness of surface and base course combined depends on both the traffic as well as GI value.

Note

- In actual practices we have curves available for total combined thickness and thickness of surface and base course only corresponding to traffic & GI value. Hence from total thickness of sub base is obtained by deducting the thickness of surface and base course combined from total thickness.
- GI values lies between 0 – 20
- Higher the GI value poorer the soil and hence higher thickness of pavement required.

Limitation

i. Quality of pavement material used is not consider,

ii. Thickness required is same even if better quality of material used.

iii. Total thickness of pavement depends upon group index value whereas thickness of base coarse and surface coarse depends upon group index and traffic volume.

Now this load values are compare with the standard load values and CBR value is found

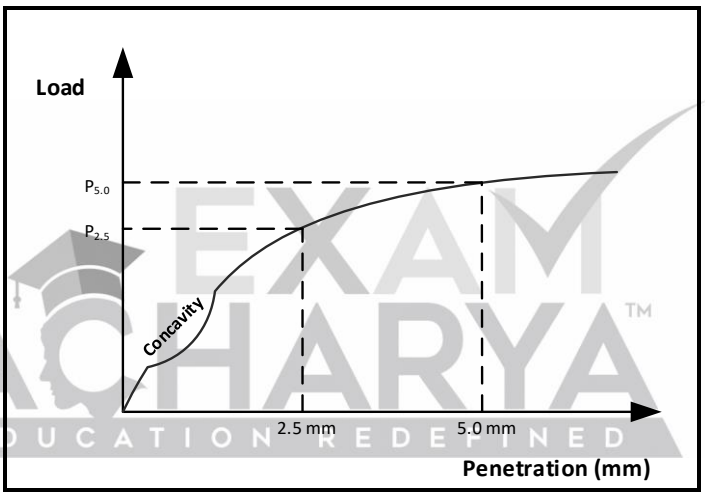
$$CBR_{value} = \begin{matrix} CBR_{2.5} = \frac{P_{2.5}}{1370} X\ 100 \\ CBR_{5.0} = \frac{P_{5.0}}{2055} X\ 100 \end{matrix}$$

Note

- Generally CBR 2.5 > CBR 5.0 but if CBR 5.0 is more than the test should be repeated and whichever comes higher will be adopted as CBR value

Initial concavity in CBR curve

If there is any initial concavity found in CBR curve then load corresponding to 2.5 and 5.0 mm penetration are wrong value.



Reason for initial concavity

Improper compaction to the top surface of the soil. Top surface of soil and bottom of plunger may not be truly horizontal.

Design of thickness of pavement by CBR method

Thickness of pavement required above test layer,

$$\mathbf{T} = \sqrt{\left(\frac{1.75P}{CBR\ value}\right) - \frac{P}{\pi p}} \boldsymbol{c.m.}$$

Where,

P = wheel load in kg

p = Contact pressure or tyre pressure,

$$\frac{P}{\pi p} = \frac{P}{\frac{\pi P}{A}} = \frac{A}{\pi} = \frac{\pi a^2}{\pi} = a^2$$

Limitation

Quality of material is not considered for thickness design.

This method is not valid for higher value for CBR.

CBR ≯ 12%

Semi Empirical or Semi – Theoretical Methods

These methods are based on stress strain function and experience e.g. Triaxial test method.

Triaxial Method

Thickness of pavement required above sub grade layer

$$T_P = \left(\sqrt{\left(\frac{3PXY}{2\pi E_s \Delta}\right)^2 - a^2}\right) - \left(\frac{E_s}{E_p}\right)^{\frac{1}{3}} \text{ (Two layer system)}$$

$$T_P \propto \left(\frac{1}{E_P}\right)^{\frac{1}{3}}$$

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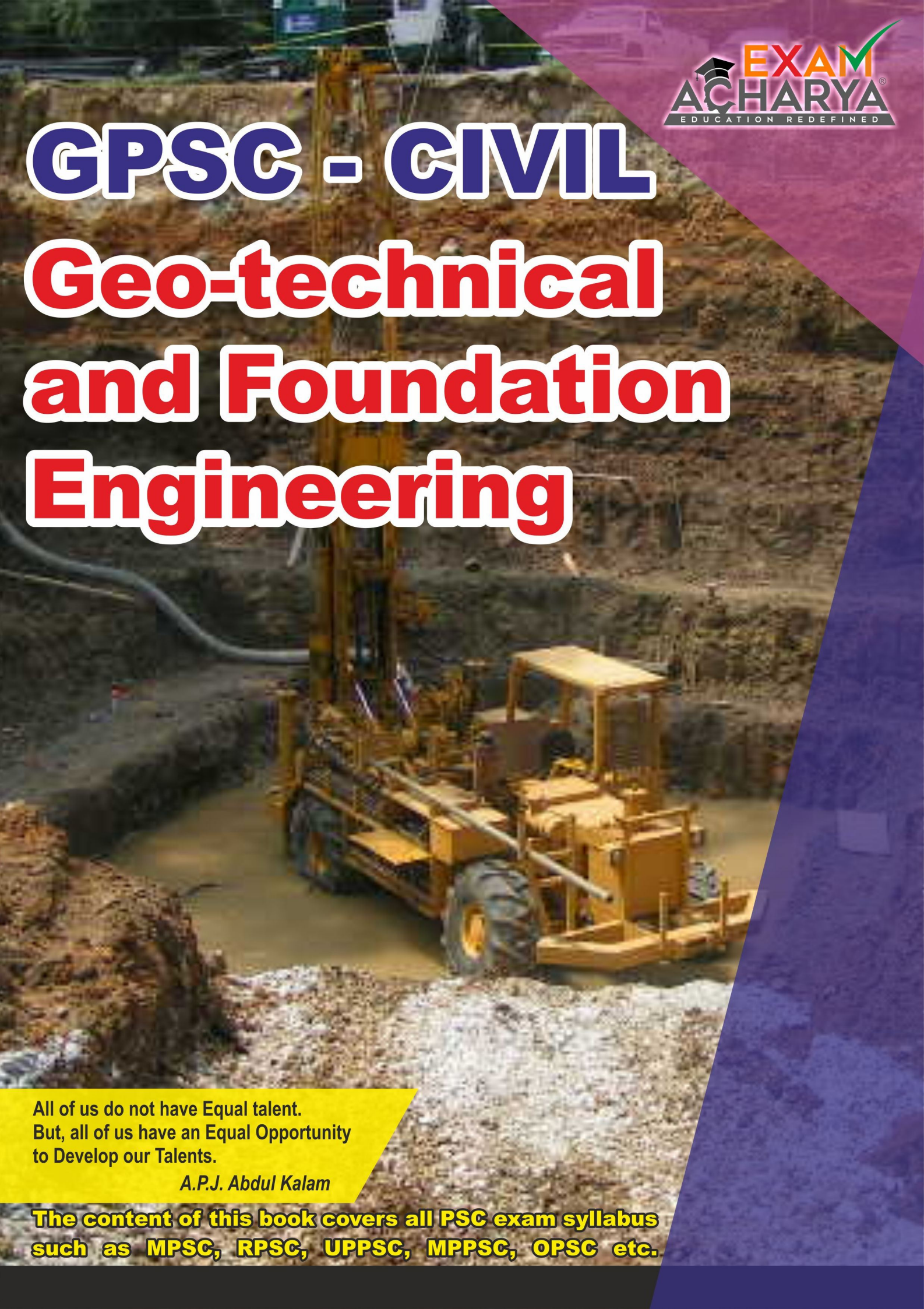


All of us do not have Equal talent.
But, all of us have an Equal Opportunity
to Develop our Talents.

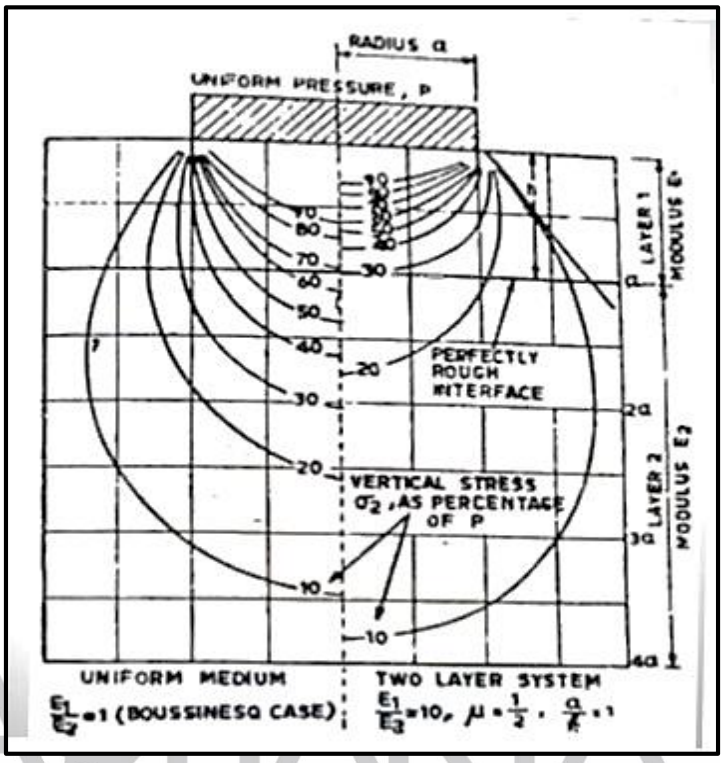
A.P.J. Abdul Kalam

The content of this book covers all PSC exam syllabus such as MPSC, RPSC, UPPSC, MPPSC, OPSC etc.

As per layered system,

$$E_{base\ course} > E_{sub\ base\ course} > E_{soil\ sub\ grade}$$

Young's modulus of elasticity of upper layers should be higher as compared to that lowered layer.



Displacement Relationship by Burmister's

For flexible plate

The wheel load acting over a pavement or on any other surface is considered flexible plate base.

$$\Delta = 1.5\left(\frac{pa}{E_s}\right)F_2$$

Where

Δ = Design deflection

p = Contact pressure at load surface due to wheel load

a = Radius of contact area.

RIGID PAVEMENT

Stress Analysis (IRC: 58-2012)

Design parameter

Modulus of Sub Grade Reaction

$$\mathbf{k} = \frac{p}{\Delta} = \frac{p}{0.125} kgcm^{-2}$$

Equivalent Radius of Resisting Section

Radius of area effective in resisting BM.

$$\mathbf{b} = \sqrt{1.6a^2 + h^2} - 0.675h \text{ (if } a < 1.724h)$$

$$\mathbf{b = a \text{ (if } a \geq 1.724\ h)}$$

Radius of Relative Stiffness

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

Where,

p = Tyre pressure or contact pressure in kg/cm^2,

Δ = Design deflection

a = Radius of contact area (in cm)

h = Thickness of slab

μ = Poisson's ratio

TEMPERATURE STRESSES

Temperature stresses are developed in cement concrete pavement due to variation in the slab temperature and resistance against deformation provided by the weight of slab and friction between slab and ground. The stresses are caused by.

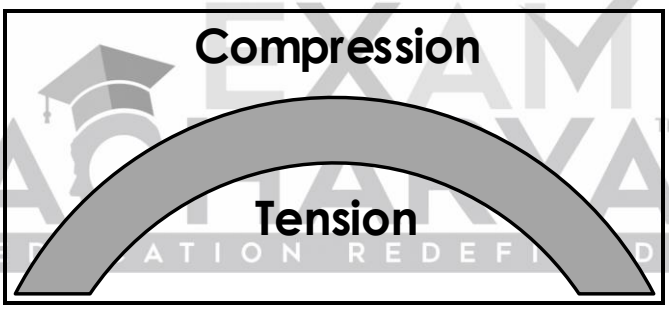
a. Daily variation resulting in temperature gradient across the thickness of slab

b. Seasonal variation resulting in overall change in slab temperature.

Daily variation will leads to warping of the slab. [Temperature differential between the top and bottom of the slab causes curling i.e warping stress in the pavement].

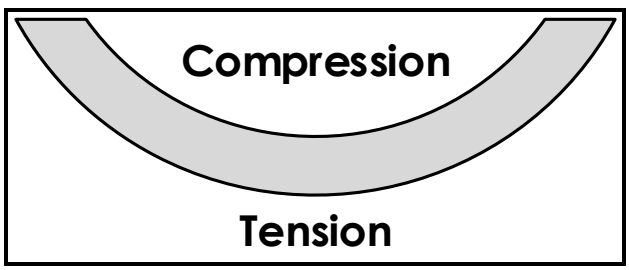
Day Time

Slab tries to expand at top but weight tries to resist it hence compression develops at top.



Night Time

Slab tries to contact top, but it is restrained by weight hence tension develops at top.



$$[\text{B x } \frac{L}{2} X\ h]\gamma_{conc} \text{ f} = \text{B x h x } \sigma$$

$$\sigma = \frac{f\gamma_{conc}L}{2}$$

Note
- As slab is trying to contract from both side hence half of the length of slab has been taken.
- During summer compression develops in the slab.

CRITICAL COMBINATION OF STRESSES

Out of various wheel stresses.

1. Corner stress is maximum as there is discontinuity in both direction
2. Interior stress is minimum
3. Edge stress is in intermediate range

Temperature stress is critical at the edge and interior and it is minimum at corner.

Note
- At the corner resistance due to weight is minimum, hence warping stress is minimum.

In combination of wheel load temperature, edge region is most critical hence designing is done using edge region stress and however checking is done for corner region.

Certain Combination

Summer and Mid – day

$$\sigma_{load\ edge} + \sigma_{warping\ edge} + \sigma_{friction}$$

Winter Mid – day

$$\sigma_{load\ edge} + \sigma_{warping\ edge} + \sigma_{friction}$$

Mid – Night

$$\sigma_{load\ edge} + \sigma_{warping\ edge}$$

Filter has the original thickness of δ. But due to expansion of slab, it gets compressed to max of $\frac{\delta}{2}$.

$$L\alpha\Delta T = \frac{\delta}{2}$$

$$\mathbf{L = \frac{\delta}{2\alpha\Delta T}}$$

Where,

L = Maximum spacing between expansion joint

$\boldsymbol{\delta}$ =Gap of expansion joint

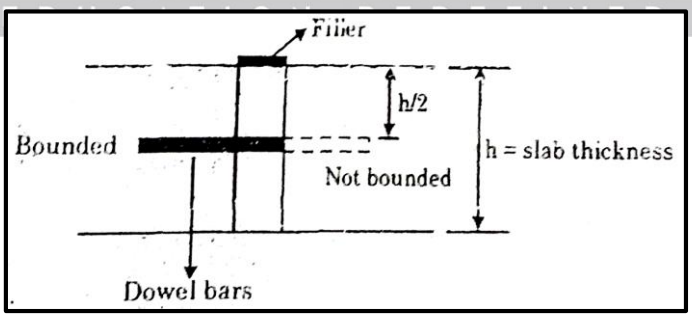
α = Coefficient of thermal expansion

ΔT = Rise in temperature.

Contraction Joint

It is provided to control crack due to shrinkage and moisture variation.

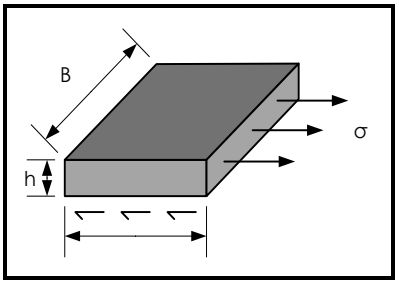
To regulate the crack i.e. to ensure that crack forms at predetermined location, slab is weakened at certain intervals. These locations are called contraction joint.



Spacing of Contraction Joint

During initial curing period shrinkage occurs in the concrete and if this shrinkage is resisted tensile stress develops in the concrete slab.

Fall of temperature will also develop the tensile stress in the concrete slab.



$$\sigma_{st} A_{st} = B \; X \; \frac{L}{2} X \; h \; X \; \gamma_{conc} \; X \; f$$

$$\mathbf{L = \frac{2\sigma_{st} A_{st}}{B h \gamma_{conc} f}}$$

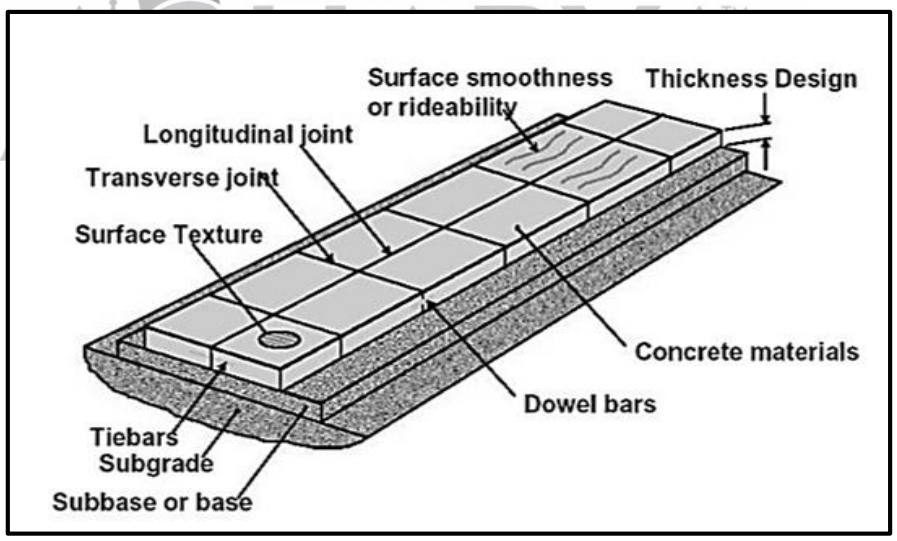
Where,

σ_{st} = Permissible tensile stress in steel

A_{st} = Area of steel in complete width of slab

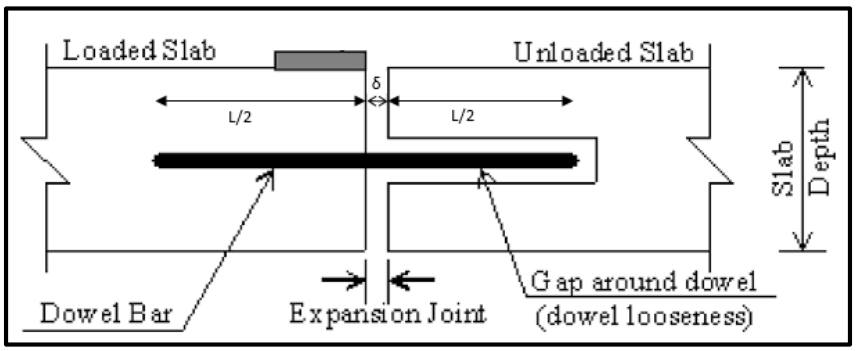
f = Coefficient of friction

Longitudinal Joint



Longitudinal joints are provided along the length of pavement. It reduces the warping stress. The normal width of slabs and provided longitudinal joint. We generally provides tie bars at the longitudinal joint. The tie bars ensure that the two adjacent slab remains firmly together. Load is actually transferred to the adjacent slab due to aggregate interlock. Tie bars are bounded with concrete and

DOWEL BAR (DESIGN)



Dowel bars act as load transfer devices across transverse joint and they keep the two slab at the same height. They are mild steel round bars bonded on one side and free on the other side. Normally 25 mm to 40 mm diameter and 400 and 500 mm length are provided. Stresses in the dowel bars are.

a. Shear stress
b. Bending stress
c. Bearing stress.

The stress in the dowel bar is given by Bradbury analysis. Load transfer capacity of single dowel bar is given by

Shear

$$P_s = \frac{\pi}{4} d^2 X \sigma_s$$

Where,

P_S = Load transfer capacity of dowel bar in shear

d = Dia of dowel bar

σ_s = Permissible shearing stress in steel,

1. ***Routine Maintenance***

   It includes the following works

   - Filling up of pot holes and patch repairs
   - Maintenance of shoulders and the cross slope
   - Cleaning of side drains and culverts
   - Maintenance of road signs
   - Road side arboriculture.

2. ***Periodic Maintenance***

   These include

   - Renewals of wearing course of pavement
   - Renewals of top surface of gravel roads and metalled road
   - Preventive maintenance of various items

3. ***Special Repairs***

   It includes the following works:

   - Strengthening of pavements structure
   - Widening of roads
   - Construction of road islands
   - Reconstruction of pavement
   - Repairs of damages caused by floods
   - Road signs

DEFECTS IN FLEXIBLE PAVEMENT

i. **Hair line cracks:** Short and fine cracks at short interval

ii. **Aligator or map cracking:** Random deep cracks. It may occur due to repeated application of heavy wheel roads.

DEFECTS IN RIGID PAVEMENTS

i. **Scaling of cement concrete:** Deterioration of concrete due to deficiency in mix or some chemical impurities in the mix

ii. **Shrinkage cracks:** Develop during curing operations

iii. **Spalling of joints:** Due to dislocation of filler material below joint.

iv. **Warping cracks:** If joint is not well design to accommodate the warping of slab edges, this result in excessive stresses due to warping and cracking at the edges.

v. **Structural cracks:** Due to inadequate slab thickness.

OVERLAY

Strengthening may be done by providing additional thickness of the pavement which is called overlay.

Flexible Overlay Over Flexible Pavement

$$h_o = h_d - h_e$$

Where,

h_o = Overlay thickness required (cm)

h_d = Total design thickness required (cm)

h_e = Total thickness of existing pavement (cm)

Benkelman Beam Deflection Method

Characteristic deflection (D_c)

$$D_c = D + t.\sigma$$

Where,

D = Design deflection

σ = Standard deviation

t = Depends on % of deflection values to be covered in design.

$\overline{D}$ = Mean value of deflection at 'n' points.

New Batches are going to start.....

Contact:

7622050066

Test Series Available..

Total weekly test : 35

Total mid subject test : 16

Total full length test : 13

Mock test : 16

Total test : 80

Flexible Overlay Over Rigid Pavement

$$h_f = 2.5\ (f.\ h_d - h_e)$$

Where,

h_f = flexible overlay thickness

h_d = Design thickness of rigid pavement

h_e = existing thickness of rigid pavement

f = factor depend upon modulus of existing pavement

$$h_b = 1.66\ (f\ .\ h_d - h_e)$$

Where

h_b = thickness of bituminous overlay.

Qu5 What are the major stresses in CC pavement?

a) Wheel load stress

b) Warping stress

c) Wheel load and warping stress

d) Frictional stress

Qu6 The maximum stress in summer by pavement is experienced at

a) Morning

b) Mild noon

c) Evening

d) Night

TEST YOUR SELF

Qu7 What is the gap provided in slabs?

a) 20 mm

b) 30 mm

c) 35 mm

d) 40 mm

Qu8 The minimum diameter of dowel bar used is

a) 25 mm

b) 35 mm

c) 40 mm

d) 50 mm

Answer

1-(a), 2-(d), 3-(c), 4-(a), 5-(c), 6-(b), 7-(a), 8-(a)

iv. Environmental: Facilities to the traffic, atmospheric condition and locality.

Vision

6/6 vision (Normal vision)

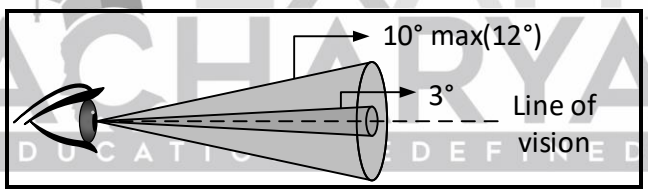
Normal vision is defined as the ability of a person to recognize a letter of size 8.5 mm from a distance of 6 meter.

$$\textbf{Vision} = \frac{\boldsymbol{abnormal\ vision}}{\boldsymbol{Normal\ vision}} \leq \mathbf{1}$$

6/9 vision

A person 6/9 vision has poorer than normal vision because he can recognize any object at a distance of 6 m what a normal person can recognized at a distance of 9 m.

Peripheral Vision

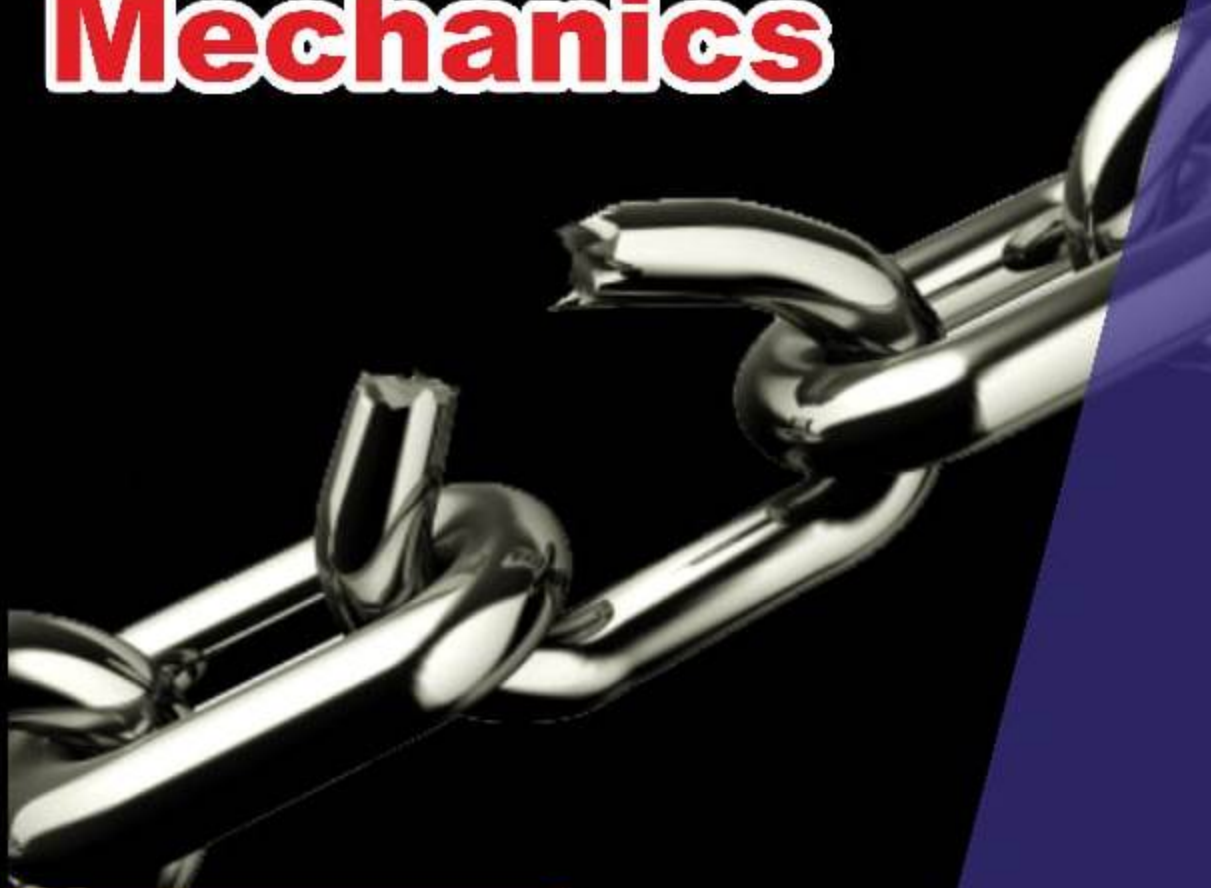


Sharper vision is concentrated in zone formed by a cone of 3˚ angle about centre of retina. Vision is considered as satisfactory up to 10˚cone (12˚ max). It is important to consider peripheral vision for location of sign board of information message. Angle of peripheral vision decline as speed increases. Peripheral vision deals with total visual field for two eyes and angle of peripheral vision is about 160˚ on horizontal plane and 115˚ on vertical plane.

EXAM ACHARYA

GPSC - CIVIL

Solid Mechanics



"Education is the most Powerful Weapon which you can use to change the world."

A.P.J. Abdul Kalam

The content of this book covers all PSC exam syllabus such as MPSC, RPSC, UPPSC, MPPSC, OPSC etc.

GPSC - CIVIL

Solid Mechanics

C. Braking Characteristics

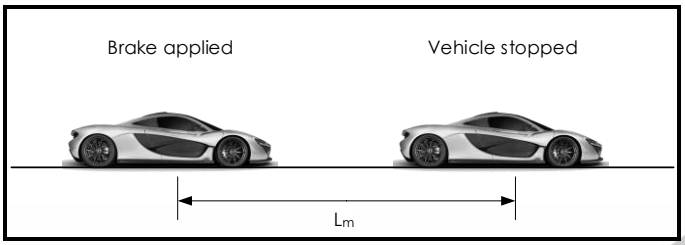
i. Braking Test

At least two of following three parameters are needed during the braking test in order to determine skid resistance of pavement.

a. Braking distance (L)

b. Initial speed (U)

c. Actual duration on break application (d)



Retardation

As we know that

$$V = u + at$$

$$0 = u + at$$

$$\mathbf{(-\ a) = \frac{u}{t}}$$

$$\mathbf{Retardation = \frac{initial\ speed}{Time}}$$

Thus, initial velocity and braking length is known 'f' can be calculated. After the application of brakes, the work done against the frictional force for stopping the vehicle will be equal to kinetic energy of the vehicle.

$$\frac{1}{2}mu^2 = fwL$$

iv. Brake Efficiency

$$\eta_B = \frac{f_{obtained}}{f_{max}} X\ 100$$

$$f_{obtained} = \frac{u^2}{2gL}$$

TRAFFIC STUDIES

The traffic surveys for collecting traffic data are also caked census. These studies help in deciding the geometric design features and traffic control for safe and efficient traffic movements.

The various traffic studies generally carried out are.

a. Traffic volumes study
b. Speed studies
    i. Spot speed study
    ii. Speed and delay study
c. Origin and destination study
d. Traffic flow characteristics
e. Traffic capacity study
f. Parking study
g. Accident study.

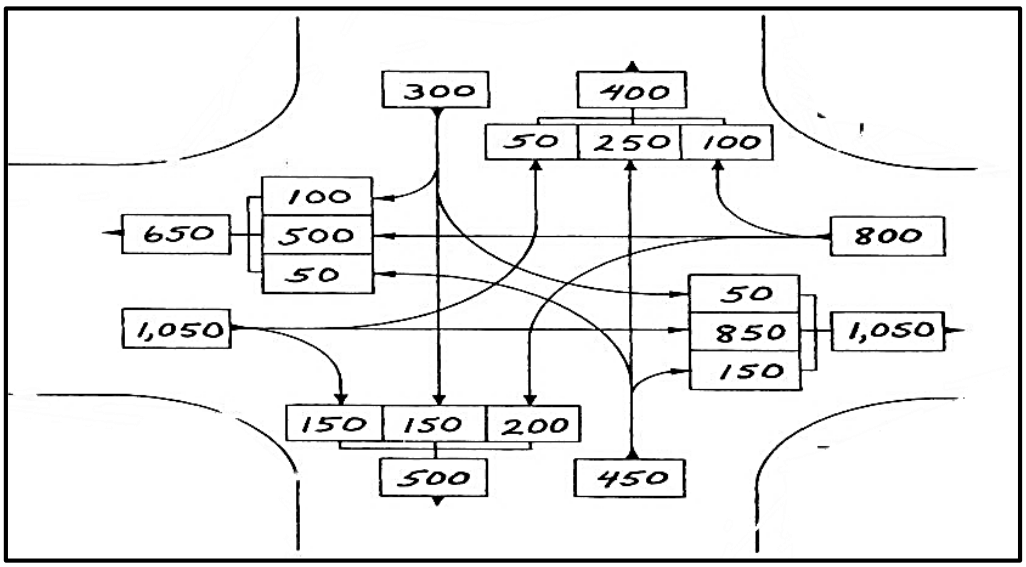
TRAFFIC VOLUME STUDY

Traffic volume is the number of vehicles crossing a section of road per unit time is used to measure the quantity of traffic flow.

It can determine by,

$$\mathbf{q} = \frac{n\ X\ 3600}{T} vpH$$

Traffic Volume Calculation



The traffic flow varies from time to time as hourly traffic volume varies considerably during day hourly volume will be much higher than the average hourly volume. Daily traffic volumes vary in week and during seasons. Therefore, true picture is to be obtained for pattern of hourly, weekly, daily, and seasonal variation including class of traffic (busses, truck, cars motorcycles and etc.) during traffic volume study traffic variations and the direction of each class of traffic is recorded with the information of their turning movements. Traffic volume counts is done with the help of mechanical counters or manually, using pneumatic tube, multiple recorder. At first the fluctuations of traffic volume during the hours of day and the daily variations are observes. After that with the help of statistics the peak hourly traffic volumes and average daily traffic volumes are calculated.

Passenger Car Unit

Under mixed traffic condition it is difficult to find traffic volume, density, capacity etc. there all class of vehicle is converted into a standard vehicle unit which is called as passenger car unit factor affecting PCU.

a. Dimension of vehicle,

b. Speed of vehicle

Representation of Traffic Volume Data

i. Annual Average Daily Traffic (AADT)

It is the average 24 hr traffic volume at a given location over a full 365 days. Total traffic and classified are calculated. It helps in deciding the relative importance of a route and road development. It includes seasonal variations also.

$$\mathbf{AADT} = \left[\frac{\textit{No of vehicle throught one year}}{365}\right]_{\textit{vehicle per day}}$$

ii. Average Daily Traffic (ADT)

It is the average 34 hr volume at a given location for some period of time less than a year. For this minimum of 7 days count is done to include the daily variation like on Saturday and Sunday.

$$\mathbf{ADT} = \left[\frac{\textit{No of vehicle throught one week}}{7}\right]_{\textit{vehicle per day}}$$

iii. Annual Average Weekday Traffic (AAWT)

$$\mathbf{AAWT} = \left[\frac{\textit{No.of vehicle throught weekday in a year}}{260}\right]_{\textit{vehicle per day}}$$

iv. Annual Average Hourly Traffic (AAHT)

$$\mathbf{AAHT} = \left[\frac{\textit{AADT}}{24}\right]_{\textit{vehicle per hour}}$$

Important Chart

i. Trend Chart

Trend chart shows the traffic volume trend over a certain period of time.

$$\textbf{Daily expansion factor} = \frac{Average\ \ Total\ vol.for\ a\ week}{Average\ volume\ for\ particular\ hour}$$

$$\textbf{Monthly expansion factor} = \frac{AADT}{AADT\ for\ particular\ month}$$

Thus if 24 hour count at a location is done and hourly volume is calculated, we can calculated the hourly expansion factor for each hour.

Peak hour factor,

$$PHF = \frac{Traffic\ volume}{Peak\ traffic\ volume}$$

PHF for 5 min,

$$PHF_5 = \frac{Traffic\ volume}{Peak\ traffic\ for\ 5\ min.}$$

PHF for 15 min.

$$PHF_{15} = \frac{Traffic\ volume}{Peak\ traffic\ for\ 15\ min.}$$

$$0.25 \leq PHF_{15} \leq 1$$

Thus, it has been observed that 30th highest hourly volume gives a satisfactory result in terms of performance and is also economical in nature. As per Indian condition 30th highest hourly volume is 8 -10% of AADT, for example of AADT is 2000 vehicle vehicle per day 30th highest hourly volume will be 160 – 200 vehicle per hour.

If 30th highest hourly volume is adopted for desire than there will be congestion only during 29th hours in the year. The thirtieth highest hourly volume for design.

SPEED STUDY

Spot Speed

It is an instantaneous speed of vehicle at a particular section of road or time. Spot speed is used to design horizontal and vertical curve, signal, accident analysis and location of traffic sign. Spot speed is measured by,

a. Enoscope
b. Contact pressure tube
c. Loop detectors.

Average Speed

It is average of spot speed of all vehicle passing a given point of road.

A. Time Mean Speed (V_t)

Arithmetic mean of speed of vehicle during an interval of time is known as time mean speed.

$$V_t = \frac{V_1+V_2+V_3+\cdots\ldots\ldots+V_n}{n}$$

B. Space Mean Speed (V_S)

Average speed of vehicle over a certain road length at any time is known as space mean speed.

Factors Affecting the Spot Speed

a. Pavement
b. Width of the curve
c. Sight distance
d. Gradient
e. Pavement
f. Unevenness intersections
g. Roadside developments
h. Enforcement
i. Traffic condition
j. Driver
k. Vehicle and
l. Motive of travel

Presentation of Spot Speed Data

i. Average speed of vehicle

It is the space mean speed and time mean speed. From the spot speed data of the selected samples, frequency distribution tables are prepared for various speed ranges and no. of vehicles in such range. This frequency distribution table prepared gives the general information of the speed distribution pattern. From this space man and time mean speed are calculated.

ii. Cumulative speed of vehicle

A graph is plotted between average value of each speed group and cumulative percentage of vehicles travelled at or below different speeds.

From the above graph 85^{th} percentile speed is found out which means that only 15 percent of vehicles exceeds this speed during that stretch.

iv. Elevated observations.

v. Photographic technique.

i. Floating Car or Riding Check Method

This method is suitable for two lane traffic.

In floating car method a test vehicle is driven over a given course of travel at approximately the average speed of the stream thus trying to float with the traffic stream, four observers are required in this case.

Observer 1: Note time at various control point such as interaction, bridges and any other fixed points in each trip. He also note the amount of delay at each point.

Observer 2: Note the time, location and cause of these delays

Observer 3: Note the no. of vehicle overtaking the test vehicle and that overtaken by the test vehicles.

Observer 4: Note the no. of vehicle travelling in the opposite direction in each trip.

In this case the test is carried out in two directions say when flow and average journey time of all vehicles is to be calculated in north south direction, the test is run in N-S as well as S – N direction

$$\textbf{Traffic flow, q} = \frac{n_a + n_y}{t_w + t_a}$$

$$\textbf{Journey time of flow, } \bar{t} = \left[t_w - \frac{n_y}{q}\right]$$

Where,

t_w = Average journey time when test vehicle travel with the flow.

t_a = Average journey time when test vehicle travel against the flow.

n_a = Average number of vehicle travelling in the direction of flow (this data is calculated by the fourth observer of opposite side test vehicle).

Information collected include the place and time of origin and destination, route, locations of stoppage, the purpose of the trip, type of vehicle and number of passengers in each vehicle.

In this method the data is collected quickly in short duration

Main drawback of the method is that the vehicles are stopped for interview.

b. License Plate Method

Entire area under study is marked out and the observers are simultaneously stationed at all points of entry and exit on all the routes reading into and out of the area.

Each party notes the license plate number of the vehicles entering and leaving the marked area and the time.

After collecting the field data major work remains of the office computations and analysis by tracking each vehicle number and its time of entering and leaving the marked area.

This method is quite easy and quick as far as field work is concerned. However, involves a lot of office computations on tracing the trips through a new work of stations

Hence a large number of teams are required to take simultaneous observations when a large area is to be surveyed.

This method is quite advantages when the area consideration is small like an intersection of a small business centre.

c. Return Post Card Method

Prepaid business reply post cards with return address are distributed to the road uses at some selected points along the route or the cards are mailed to the owners of vehicles. The questionnaire to be filled in by the road user is printed on the card, along with a request for co – operation and purpose of the study. The

sampling and mode of data collection. The sample size should be decided keeping in view the desires accuracy and cost.

f. Work Spot Interview Method

The transportation needs of work trips can be planned by collection the O and D data at work spots like the offices, factories, educational institutions etc. by personal interviews.

Representation of O and D Data

1. **O and D table:** It should have number of trips between different zone.
2. **Desire line:** Desire line are straight line connecting origin of destination. it shows actual desire of road users. Thickness of desire line is directly proportional to number of trips in both directions.
3. **Pie chart:** It shown by a circle in which diameter of circle is directly proportional to number of trips.

TRAFFIC CAPACITY AND FLOW ANALYSIS

Important Definition

Traffic Density (k)

It is defined as the number of vehicles occupy a unit length of road at a given instant. It is expressed in vehicle per km.

Jam Density (k_j)

It is maximum value of traffic density in which movement of vehicle is not possible. This condition is known as jam condition. Relations between traffic volume and traffic density.

Traffic volume = speed x Traffic density

Time Headway (t_H)

Basic capacity as per space headway (theoretical capacity).

$$q_{theoretical} = [\frac{1000V}{S}]_{vehicle/hr}$$

Basic capacity as per time headway (maximum theoretical capacity)

$$(q_{theoretical}) = [\frac{3600}{t_H}]_{vehicle/hr}$$

b. Possible Capacity

Possible capacity exists between most ideal condition to worst condition

$$0 \leq possible\ capacity \leq Basic\ capacity$$

c. Practical Capacity

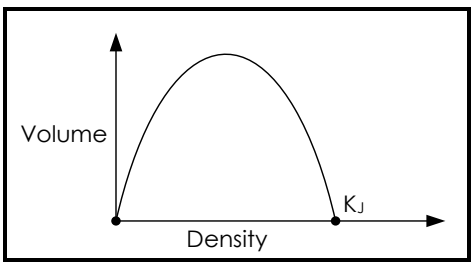
This is the capacity under ordinary condition (some factors are favorable, and some are unfavorable).

$$0 < Practical\ capacity < Basic\ capacity$$

RELATION BETWEEN SPEED DENSITY AND VOLUME

As per Green shields the relationship between the speed and density should be assumed linear. Note that at jam density (i.e., maximum density) space mean speed will be zero because vehicles will be in stand still conditions. When density is zero i.e., when there is no vehicle on road the speed will be maximum called free mean speed.

Relation between speed and density is thus given by,



$$V_s = v_f - \frac{v_f}{K_j}K$$

New Batches are going to start.....

Contact:

7622050066

Test Series Available..

Total weekly test : 35

Total mid subject test : 16

Total full length test : 13

Mock test : 16

Total test : 80

$$q_{max} = \frac{V_f K_j}{2} - \frac{V_f K_j}{4}$$

$$\boldsymbol{q_{max} = \frac{V_f K_j}{4}}$$

3. To find Speed at Maximum Flow (i.e. Volume)

For max flow $\frac{dq}{dV_s} = 0$

$$\frac{d[K_J V_S - \frac{K_j V_S^2}{V_f}]}{dV_S} = 0$$

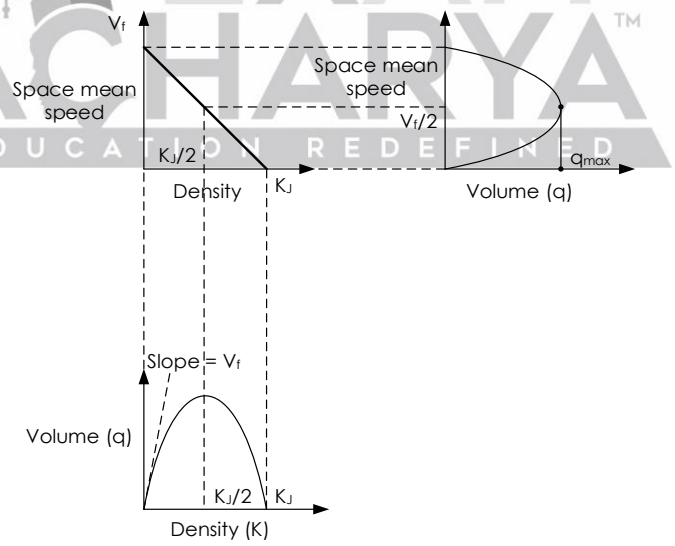
$$K_j - \frac{2K_j V_s}{V_f} = 0$$

$$\boldsymbol{V_S = \frac{V_f}{2}}$$

Thus, for max volume speed should be half of free mean speed.

Note

- The max flow is called capacity flow



TRAVEL TIME

Travel time is defined as the time taken to complete a journey. Travel time per unit length of road is inversely proportional to the speed. If T is travel time and V is speed (kmph) then

ACCIDENT STUDY

Type of Accident

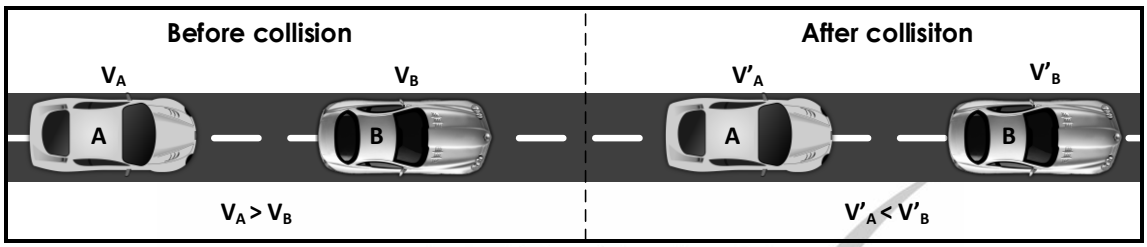
i. A moving vehicle collides with a parked vehicle,

ii. Two vehicles approaching from different direction collides at an intersection

iii. Head on collision of two vehicle approaching from opposite direction

iv. A moving vehicle collides with an object like trees, electrical pole, dividers etc.

Newton's Law of Collision



Coefficient of Restitution

Coefficient of restitution e = $\frac{velocity\ of\ seperation}{velocity\ of\ approach}$

$$\mathbf{e = \frac{(V'_B - V'_A)}{(V_A - V_B)}}$$

Case 1: If e = 1

Collision is called perfectly elastic

$$\therefore \mathbf{1 = \frac{(V'_B - V'_A)}{(V_A - V_B)} = \frac{velocity\ of\ seperation}{velocity\ of\ approach}}$$

Velocity of separation = velocity of approach

Case 2: if e = 0

Collision is called perfectly plastic,

$$\frac{1}{2}m_A V_1^2 - \frac{1}{2}m_A V_2^2 = m_A g F S_1$$

$$V_1^2 = V_2^2 + 2FgS_1$$

$$\boldsymbol{V_1 = \sqrt{V_2^2 + 2FgS_1}}$$

Step 2: At collision

Momentum just before collision = Momentum just after collision

$$m_A V_2 + m_b . 0 = (m_A + m_B)V_3$$

$$V_2 = \frac{(m_A + m_B)V_3}{m_A}$$

$$\boldsymbol{V_2 = \frac{(m_A + m_B)V_3}{m_A}}$$

Step 3: After collision

$$\frac{1}{2}(m_A + m_B)V_3^2 - 0 = ((m_A + m_B)gFS_2$$

$$V_3 = \sqrt{2gFS_2}$$

$$\boldsymbol{V_3 = \sqrt{2gFS_2}}$$

V_3 is responsible for the accident it is called critical speed.

Step 1: Before Collision

$$V_{A_1} = \sqrt{V_{A_2}^2 + 2gfsA_1}$$

$$V_{B_1} = \sqrt{V_{B_2}^2 + 2gfsB_1}$$

Step 2: At collision

Moment equation in direction of vehicle A,

$$m_A V_{A_2} + m_B . 0 = m_A V_{A_3} cos\theta_A + m_b V_{b_3} sin\theta_B$$

$$V_{A_2} = V_{A_3}\, cos\theta_A + (\frac{m_B}{m_A}) V_{B_3} sin\theta_B$$

In direction of vehicle B,

$$m_A . 0 + m_B V_{B_2} = m_A V_{A_3} sin\theta_A + m_b V_{B_3} cos\theta_B$$

$$V_{B_2} = \left(\frac{m_B}{m_A}\right) V_{A_3} sin\theta_A + V_{B_3} cos\theta_B$$

Step 3: After collision

$$V_{A_3} = \sqrt{2gfsA_2}$$

$$V_{B_3} = \sqrt{2gfsB_2}$$

PARKING STUDY

There are two types of parking.

i. On street parking (kept facility)

ii. Off street parking.

GPSC - CIVIL

Surveying

EXAM ACHARYA
EDUCATION REDEFINED

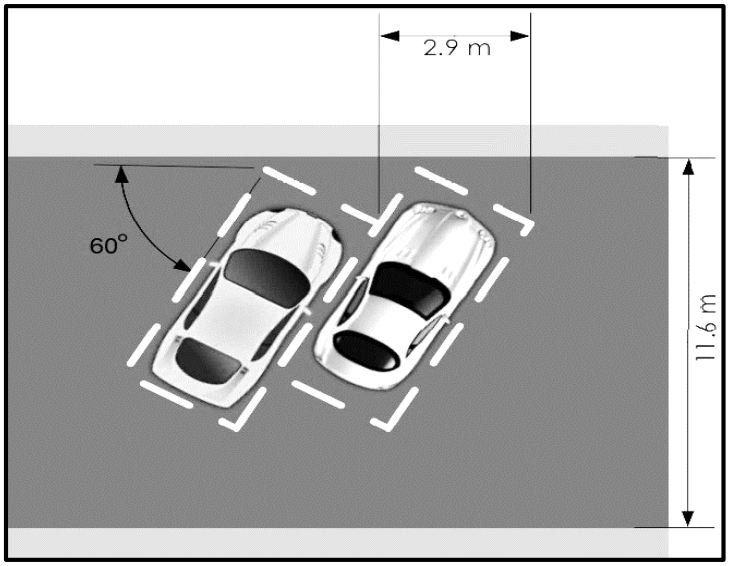
The best Brains of the Nation may be found on the last Benches of the Classroom.

A.P.J. Abdul Kalam

The content of this book covers all PSC exam syllabus such as MPSC, RPSC, UPPSC, MPPSC, OPSC etc.

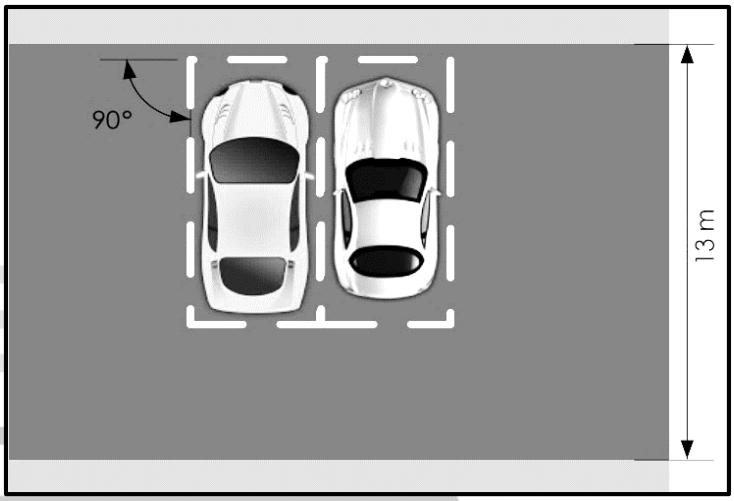
iv. 60°Parking

$$N = \frac{L-2}{2.9}$$



V. 90°Parking

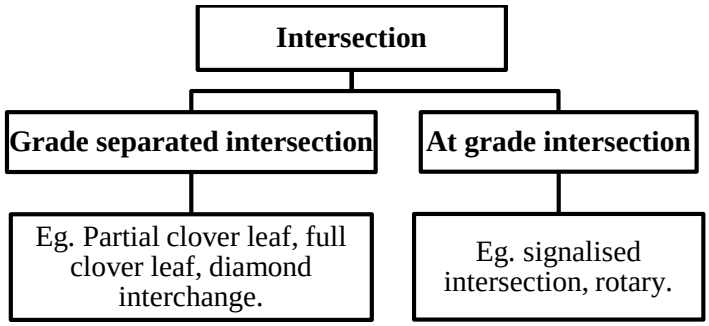
$$N = \frac{L}{2.5}$$



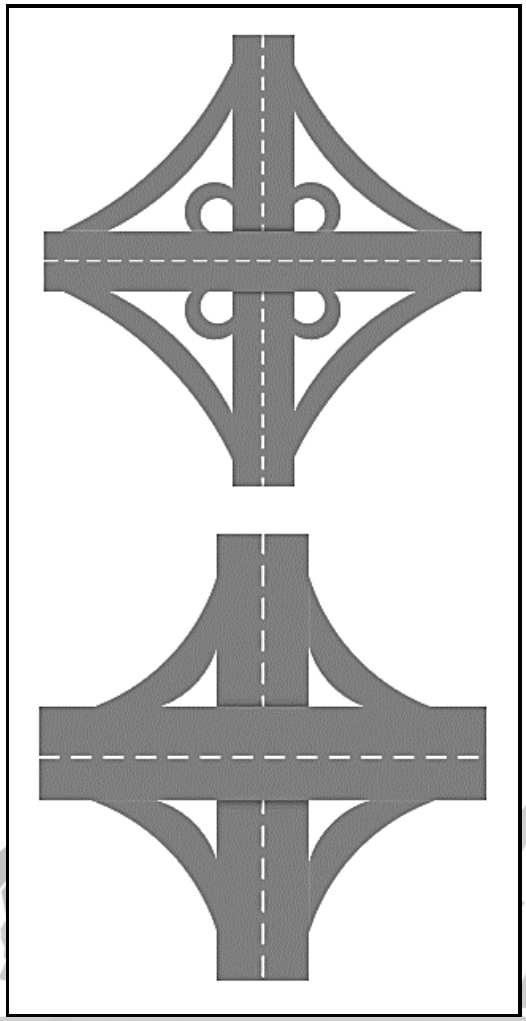
Off Street Parking

When parking facility is provided at separate place away from kerb it is known as off street parking. The main advantage of these parking is there no conjection and delay on the road as it is in kerb parking.

INTERSECTION



ii. Full Clover Leaf

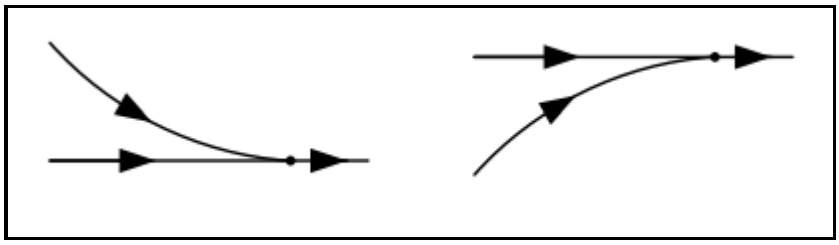


At Grade Intersection or Level Crossing

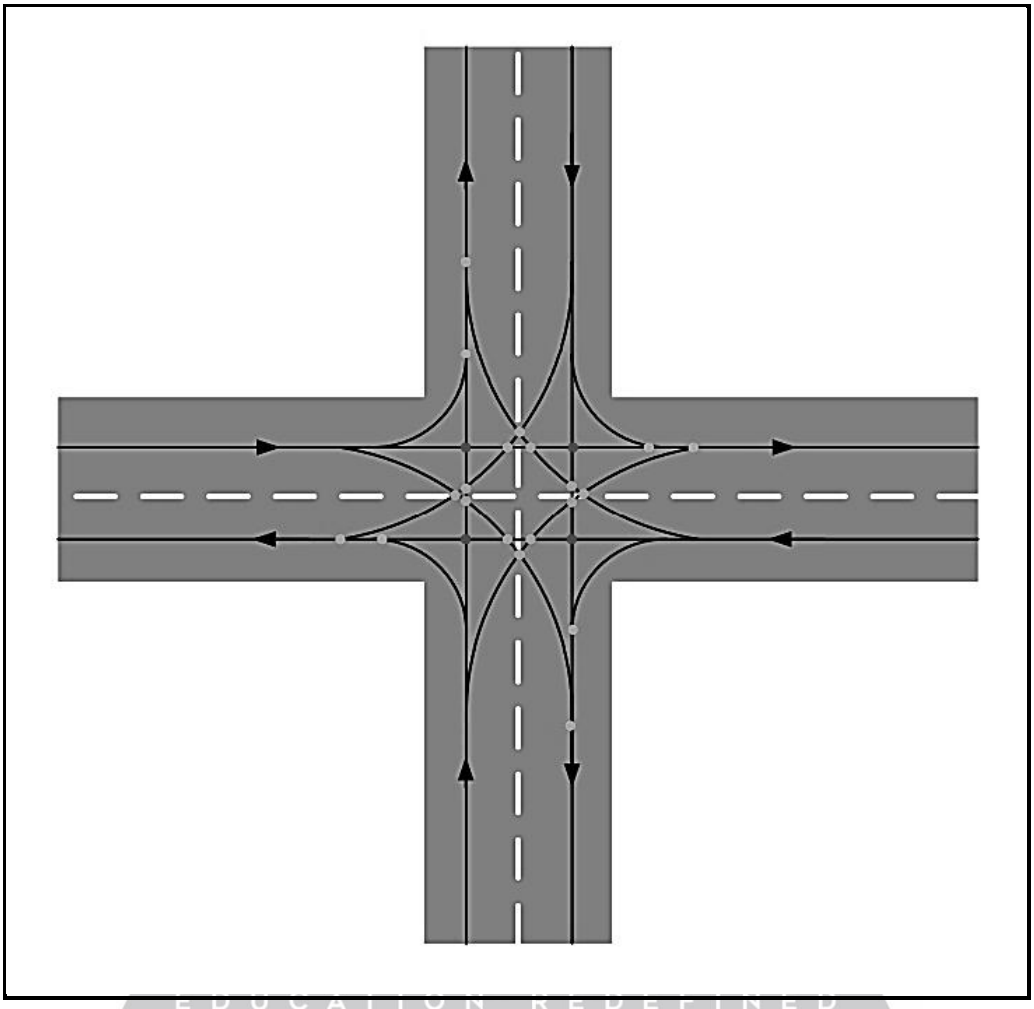
When two roads meet at same level.

Conflict Point

i. Merging conflict



Two Lane Two Way Road



Here,

Crossing conflict = 4

Weaving conflict = 12

Merging conflict = 8

∴ Total conflict = 24

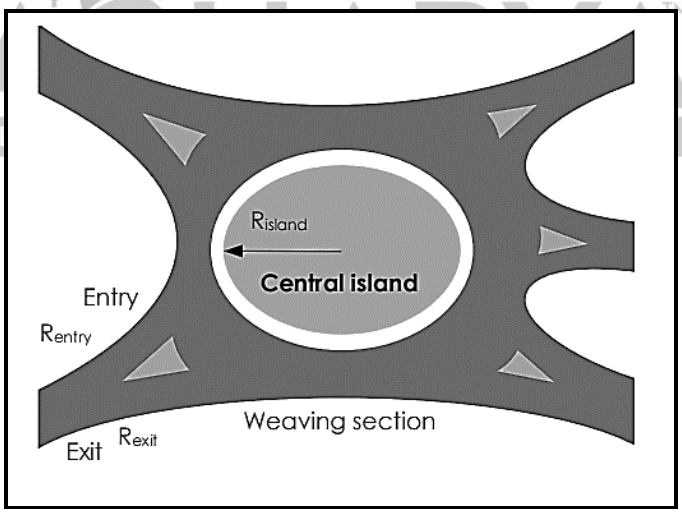
Conflict Points of Different Types of Road

No. of lane		A (2 way) B (2 way)	A (2 way) B (1 way)	A (1 way) B (1 way)
Road A	Road B			
2	2	24	11	6
2	3	24	11	8
2	4	32	17	10
3	3	24	13	11
4	4	44	25	18

ROTARY

The rotary intersection of roads is also called as traffic rotary which is nothing but enlarged intersection of roads where vehicles cross the roads or change their direction without stopping.

IRC suggested to design the rotary for maximum traffic volume of three thousand vehicle per hour and minimum 500 vehicle per hour entering from all the legs.



Note
- Circular shape rotary is prefer when traffic in both the crossroad are equal.
- Elliptical shape is generally preferred when traffic in one road is significant as compare to the traffic in another cross road.
- Tangential and turbine shape rotary is not prefer because of over speeding due to long route weaving section.

GENERAL GUIDELINE FOR DESIGN OF ROTARY AS PER IRC

i. Design Speed for Rotary

V= 30 kmph (urban area)

V = 40 kmph (rural area)

ii. Radius at Entry, Exit and Central Island

Entry to the rotary is not straight small curvature is also introduced to forcefully speed of vehicle. Super elevation in the rotary is equal to camber of road but for calculation of radius at entry super elevation is assumed at zero.

$$R_{entry} = \frac{V^2}{127f}$$

$$R_{exits} = (1.5\ to\ 2)X\ R_{entry}$$

$$R_{island} = \frac{4}{3}X\ R_{entry}$$

iii. Width at Entry and Exit

If, e_1 = Width at entry

e_2 = Width at exit

Entry width and exit width of rotary is governed by traffic entering and leaving the interection and width of approaching road.

Function of Traffic Control Devices

Devices are classified into three functional groups as follows

a. Regulatory Devices

This give the road user notice of traffic laws or regulations that apply at a given place or on given road way. Disregard of such devices is publishable as an infraction, violation or misdemeanor.

e. g : stop, no turning, do not enter, no parking etc.

b. Warning Devices

These call attention of the road user to conditions on or adjacent to the roadway that are potentially hazardous to traffic operations. E.g.: road narrow, divided highway ends, slippery when wet, railroad crossing etc.

c. Guiding devices

These provide directions and information to the road user regarding route designation, distances, destinations point of interest and other geographical or cultural information

e.g. Airport 20 km, Railway 30 km

TRAFFIC SIGNALS

Traffic signals are control devices which could alternately direct the traffic to stop and proceed at intersections using red and green traffic light signals automatically. Main requirement of traffic signal are to draw attention, provide meaning and time to respond and to have minimum waste of time.

Fully actuated signal is a signal whose timing (cycle length green time etc) is completely influenced by the traffic volumes, when detected on all the approaches).

Fully actuated signals are not commonly used at intersections of two major streets and where substantial variations exits in all approach traffic volumes over the course of a day.

Type of Coordination of Traffic Signal System

There are four general types of coordination of signals for road network as listed below.

i. Simultaneous System

In this system all the signals along a given road always show the same indication (green, red etc) at the same time. As the division of cycle is also the same at all intersections this system does not work satisfactory.

ii. Alternate System

In this alternate signals or groups of signals show opposite direction in a route at the same time. This system is also operated by a signal controller, but by reversing the red and green indicator connections at successive signal systems. This system generally is considered to be more satisfactory than the simultaneous system.

iii. Simple Progressive System

A time schedule if made to permit as nearly as possible a continuous operation of group of vehicle along the main road at a reasonable speed. The signal phases controlling "go" indication along this road is scheduled to work at the predetermined time schedule. The phase and intervals at each signal installation may be different but each signal unit works as fixed time signal with equal signal cycle length.

iv. Flexible Progressive System

In this system it is possible to automatically vary the length of cycle. Cycle division and the time schedule at each signalized intersection with help of a computer. This is the most efficient system of all the four types described above.

Terminology

Green Time

Green time for a particular road is designed as per the traffic volume on that road. It is provided to allow the traffic flow.

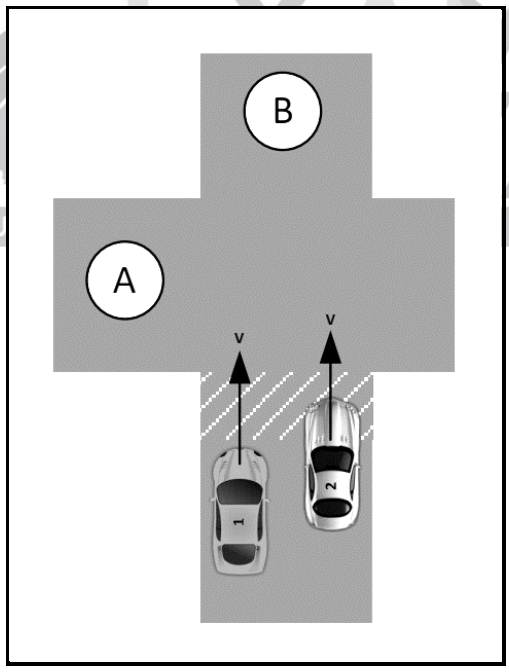
Red Time

Red time is provided to stop the traffic on road. It is design on the basic of traffic volume of crossroad.

Amber Time

It is the warning time clearance time which is provided after green time for clearance of traffic in order to allow the traffic flow in crossroad

Design of Amber Time



Saturation flow rate (vehicle/hr), $S_i = (\frac{3600}{h})_{vehicle/hr}$

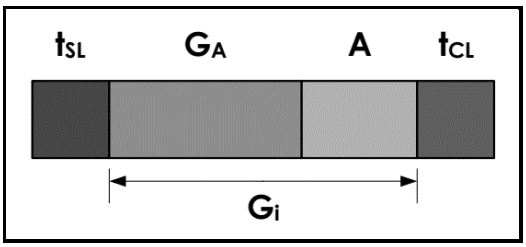
Clearance Lost Time

During phase change and clearance time is not utilized effectively which is known as clearance lost time.

Effective Green Time (G_i)

Effective green time is actual time available for vehicle to cross the intersection.

$$\mathbf{G_i = G + A - T_L}$$



Note
- If clearance lost time is not known then it can consider equal to amber time

CAPACITY OF LANE

$$\textbf{Capacity of lane} = (\frac{3600}{h} X \frac{G_i}{C})$$

Where,

h = saturation time headway

G_i = Effective green time

C = total cycle time

$\frac{3600}{h}$ = Solution flow

$\frac{G_i}{C}$ = Green ration

Capacity lane = Saturation flow X Green ratio

R = All red time (clearance time)

Y = Sum of ration of normal to saturation flow

$= y_A + y_B + \cdots$

$= (\frac{q_A}{S_A})_{for\ phase\ 1} + (\frac{q_B}{S_B})_{for\ phase\ 2} + \cdots$

Effective Green Time

$$G'_A = \frac{Y_A}{Y}[L_o - L]$$

$$G'_B = \frac{Y_B}{Y}[L_o - L]$$

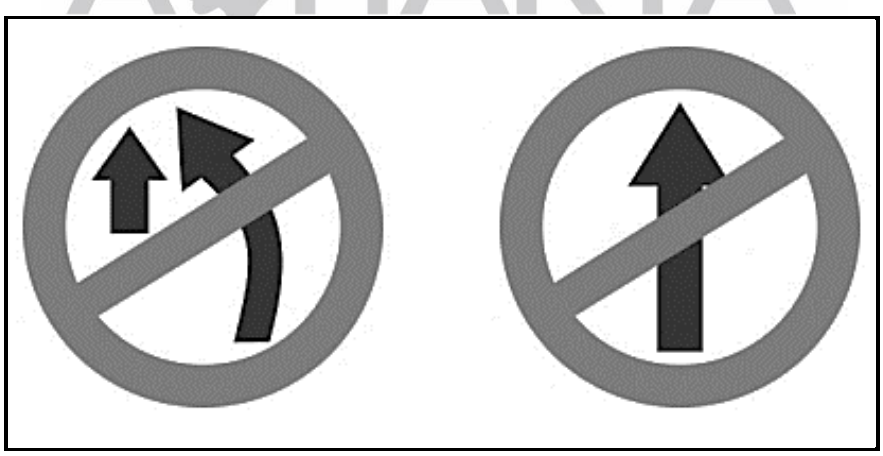
TRAFFIC SIGN

a. Regulatory or Mandatory Sign

Shape = circular

Background color = white

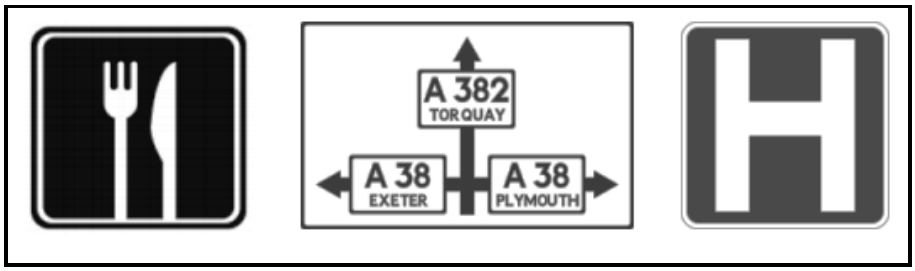
Boundary = Red



c. Information Signal

Shape = rectangular

Color = not fixed



Written letter on a black color.

New Batches are going to start.....

Contact:

7622050066

Test Series Available..

Total weekly test : 35

Total mid subject test : 16

Total full length test : 13

Mock test : 16

Total test : 80

Qu5 The PCU value for car is

a) 0.5

b) 1.5

c) 3

d) 1

Qu6 The minimum PHF value is

a) 0.25

b) 0.5

c) 0.1

d) 1

TEST YOUR SELF

Qu7 Angle of peripheral vision on horizontal plane is

a) 115 degree

b) 135 degree

c) 150 degree

d) 160 degree

Qu8 Find out co efficient of friction if breaking distance is 5.8 m and speed is 30 km/hr?

a) 0.576

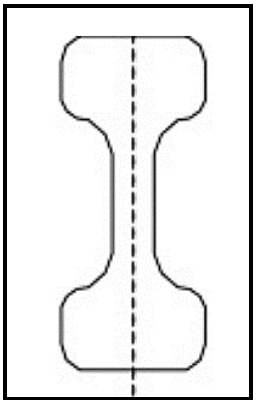
b) 0.611

c) 0.629

d) 0.345

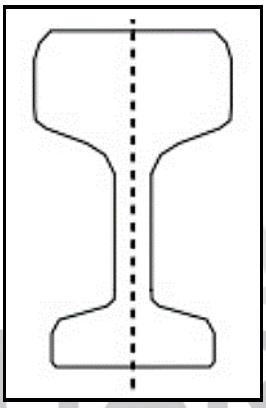
Answer

1-(b), 2-(b), 3-(b), 4-(c), 5-(d), 6-(a), 7-(d), 8-(b)



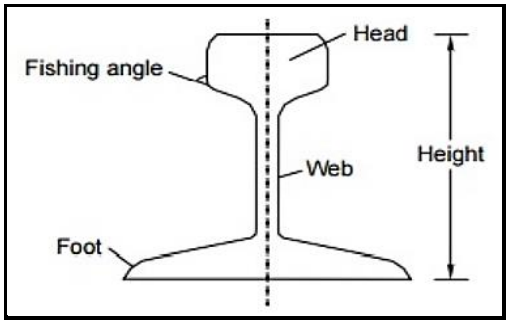
2. Bull Headed Rails

In bull headed rails the head was made a little thicker and stronger than the lower part.



3. Flat Footed Rails

Flat footed rails are also called Vignole's rails after the name of the inventor. Bearing plates are used between the sleeper and rail at rail joints. These rails are designated by weight of rail per unit length. 52 kg/m or 52 MR and 60 kg/m or 60 MR Flat footed rails are used in India. 52 kg rails is suitable up to speed of 130 kmph and 60 kg rail is suitable up to speed of 160 kmph.



DEFECTS ON RAILS

1. Corrugated Rails

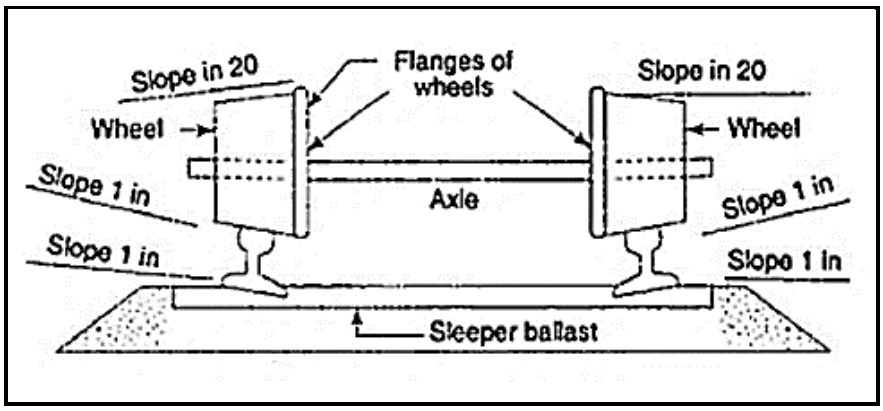
The corrugation of rail consist of minute depressions on the surface of the rails. These are usually created at the place where either brakes are applied or train starts. When train pass over it roaring sound occurs.

2. Kinks in Rails

When ends of adjoining rails, move slightly out position, kinks are formed. These occurs due to loose packing of joints.

CONING OF THE WHEEL

The wheels of the train are made at a slope of 1:20 this is known as coning of the wheel.



Advantages of Coning the Wheels

Coning the wheels reduces the depreciation of the wheel rims and rails. Depreciation is caused because of the friction action of rims with inner faces of the rail top. Coning also gives an option of lateral drift of the hinge with its wheels. Coning also prevents to some extent, the slipping of the wheels.

TYPES OF WELDED RAILS

Standard Rail Length

B.G. = 13 m

M.G, N.G = 12 m

Types of Welded Rails

In India the present practice is to use the following types of welded rails:

1. Long Welded Rails (LWR)

Long welded rails are one whose central part does not undergo any longitudinal movement and only end portion are affected due to temperature variations.

MAXIMUM AXLE LOAD

In India, the ratio between the weight of the rail and the locomotive axle load is taken as $\frac{1}{560}$.

$$\frac{\textbf{weight of the rail}}{\textbf{locomotive axle load}} = \frac{\mathbf{1}}{\mathbf{560}}$$

For a 52 kg/m rail

Maximum axle load = 52 x 560

= 29120 kg

= 29.12 tonne

CREEP OF RAILS

Creep is defined as the longitudinal movement of the rails in a track in the direction of motion of the locomotives.

Creep is common to all railway tracks, but varies considerably in magnitude. In some places its magnitude is negligible but at some other places its value may be as high as 15cm per month.

Indications of Creep

The occurrence of creep can be noticed by:

1. Closing of successive expansion spaces at rail joints in the direction of creep and opening out of joints at the point from where the creep starts.
2. Marks on rail flanges and webs made by spike heads by scratching as the rails slide.

WEARING OF RAILS

The following measures may be adopted to minimize wear of rails.

1. By coning of wheels
2. By Providing super elevation of curves.

In addition to the above-mentioned measures, the following measures can be employed:

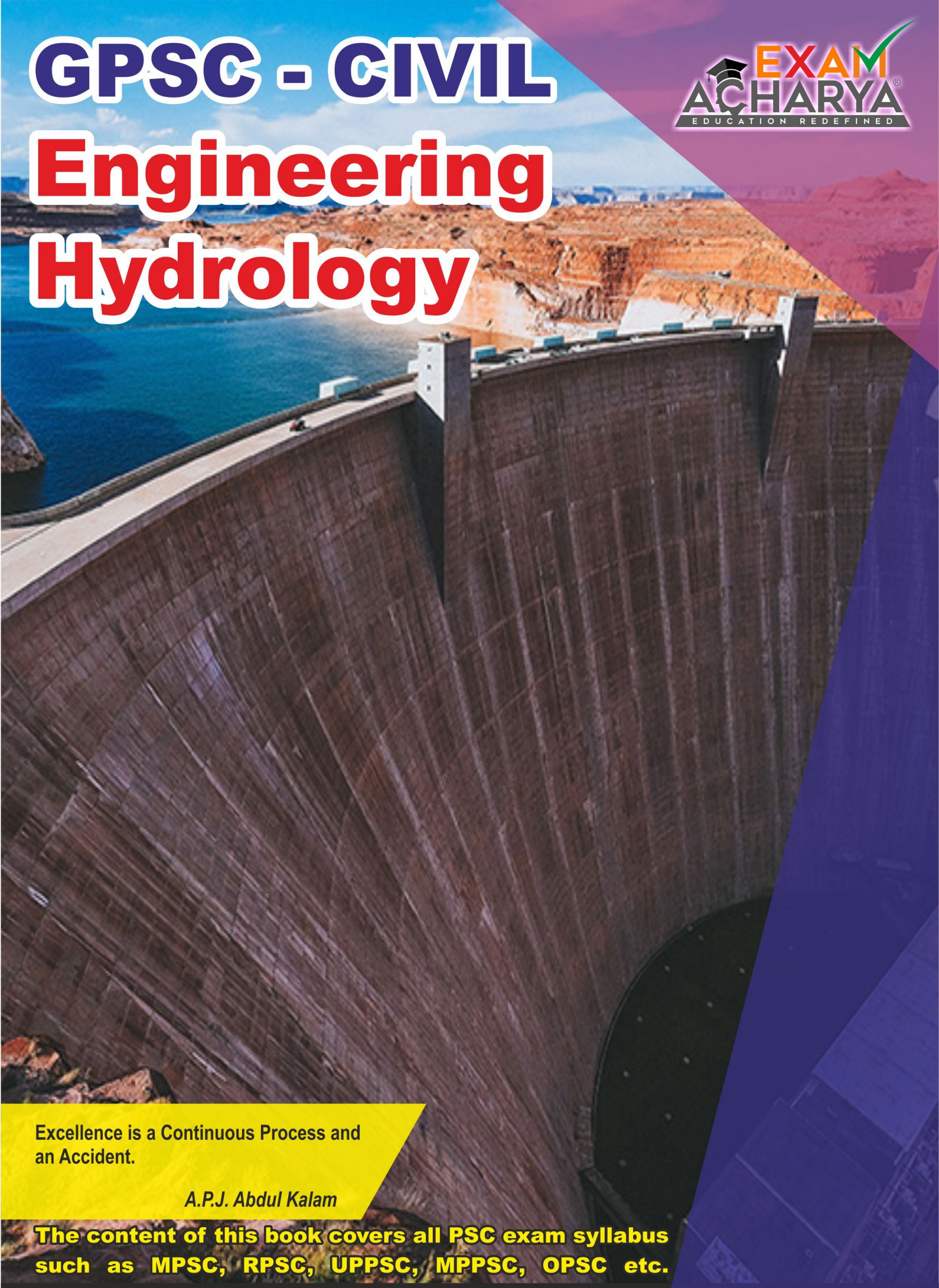
1. Use of special alloy steel.
2. Reduction of expansion gap
3. Reduction in number of joints by welding rails.
4. Regular tightening of fish bolts and packing of ballast is necessary to reduce the wear at ends
5. Welding or dehogging of battered ends at proper time will also reduce wear.
6. Maintenance of track with special reference to the joints is necessary to reduce the wear.
7. Exchange of inner and outer nails on curves.
8. The application of lubricating oil on curves on the inner side of the head of outer rail results in reduction of wear of rail.
9. Maintenance of correct gauge will reduce the side wear.

CHECK RAIL

At curve the check rails parallel to the inner rails can be introduce to check wear. Because the gap between the inner rail and check rail is equal to flange thickness of wheel so the outer wheel is prevented from damaging the outer rail. Thus the side wear on inner side of the outer rail is reduced by introducing the check rail.

In India the gap between the inner rail and check rail is kept as 44 mm for B.G track and 41 mm for M.G. track.

GPSC - CIVIL Engineering Hydrology



EXAM ACHARYA
EDUCATION REDEFINED

Excellence is a Continuous Process and an Accident.

A.P.J. Abdul Kalam

The content of this book covers all PSC exam syllabus such as MPSC, RPSC, UPPSC, MPPSC, OPSC etc.

Types of Rail Joints (According to position of sleepers)

(i) Supported joint – rail end rest on sleeper.

(ii) Suspended joint – rail ends are projected beyond the sleepers.

(iii) Bridge joint – rail ends are projected beyond the sleepers but connected by metal flat.

Types of Rail Joints (According to position of joint)

(i) **Square joint**: - The joints in one rail are exactly opposite the joints in the other rail.

- This joint is common on Indian railway.

(ii) **Staggered joint:** - The joints in one rail are staggered and are not opposite to the joints in the other rail.

- This joint is preferred on curved tracks.

COMPOSITE SLEEPER INDEX (CSI)

It is an index used to determine the stability of a particular timber for use as a sleeper. This index is derived from composite properties of strength and hardness.

$$\textbf{C.S.I} = \frac{S + 10H}{20}$$

Where,

S = Strength index, both for green and dry timber at 12 % moisture content.

H= Hardness index, both for green and dry timber at 12 % moisture content.

Minimum values of C.S.I prescribed on Indian Railways is as follows:

Type of sleeper	Minimum C.S.I.
Track sleeper	783
Crossing sleeper	1352
Bridge Sleeper	1455

Function of Sleeper

i. To hold the rails to gauge in all situations i.e exact gauge along straight and flat curves, slightly loose on sharp curves and slightly tight in diamond crossing.

ii. To support the rails firmly and evenly throughout.

iii. To distribute the load transmitted through rails over large area of ballast underneath or to the bridge girders as the case may be.

iv. To hold the rails to proper level in turnouts and crossovers and at 1 in 20 in wars slope along straight tracks.

v. To provide an elastic medium between the rails and ballast and also to absorb the vibrations caused due to moving axle loads.

vi. To maintain proper alignment of the track. On curves proper cant is provided by raising the outer rail and tamping he required quantity of ballast bellow the rails.

vii. To provide the general stability of the permanent way throughout.

viii. To provide the insulation of track for the electrified for signaling.

ix. To provide easy replacement of the rail fastenings without any serious traffic disturbances.

x. Holding rails to correct gauge and alignment.

xi. Firm and even support to rails.

Disadvantages of wooden sleepers

They are easily subjected to wear and decay due to various factors, i.e vermin, white ants, rail cutting, warping, etc, hence these have a short life.

i. They do not maintain the gauge accurately
ii. They easily develop cracks with beater packing
iii. They require the highest maintenance cost as compared to other types of sleepers.
iv. They get easily disturbed from their positions under heavy loads
v. They need special treatment for fire protection
vi. Their scrap value is low.
vii. They are not suitable for modern LWR track because of their lighter weight.

Description of wooden sleepers

Size of wooden sleepers in mm (B.G) for ordinary track 2750 x 250 x 130 (9 ft x 10 inch x 5 inch). Life of sleeper for B.G 19 year and 31 years for M.G.

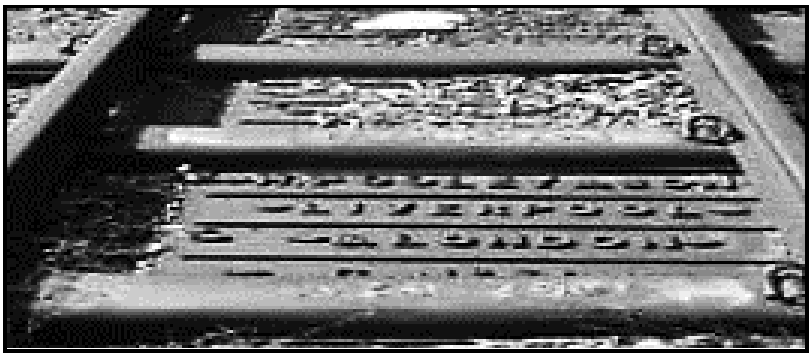
ii. Steel Sleeper

They are in the form of steel through on which rails are fixed by keys or nuts or bolts.

Types of cast iron sleepers

a. C.I. pot sleepers

b. CST – 9 sleepers



Advantages of cast iron sleepers

i. Long life up to 50- 60 years

ii. High scrap value as they can be remolded.

iii. Can be manufactured locally

iv. Provided sufficient bearing area.

v. Much stronger at the rail seat

vi. Prevent and check creep of rail.

vii. They are not attacked by vermin.

Disadvantages of iron sleepers

i. They are prone to corrosion and cannot be used in salty formations and coastal areas.

ii. Not suitable for track circuited portions of railways

iii. Can badly damage under derailment

iv. Require a large number of fastening materials

v. Difficult to maintain the gauge as the two pots are independent.

vii. Difficult to handle and may be easily damaged.

viii. They are expensive.

ix. Prevent buckling more efficiently

x. Initial cost is high but proves to be economical in long run

xi. Effectively and strongly hold the track to gauge.

xii. Inflammable and fire resistance.

Disadvantages of concrete sleepers

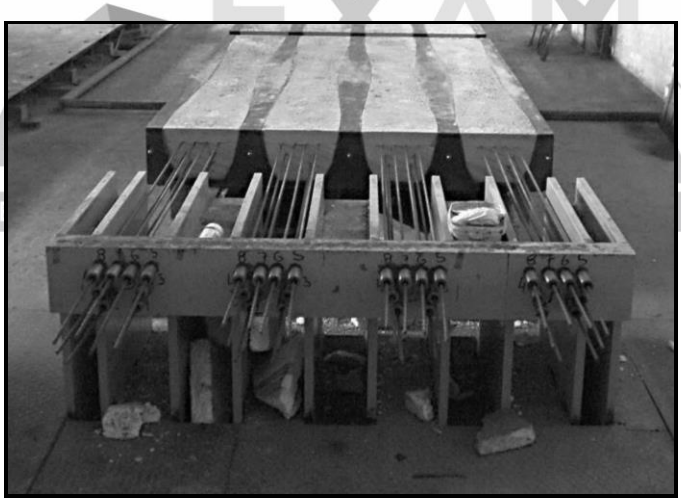
i. Difficult to be handled

ii. Difficult to be manufactured in different sizes thus cannot be used in bridges and crossing.

iii. Can be damaged easily while loading and unloading

v. Pre stressed concrete sleepers

The concrete is put under a very high initial compression. All the disadvantages of RC sleepers have been



Two types of pre stressed sleepers

i. Pre tensioned sleeper

ii. Post tensioned sleepers

also included at parameters to be considered while arriving at the geometric design of the track. Gradients in the track including grade compensation rising gradient, and falling gradient, curvature of the track including horizontal and vertical curves, transition curves, sharpness of the curve in terms of radius or degree of the curve or super elevation on curves, etc. Alignment of the track, including straight as well as curved alignment.

Necessity for Geometric Design

The needed for proper geometric design of a track arises because of the following considerations:

a. To ensure the safe and smooth running of trains.
b. To achieved maximum speed
c. To carry heavy axle load
d. To avoid accidents and derailments due to a defective permanent way.
e. To ensure that the track requires least maintenance
f. For good aesthetics.

GRADIENTS

Gradients are provided to negotiate the rise or fall in the level of the railway track. A rising gradient is one in which the track rises in the direction of the movement of traffic and a down or falling gradients is one in which the track losses elevation in the direction of the movement of traffic

Objective of Gradients

Gradients are provided to meet the following objectives.

a. To reach various stations at different elevations.
b. To follow the natural contours of the ground to the extent possible
c. To reduce the cost of earth work.

negotiate gradients steeper than the ruling gradient. In sections with momentum gradients there are no obstacles provided in the form of signals etc. which may bring the train to a critical junction. The quantity of motion of a moving body, measured as a product of its mass and velocity.

d. Gradients in Station Yards

The gradients in station yards are quite flat due to the following reasons

a. To prevent standing vehicles from rolling and moving away from the yard due to the combined effect of gravity and strong winds.
b. To reduce the additional resistive forces required to start a locomotive the extent possible.
c. It may be mention here that generally yards are not leveled completely and certain flat gradients are provided in order to ensure good drainage.
d. The maximum gradient prescribed in station yards on Indian Railways is 1 in 400 while the recommended gradient is 1 in 1000.

Grade Compensation on Curve

Curves provided extra resistance to the movement of trains. As a result, gradients are compensated to the following extent on curves.

a. On BG tracks 0.04% per degree of the curve or $\frac{70}{R}$ whichever is minimum.
b. On MG tracks 0.03% per degree of the curve or $\frac{52.5}{R}$ whichever is minimum.
c. On NG tracks 0.02% per degree of the curve or $\frac{35}{R}$ whichever is minimum.

Where,

R = radius of the curve in meters.

Maximum Limit of Super Elevation

Track	Speed <120 kmph	Speed > 120 kmph
BG	16.50 cm	18.50 cm
MG	10 cm	-
NG	7.6 cm	-

Maximum value of super elevation is 1/10 of the gauge.

When loads or pressure on both rail is equal the cant provided is known as equilibrium cant.

CANT Deficiency

The actual cant is provided on the basis of equilibrium speed or average speed of different trains. For the trains running higher the speed of equilibrium speed actual cant requirement is more the provided. This shortage of cant is known as cant deficiency. cant deficiency is the difference between the equilibrium cant necessary for the maximum permissible speed on a curve and the actual cant provided.

Limit of CANT Deficiency

Cant deficiency is limited because

a. Higher cant deficiency gives much discomfort to passengers.

b. Extra pressure and lateral force on outer rail.

Track	Speed <120 kmph	Speed > 120 kmph
BG	7.6 cm	10.00 cm
MG	5.1 cm	-
NG	3.8 cm	-

rigidity of the wheel base cause the trailing axle to occupy a different position. In an effort to make up for the difference in the distance travelled by the outer wheel and the inner wheel, the inside wheels slip backward and the outer wheels skid forward. A close study of the running of vehicles on curves indicates that the wear of flanges eases the passage of the vehicle round curves as it has the effect of increasing the gauge. The widening of the gauge on a curve has, in fact, the same effect and tends to decrease the wear and tear on both the wheel and the rail.

The width on cures **(w)** = $\frac{13(B+L)^2}{R}$ ... ... in cm

Where,

B = rigid wheel base in meters

= 6 m for B.G track

= 4.88 m for M.G track

R = Radius of the curve in meters

L = Lap of flange in meters.

POINTS AND CROSSINGS

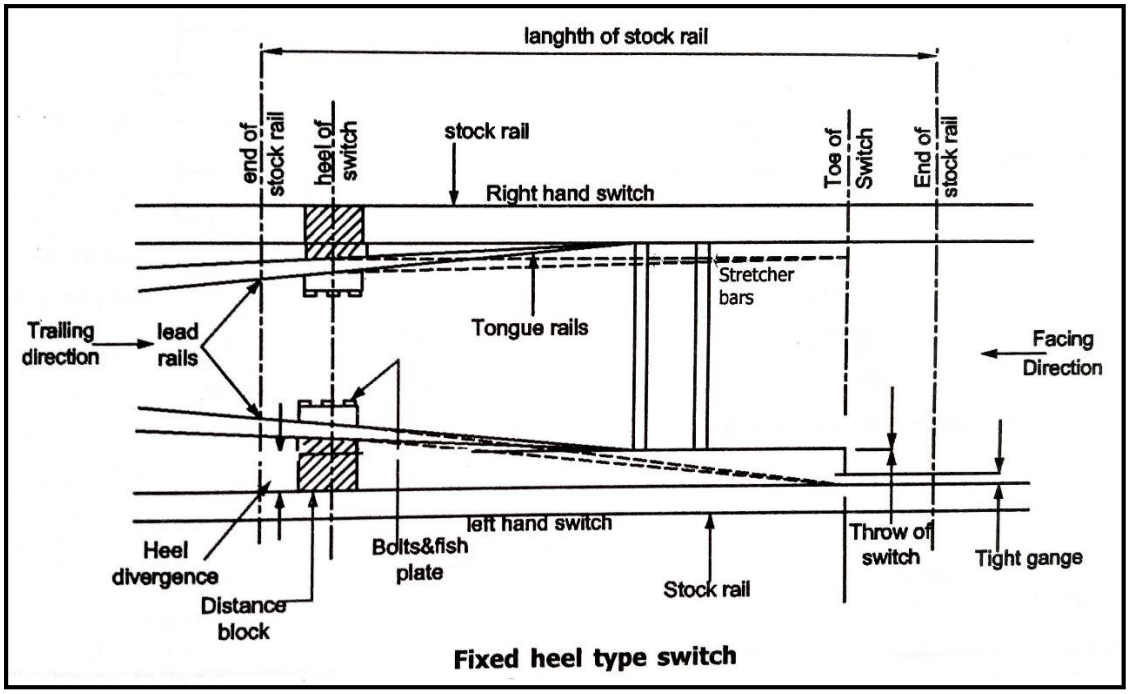
Points and crossings are special arrangements provided on railway tracks for enabling trains to be diverted from one track to another.

Functions of Points and Crossings

1. Points and crossings provided flexibility of movement by connecting one line to another according to requirements.
2. They also help for imposing restrictions over turnouts which necessarily retard the movements.

TURNOUT

Turnout is the simplest combination of points and crossings by operation of which a train is diverted to another track.



Fixed heel type switch

New Batches are going to start.....

Contact:

7622050066

Test Series Available..

Total weekly test : 35

Total mid subject test : 16

Total full length test : 13

Mock test : 16

Total test : 80

Qu5 Kinks on rail forms due to

a) Battering action of wheels

b) Due to loose packing of joints at end

c) Due to improper ballast material

d) Use of fish plate at joints

Qu6 CST-9 sleeper is used upto speed of

a) 110 kmph

b) 120 kmph

c) 130 kmph

d) 145 kmph

TEST YOUR SELF

Qu7 For a sleeper density (in +5), number of sleepers required for constructing a broad gauge (BG) track of length 650.

a) 975

b) 918

c) 900

d) 880

Qu8 The grade compensation of 4° curve on a Broad gauge railway track is

a) 0.20%

b) 0.16%

c) 0.12%

d) 0.08%

Answer

1-(b), 2-(c), 3-(c), 4-(d), 5-(b), 6-(c), 7-(b), 8-(b)

9. Tunnels provide protection from bombing during aerial warfare.
10. Tunnels avoid acquisition of costly land property.
11. Tunnels provide protection against weathering agencies like wind, rain, sun etc.

Disadvantages

1. The initial cost of construction of a tunnel is high as compared to an open cut
2. Construction of tunnels requires long time in completing as compared to open cut.
3. Specialised equipments and methods are required.
4. It is necessary to have skilled labour and technical supervision of high order for the construction of a tunnel.

CLASSIFICATION OF TUNNELS

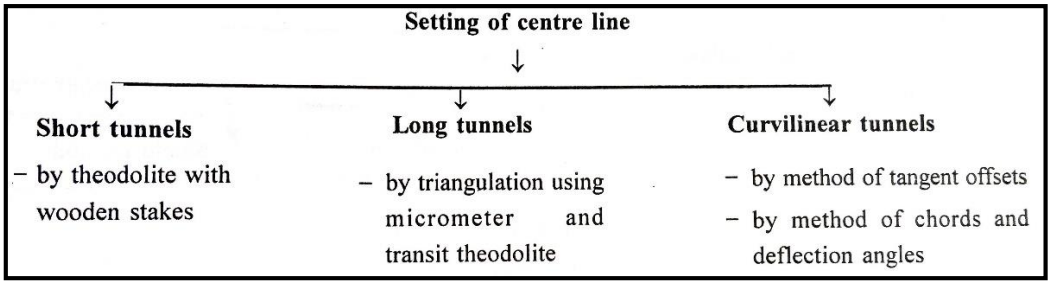
Classification Based on the Purpose

Traffic Tunnels: For carrying traffic such as

i. Highway tunnels
ii. Railway tunnels
iii. Pedestrian tunnels
iv. Navigation tunnels
v. Subway tunnels

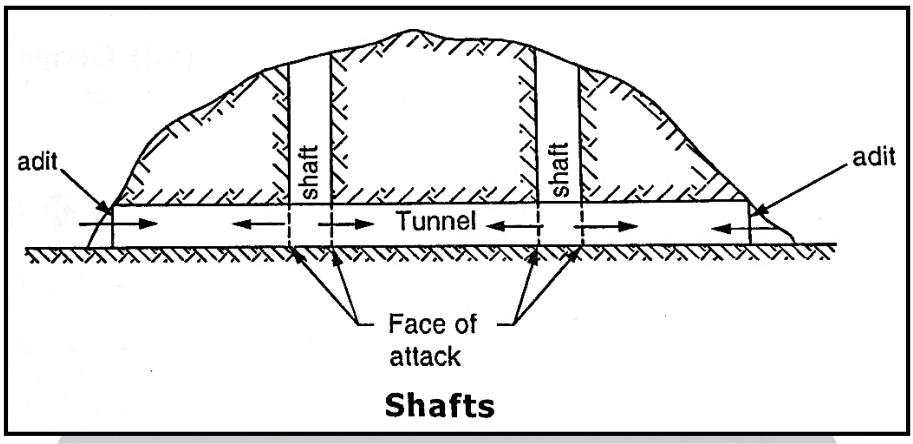
Conveyance Tunnels: For conveying utilities such as

i. Water supply tunnels
ii. Hydroelectric tunnels
iii. Sewer tunnels
iv. Tunnels for carrying public utility services



SHAFTS

Shafts are vertical wells or passages reaching from ground surface down to the tunnel roof along the centre line of a tunnel at one or more points, between the entrances, to permit the tunnel excavation to be attacked at several points at the same time. Each shaft provides two additional faces to work as shown in figure.



- Shaft facilitate removal of muck water
- Shaft facilitate delivery of materials.
- Shafts provide passage for workman, construction tools, machinery, etc

PORTALS

The main entrance of the tunnels are known as portals. These are the actual doorway of tunnels.

EXAM ACHARYA
EDUCATION REDEFINED

GPSC - CIVIL

Fluid Mechanics and Hydraulic Machines

"Success Consists of going from Failure without Loss of Enthusiasm."

Winston Churchill

The content of this book covers all PSC exam syllabus such as MPSC, RPSC, UPPSC, MPPSC, OPSC etc.

CLEAR YOUR CONCEPT

Qu1 Which one of the following is a component of a shield for tunneling?

a) Linear plate

b) Trench jack

c) Stiffener

d) Cutting edge

Qu2 Tunnel alignment is carried out by

a) Surface theodolite traverse

b) Triangulation

c) Compass traverse

d) Aerial photography

Qu3 In full face method of constructing tunnel, the first operation relates to

a) Removal of bottom portion

b) Excavation of one drift at the centre

c) Removal of top portion

d) Excavation being done along the perimeter

Qu4 Which of the following method of tunneling is used in hard rocks

a) Fore poling method

b) Needle Beam Method

c) Heading and Benching method

d) Shield tunneling method

CHAPTER – 8

BRIDGE ENGINEERING

INTRODUCTION

A bridge is an arrangement made to cross an obstacle in the form of a low or a ground or stream or a river or over a gap without closing the way beneath. The bridges are required for the passage of railways, roadways, footpaths and even for the carriage of fluids.

It is quite evident that the development of the science of bridge engineering has taken place with the development of human civilization. In the beginning, the men used fallen trees or wooden logs to function as the bridges.

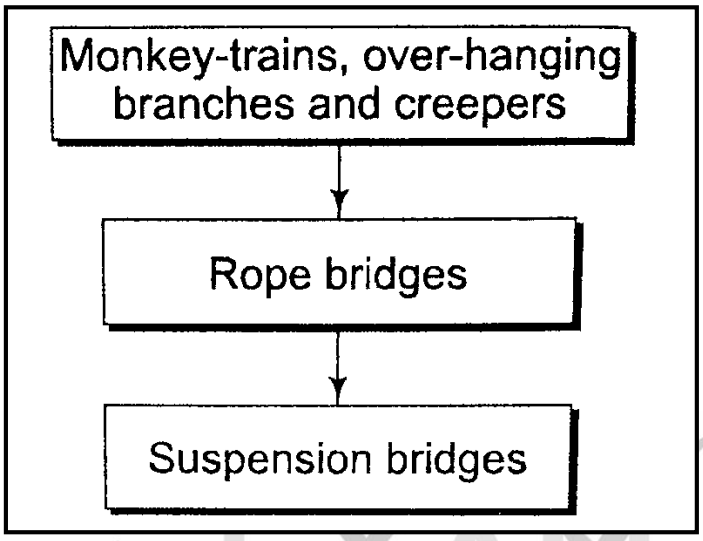
At present the bridge engineering has become a specialized subject by itself.

Following are the important factors which are responsible for putting the subject of bridge engineering on the scientific footing:

1. Advances made in other branches of engineering such as hydraulics, soil mechanics, structural engineering etc,
2. Advent of new materials of construction.
3. Concept of new design ideas in theory.
4. Improvement in the methods of construction.
5. Increase in loads of railways and highways etc.

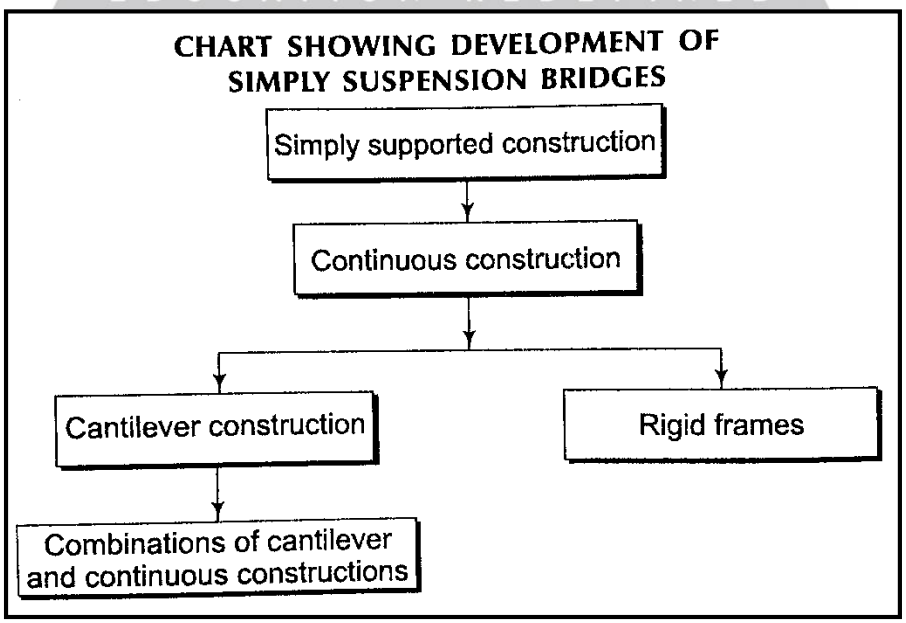
Suspension Bridges

It was observed that even monkeys from the monkey – trains, one monkey linking with another for getting across a long gap over the tree – tops. The suspension bridges are nothing but a development of the monkey trains or connecting together creepers hanging from trees for crossing, as shown in chart.



Simply Supported Bridges

The development of simply supported bridges is shown in chart.



iii. Changing attitudes towards aesthetics in bridges.

iv. Increasing knowledge of the properties and behaviour of new materials

v. Changing requirements of traffic and communication and

vi. Improvement of various construction techniques.

The new trends in the design of bridges are sophistication and very accurate analysis. The need of sophistication has arisen because of the following factors:

i. Availability of computer Aided Design (CAD) for quick and accurate analysis

ii. Efforts to make maximum use of local resources with appropriate technology.

iii. increasing awareness of durability, serviceability and constructability, inspection and maintenance, aesthetics and quality assurance

iv. increasing knowledge of other forces acting on structure which very much affect the analysis and design.

v. Use of new materials having high strength and

vi. Use of very large spans.

With the help of computer, it is now possible to design many complex structural forms for different load combinations. This has resulted in the better analysis of structures. The properties of materials are also known better and hence both the things have allowed engineers to adopt higher stress in materials and to reduce overall margin for safety. Another major change in design of bridges is the adoption of limit state concept instead of working stress concept.

Following are the two notable developments in bridge construction techniques:

i. Use of cantilever construction method; and

ii. Use of push launching of the entyre superstructure

Several bridges have been designed and constructed in India with the help of these techniques.

flooring, guard stones, handrails, etc. Thus, superstructure consists of structural members carrying a communication route.

The other components of the bridge are approaches, bearings and river training works like aprons, revetment for slopes at abutments, etc.

IMPORTANCE OF BRIDGES

1. The bridges serve as the most useful links on the land connecting big towns and cities and hence, in case of war or calamities the destruction of bridges stops the mobility of army or essential goods.
2. The site of a bridge should therefore be properly selected with respect to strategic considerations and all proper precautions and measures should be taken to maintain the bridges in the perfect working order.
3. The subject of bridge engineering is given special attention during the course of military training due to the fact that the army should be capable of putting quickly the new bridges, while advancing and if destroying the existing bridges while retreating.
4. The construction of bridge in a road or rail project is the costliest part and hence, it calls for the utmost economy.
5. It takes the longest time for completing and requires carefully planning, considerable amount of forethought and detailed study of various aspects.
6. It may also be noted that the bridges across rivers and streams are the most vulnerable because any major damage to the structure can completely upset the total communication system.

It is for this reason that no undue risk can be taken in their design and construction. The economy in bridge construction as well as its long life can be successfully achieved only by the use of proper materials, effective supervision and economic method of construction.

- Embankment, Guide banks & Spurs/Groynes
- Bridge river training works options study & design
- Bank, bed & abutment protection
- Flood relief openings
- Bank erosion & counter measures design
- Scour elimination & protection measures design
- Bridge soffit levels determination
- Culvert & floodway Design

Bridge Inspections / Safety Audits

- Level 1 Bridge Inspection – Routine Maintenance
- Level 2 Bridge Inspection – Condition Assessment
- Specialised inspection – Post Flood Inspection
- Bridge vulnerability study to flood Hazard Risk and climatic change
- Inspection programme QA/QC
- Preventative maintenance & rehabilitation programme development
- Evaluation & improving design and construction for new flood resistance bridges

2. **Ryve's formula:** Southern India

$$Q = CM^{2/3}$$

Where,

C = 6.8 for area within 25 km from coast

= 3.5 within 25 to 160 km

=10.1 for limited hilly areas

3. **Inglis formula:** This formula is used in Maharashtra state only

$$Q = \frac{4350\,m}{\sqrt{m+1.04}}$$

Where,

m = Catchment area in sq. km

Rational Method

Indirect method

This method is applicable for determination of flood discharge for small culverts only.

The runoff, $\mathbf{Q = 0.028 \times P \times F \times A \times I}$

Q = Discharge or runoff in m^3/sec

F = Co- efficient

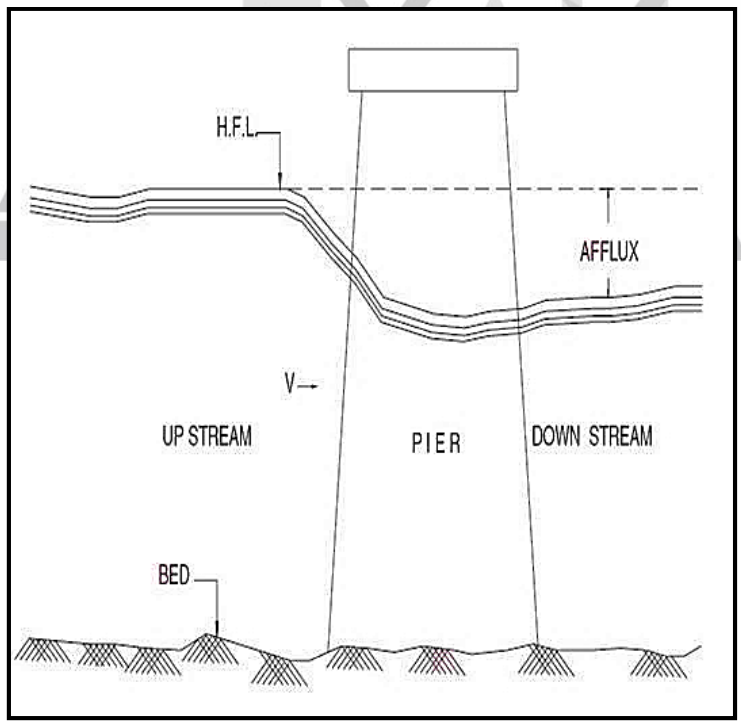
A = Catchment area in hectares

$\mathbf{I_c}$ = Critical intensity of rainfall in cm/hour

P = % coefficient of run – off

AFFLUX

- The phenomenon of heading up of water on the upstream site of the bridge is called afflux
- When a bridge is constructed, its components like abutments and piers, cause the reduction of the natural waterway.
- Due to this reduction in natural waterway, the velocity under bridge increases so as to carry the maximum food discharge.
- This increased velocity gives to a sudden heading up of water on the upstream side of the stream or river. The phenomenon of this heading up water is known as afflux.
- Thus greater the afflux greater will be velocity under downstream side of the bridge and greater will be the depth of sour consequently greater will be the depth of foundation required.
- Hence, determination afflux is necessary for the safe design of the bridge.



Selection of Bridge Site

Following are the factors to be carefully considered while selecting the ideal site for a proposed bridge:

1. connection with roads
2. Firm embankments
3. Foundations
4. Materials and labour
5. Right angle crossing
6. Straight stretch of river
7. Velocity of flow
8. Width of river

Each of the above factor will now be briefly described.

Connection with Roads

The bridges are constructed to connect the roads on either side of a river. The bridge site should therefore form a proper link between the roads on either side of a river. The bed of approaches connecting ends of bridge with the roads should be dry and hard. The approaches at the bridge site should be such that they do not involve heavy expenditure the approaches should avoid the cutting across the built – up area or religious structures because the acquisition of the land and structures will be expensive, time- consuming and sometimes may cause social problems.

Firm Embankments

The embankments on the upstream side and downstream side of bridge site should be firm, high, permanent, solid, straight and well defined. Such embankments are not disturbed at the time of heavy floods and they do not allow the course of river to alter.

v. The piers of the screw bridge have to resist excessive water pressures.

Straight Stretch of River

The river should have a straight stretch over a reasonable long distance on the upstream side and downstream side of the bridge site. Such a straight stretch of river ensure smooth and uniform flow of water and it allows smooth navigation. The curved stretch of river is not desirable as it creates problems during construction and maintenance of the bridge.

Velocity of Flow

It is very important to check that the velocity of flow at bridge site is proper. If velocity of flow is less the velocity of flow at bridge site is proper. If velocity of flow is less than a particular value, the silting will occur and on the other hand, if it is more than a particular value, the scouring will occur. As a matter of fact, the velocity of flow at bridge site should be between the range of non-silting and non – scouring velocities. The permissible velocity depends on the nature of bed of river. Table shows the permissible velocities for different types of beds of river.

TABLE: Permissible Velocities at Bridge Site

No	Nature of bed of river	Permissible velocity In cm per second
1.	Very fine sand	60 to 90
2.	Fine sand and loose clay	Upto 50
3.	Coarse sand	50 to 100
4.	Fine gravel, sandy or stiff clay	100 to 150
5.	Clay with sand	150
6.	Clay	200
7.	Soil with rock and coarse gravel	150 to 250
8.	Rock and boulders	250 to 500

1. Estimating the benefits that will accrue from the likely traffic to pass over the bridge.
2. Gathering data about the behaviour of the river at such sites by studying the available reports
3. Holding discussions with local knowledgeable people
4. Making an assessment of construction problems
5. Studying the existing pattern of traffic
6. Study of available maps
7. Visits to the various possible sites so as to understand the local features etc.

It should be possible at this stage to down the choice to three or four alternative sites for the proposed bridge.

Preliminary or Techno – Economic Feasibility Stage

In the second stage an attempt is made to bring out in full detail the comparative merits and demerits of the various alternatives site which are considered feasible in the first stage. The study of such a table would help in choosing the best site of the bridge. It is also necessary to work out the estimated costs of various alternative sites and such estimation should be done carefully so that the final cost may be within a range of plus or minus 15 percent of the final cost. For this purpose, some minimum field measurements are taken and detailed study of maps of the area is made.

The details to be obtained for each site should be tabulated with respect to the following aspects:

i. Construction and maintenance problem
ii. Distance from important city or town
iii. Expected duration of construction
iv. Length of approaches
v. Length of bridge
vi. Nature of flow at site

4. According to the form or type of superstructure, the bridges are classified as arch, bow – string girder, rigid frame or suspension bridges.
5. According to the materials of construction used for super structure the bridges are classified as cement concrete, masonry, steel or timber bridges.
6. According to the method of clearance for navigation, the bridges are classified as bascule, cut boat, lift, swing or traversing bridges.
7. According to the expected utility period of service, the bridges are classified as temporary or permanent bridges.
8. According to the function, the bridges are classified as road railway, road cum railway or pipe line bridges.
9. According to the method of connections adopted, the steel bridges are classified as riveted, welded or pin connected bridges.
10. According to the length of span, the bridges are classified as culvert, minor, major or long span bridges.
11. According to the degree of redundancy, the bridges are classified as determinate or indeterminate bridges.
12. According to the level of crossing of highways and railways, the bridges are classified as over bridges or under bridges.
13. According to the alignment, the bridges are classified as straight or screw bridges.
14. According to the loadings the road bridges and culverts are classified by the I.R.C as class AA, Class B bridges.

    It is thus seen that the bridges can be classified in a number of different ways, the classification of bridge with reference to the size has been done differently in our country by the road and rail engineers.

15. According to the road engineers, the bridges are classified on the basis of linear waterway as follows:

    i. Culverts ..... Upto 6 m

    ii. Minor bridges ..... 6 m to 30 m

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1. Simple bridge or beam bridge
2. Continuous bridges
3. Cantilever bridges
4. Arch bridges
5. Bow string girder type bridges
6. Rigid frame bridges
7. Suspension bridges
8. Cable stayed bridges

Simple Bridges or Beam Bridges

In case of simple bridges, the span is simply supported and they are sometimes referred to as the independent span bridges. Depending upon the position of superstructure, the simple bridges are divided into the following three categories:

1. Deck bridges
2. Through bridges
3. Semi through bridges.

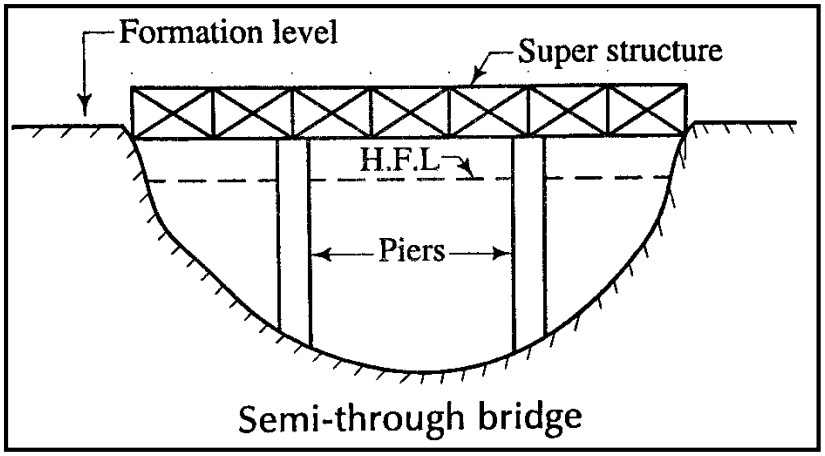
Deck Bridges

For any bridge, the following two levels are to be carefully decided:

i. **Formation level:** The ground level of approaches is to be taken into consideration for fixing the formation level of road or railway line.

ii. **Highest flood level or H.F.L:** While making the calculations for maximum flood discharge, the H.F.L for the river or stream is determined.

If it is to accommodate the superstructure of bridge between these two levels with suitable allowance for clearance as shown in fig. The bridge is known as the deck bridge.



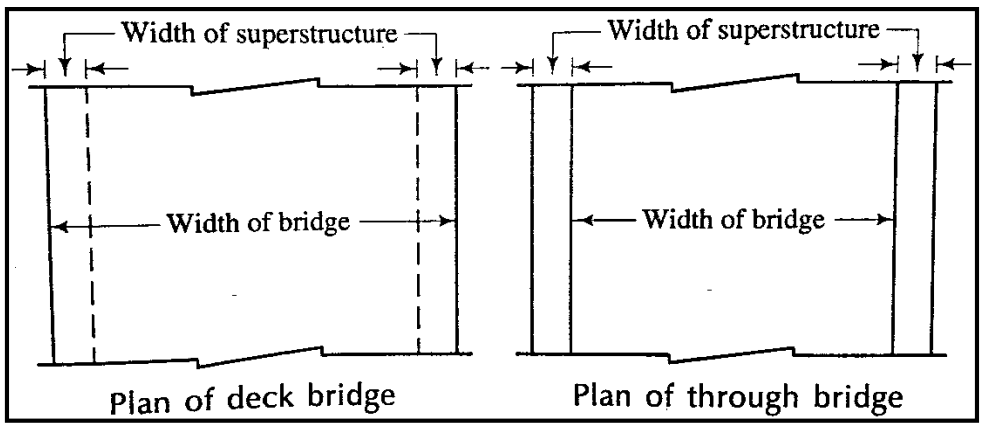
Out of three of simple bridges the deck type proves to be economical.

Following are the advantages of a deck bridge:

i. **Effect of horizontal forces:** The effect of various horizontal forces such as tractive effort and wind load will be comparatively less on a deck type bridge than that on a through type bridge. The deck bridge gets this advantage as its super structure is situated below the formation level of road or railway line.

ii. **Erection:** For steel bridges, it proves to be easier to erect the superstructure of a deck bridge than that of a through bridge.

iii. **Natural scenery:** A deck bridge grants better view of the surrounding scenery and hence, it is preferred to the through bridge for carrying the highway traffic.



moment and shear force at various sections along the span of bridge. It is therefore necessary to check that the foundations of supports rest on hard and firm soil. At places where there are chances for foundation to sink or settle, the continuous bridges are not adopted.

Following are the advantages of R.C.C continuous girder bridges over simply supported girder bridges:

i. As the bearings are placed on the centre lines of piers, the reactions at piers are transmitted centrally.

ii. It is found that the continuous girder bridge suffers less vibration and deflection.

iii. The continuous girder bridge requires only one bearing at each pier as against two bearings for simply supported girder bridge.

iv. The depth of decking at midspan is reduced and it may prove to be useful for over bridges where the headroom is of prime consideration.

v. The expansion joints required will be less.

vi. There is reduction in cost as less quantities of concrete and steel are required.

Following are the disadvantages of R.C.C continuous girder bridges over simply supported girder bridges:

i. The design is more complicated as it is a statically indeterminate structure.

ii. The detailing and placing of reinforcement are to be carried out with extreme care.

iii. The placing of concrete and removal of framework are to be executed carefully in proper sequence.

Cantilever Bridges

A cantilever bridge is formed of the cantilevers projecting from the supporting piers. The ends of a cantilever bridge are treated a fixed. A cantilever bridge combines the advantages of a simply supported span and a continuous span. For long spans and deep

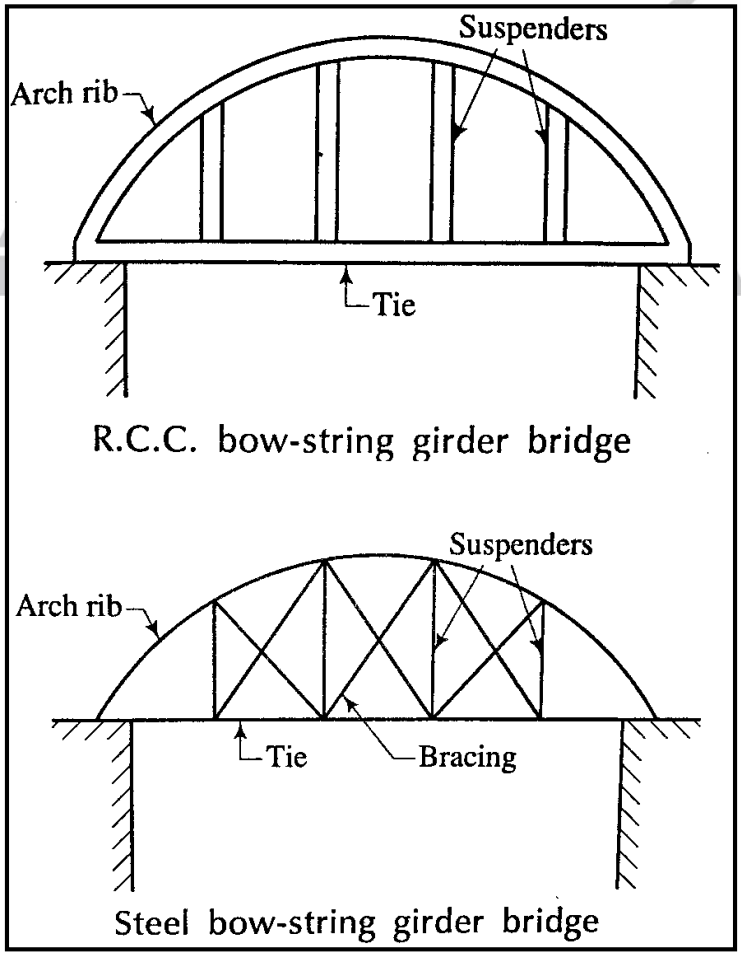
is transmitted to the arch rib through suspenders. Suitable bracing may also be provided in case of steel bow string girders.

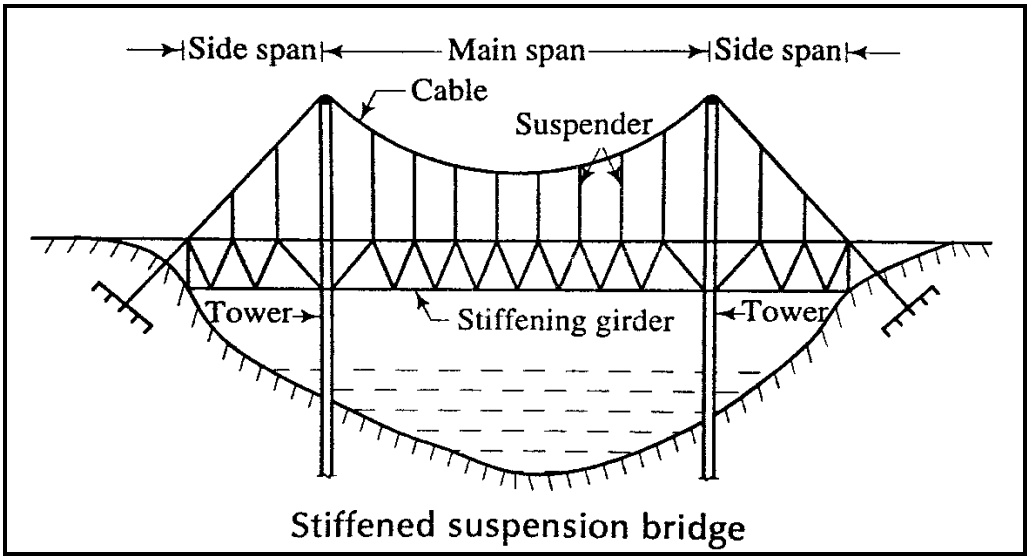
The bow string girder type bridge removes the following two disadvantages of the arch bridges:

i. The horizontal thrust is resisted by ties. Hence the reactions at supports are vertical and not inclined as in case of the arch bridges. As a result of vertical reactions the supports require lighter sections.

ii. The bow string girders project above the formation level of road or railway line. Hence the question of accommodating the rise between the level of approaches and the springing level of ach does not arise.

The bow string girder type bridges are therefore very suitable for multiple spans and at places where the available clearance is restricted.





Stiffened suspension bridge

Cable Stayed Bridges

The cable stayed bridges are similar to the suspension bridges expect that there are no suspenders in the cable stayed bridges and the cables are directly stretched from towers to connect with the decking. Thus no special external anchorage is required for the cable as in case of the suspension bridges because the anchorage at one end is done in the girder and at the other on top of tower

Each anchorage in girder introduces horizontal and vertical forces. The cross girders or diaphragms take up the vertical forces. The stiffening girders are designed to take bending stresses and also a compressive force which is induced by the horizontal component of the force on the cable.

Fig. shows the cable stayed bridges. The cable can be arranged with two plane system or one plane system as shown in fig.

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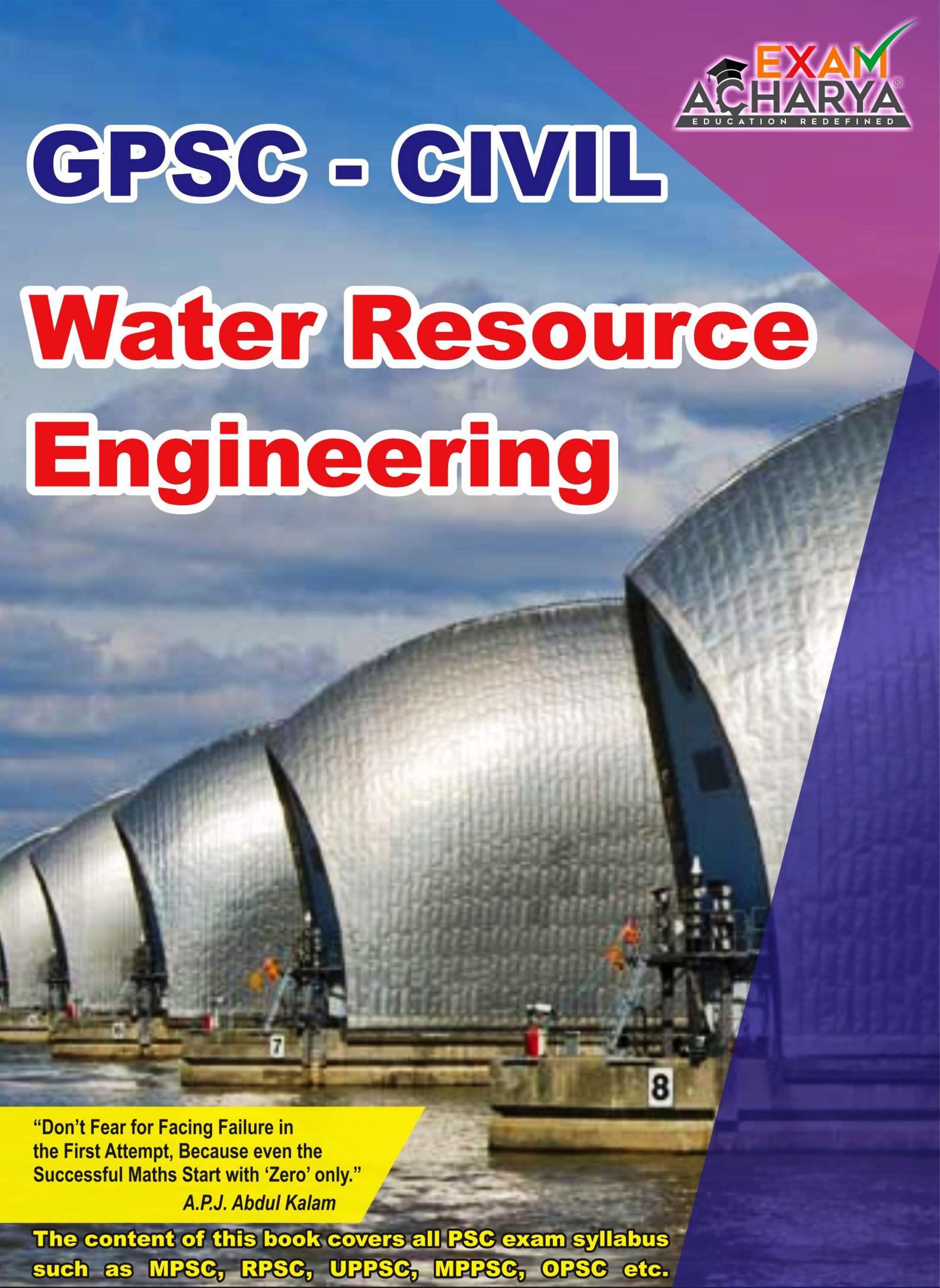
Water Resource Engineering



"Don't Fear for Facing Failure in the First Attempt, Because even the Successful Maths Start with 'Zero' only."

A.P.J. Abdul Kalam

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bridges the use is made of high strength steel generally coupled with high strength concrete.

The pre stressing of steel and concrete considerably improves the behaviour and strength of a concrete bridge. The pre stressing of steel enables it to work at a higher stress level and pre compressing the concrete delays its cracking. The new concepts techniques and methods have been developed for pre stressed concrete bridges.

Masonry

The brick masonry or stone masonry is generally used in the construction of arches for bridges of moderate span. The masonry work should be carried out in rich cement mortar. As the masonry is weak in tension, it must be checked that no tension develops in any portion of the arch under the worst combination of dead load and live load.

The bricks to be used for brick masonry should be table moulded or ground moulded, well burnt in kilns, copper- coloured, free from cracks and with sharp and square edges. They should be uniform in shape and should give clear ringing sound when struck with each other. They should be well soaked in the water before their use.

The stones to be used for stone masonry should be hard durable and tough and should be of uniform shape. They should be wetted before placed in position. In case of an arch bridge, the stones should be laid or fixed with their natural bedding planes normal to the direction of pressure. This is due to the fact that thrust in an arch is passed from voussoir to voussoir and hence the natural bedding planes should be parallel to the radiating centre line of the voussoir.

Steel

The strength and durability of mild steel have made it, suitable for adoption as construction material for superstructures. The steel bridges may either be rolled steel beam bridges or plate girder bridges or trussed bridges.

Table shows the maximum spans upto which a particular type of steel bridge can be recommended.

The weakest portion of timber construction is the connections and hence, every efforts should be made for the proper detailing of joints of the various members of the timber construction.

The wooden road bridges are classified as the temporary bridges as per I.R.C. bridge Code and they are to be designed for class B loading. It is not necessary to consider the impact load in the design of wooden road bridges. The wooden bridges, however are not suitable for the railways under the present conditions of loading.

The wooden bridges are not usually recommended on important roads in our country because of their following disadvantages:

i. The connections are to be secured with fastenings of cast iron or steel.
ii. The factor of safety for the timber bridges is taken as 4 to 5.
iii. The life of timber components are to be arranged with respect to the direction of load in such a way that excessive stress is not developed in the direction in which the timber is the weakest.
iv. They are easily liable to fire.
v. They cannot be constructed for large spans.

COMPOSITE BRIDGES

Sometimes a bridge is constructed by a combination of two dissimilar materials, such bridges are known as the composite bridges and they are adopted when it is found that a particular material, if used alone is likely to result in an unusually large section. Under such circumstances the weak material is strengthened by combining it with another material. The common examples of composite construction are;

i. Concrete beams reinforced with steel bars
ii. Precast pre stressed concrete girder with cast in situ R.C.C slab
iii. Rolled steel joints topped by a cast in situ R.C.C slab, etc.

Following are the advantages of the composite bridges:

i. To finish up to bridge so that it can be put for use

ii. To retain the earth filling and

iii. To transmit the reaction of superstructure to the foundations.

Forces Acting on an Abutment

Following forces in addition to its own dead weight act on an abutment

i. Live load surcharge

ii. Pressure of earth filling

iii. Reaction from superstructure

iv. Seismic load

v. Tractive effort

vi. Water pressure

vii. Wind load.

Live Load Surcharge

The position of live load on earth which is retained by the abutment causes pressure on the abutment. The pressure so developed is uniformly distributed and it is known as the live load surcharge.

Pressure of Earth Filling

The earth retained by the abutment causes pressure and the amount of earth pressure is worked out with the help of suitable formula.

Reaction from Superstructure

The reaction from superstructure is calculated and it may be vertical or inclined such a reaction includes the dead load of abutment impact force and live load.

Seismic Load

If the bridge is located in earthquake zone suitable allowance will have to be made for the seismic load in the design of abutment.

dimensions of an abutment should be decided by combining the theoretical approaches with practical considerations.

i. Batter: Sometimes, the uniform batter is provided on earth's side instead of footings. For arch bridges, the Trautwine's formula for batter on earth side is as follows:

$$\textbf{Batter on earth side = 1 in } \frac{24\ X\ rise}{span}$$

Thus, for an arch bridge having rise and span as 2.50 m and 15 m respectively

Batter on earth side = 1 in $\frac{24\ X\ 2.50}{15} = 1\ in\ 4$

ii. Height: The height of an abutment is fixed up by the difference between the bed level of river banks and the formation level of the road or railway line.

iii. Length: The length of an abutment is represented by the overall width of the bridge including footpaths, if any. It also depends on the use of bridge. For a railway bridge the length of an abutment will depend on the number of tracks, the gauge and the distance between the centre line of tracks. For a road bridge, the length of an abutment will depend on the lanes of road.

iv. Top width: The top width of an abutment depends on the span of the bridge. But it should not be less than 500 mm in any case. For girder bridges, the top width should be sufficient to accommodate the bed block and breast wall. For arch bridges, the various empirical formulas are used. The Trautwine's formula, which is commonly used is as follows:

$$\mathbf{E = \frac{r}{5} + \frac{a}{10} + 0.60}$$

Where,

E = Top width in m

E = Radius of soffit in m

r = Radius of soffit in m

a = Rise in m.

Wind Load

The effect of wind on moving loads and on the superstructure on pier height above water level is worked out.

In some cases, the pier will also have to resist the following forces;

a. Buoyancy of submerged part of the substructure which can be neglected for piers anchored to rocks by the dowels;
b. Force due to collision of the vessels in the navigable rivers and
c. Longitudinal force due to resistance in bearings

Conditions of Stability

The conditions of stability for a pier are the same as those mentioned in case of an abutment.

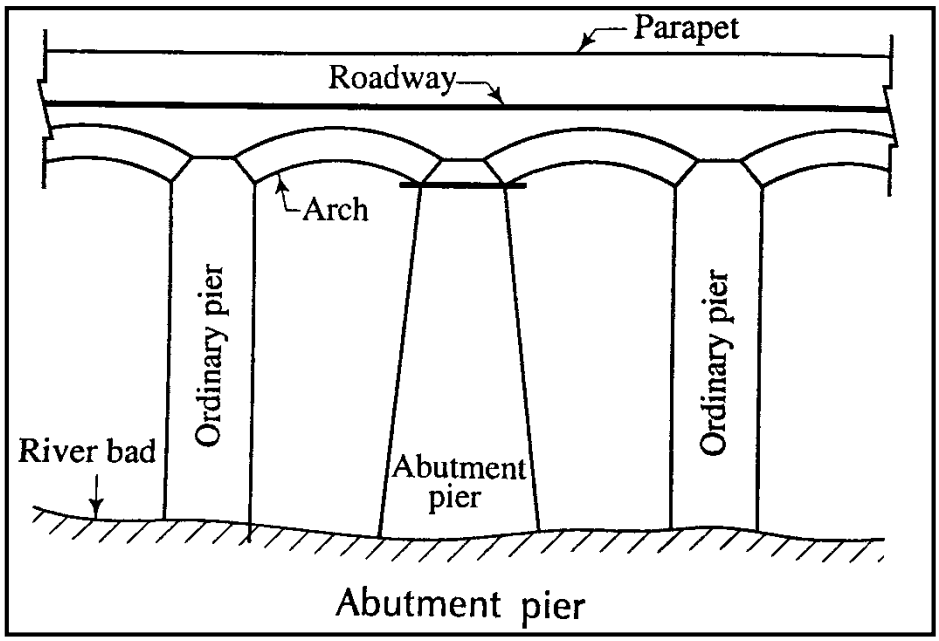
Dimensions

The various dimensions of a pier such as batter height, length and top width are decided as mentioned below in general it may be stated that the dimensions of a pier should be decided by combining theoretical approach with practical considerations.

i. **Batter:** In some case the sides of a masonry pier are provided with uniform batter.

   The value of batter varies from 1 in 12 to 1 in 24. The great value is usually adopted for low piers and the smaller value is usually adopted for high piers.

ii. **Height:** The height of a pier is fixed up by the difference between the level of river bed and the formation level of the road or railway line. It should however be seen that sufficient freeboard or clearance to the extent of about 1000 mm to 1500 mm is maintained between the bottom of superstructure and the highest flood level (for non submersible bridges) or normal flood level (for submersible bridges).



Such a pier is known as an abutment pier as shown in fig. And it is of bigger dimensions than the ordinary piers. The provision of an abutment pier affords the following two advantages:

i. The construction work of arch bridge can be carried out in sections. It proves to be speedy and economical.

ii. The effect of any failure of an arch due to earthquake or flood or any other reason can easily be localized when an abutment pier is provided. Such an effect does not extend from one end of the bridge to the other. But it stops at the abutment pier.

Wing Walls

The abutment can be either buried or its front face can be left exposed. In the latter case, the walls constructed on either side of an abutment to support and protect the embankment are known as the wing walls.

Functions

A wing wall has mainly to perform the following two functions:

i. To provide a smooth entry into the bridge site and

Dimensions

The various dimensions of a wing wall such as batter, height, length and top width are decided as mentioned below. In general, it may be stated that the dimensions of a wing wall should be decided by combining the theoretical approach with practical considerations.

i. **Batter:** The sides of wing walls may by provided with uniform batter. The value of batter may vary from 1 in 4 to 1 in 12. In case of return wing wall, the face is kept vertical.

ii. **Height:** The height of wing wall should be sufficient to retain the earth filling. It is possible to vary the height of wing wall from point to point as in case of the splayed wing walls.

iii. **Length:** The shortest length which will allow wing wall to function properly is worked out by considering the following three levels:

a. Bed level of river or stream

b. Formation level of road or railway line

c. Natural ground level of embankment.

In practical the contour plan of the bridge site is drawn and from it, the correct economic length of wing wall is worked out. The wing walls should always be founded on the natural ground and they should not be made longer than required. They should permit the earth of the approach filling to be trimmed to its natural slope.

iv. **Top width:** The top width depends on the type of wing wall. But in any case it should not be less than 500 mm.

Precautions

Following two precautions should be taken during construction of wing walls:

i. **Gap:** The wing walls are rarely designed to take part of abutment load. In that case they are rigidly connected with the abutment. In all other cases the

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Mock test : 16

Total test : 80

Principal Reference Lines

For a bridge the principal reference lines are the longitudinal centre line and the transverse centre line. For a bridge on curve, the tangent points of the curve should be established by pegs and also by pegs which are provided to define the direction of the tangents.

Replacing Original Points

If the original points are disturbed due to any reason during the progress of work, they should be carefully replaced and checked before the original points are removed or covered.

MATERIALS FOR SUBSTRUCTURES

Following are the three common materials of construction for the various substructures:

1. Cement concrete
2. Masonry
3. Steel

Cement Concrete

The mass cement concrete is an ideal material for various substructures. The usual portion of cement concrete is M 20 o 1:1.5:3 i.e., 1 part of cement, 1.5 parts of fine aggregate and 3 parts of 40 mm size coarse aggregate by volume. If it is desired to save in the quantity of concrete, the use of displacers or large blocks of stones is recommended.

Where tension is likely to occur, the reinforcement is placed in cement concrete and it is then referred to as reinforced cement concrete or R.C.C construction. The abutments and wing walls of R.C.C may be designed with or without counterforts. The beams placed at suitable spacing for support are known as the counterforts. For R.C.C. piers, the main reinforcement is vertical and secondary reinforcement is in the form of rings which bind the main reinforcement.

the substructure are within permissible limits are known as the bearings. Thus, the bearings are provided for the distribution of the load evenly over the substructure material which may not have sufficient bearing strength to bear or take up the load of superstructure directly.

Purpose of Bearings

Following are the purposes or objects of providing bearings in a bridge:

1. To absorb movements of girder
2. To allow for angular movements of girder due to deflection under the load
3. To allow for longitudinal expansion or contraction due to changes in the temperature.
4. To distribute the load on a large area
5. To keep the compressive stress within safe limits
6. To make movements of girder harmless.
7. To rotate at supports to accommodate the deflection of a simply supported girder under load.
8. To simplify the procedure in design.
9. To take up the vertical movement due to sinking of the support
10. To transfer horizontal forces developed due to application of brakes to the vehicles etc.

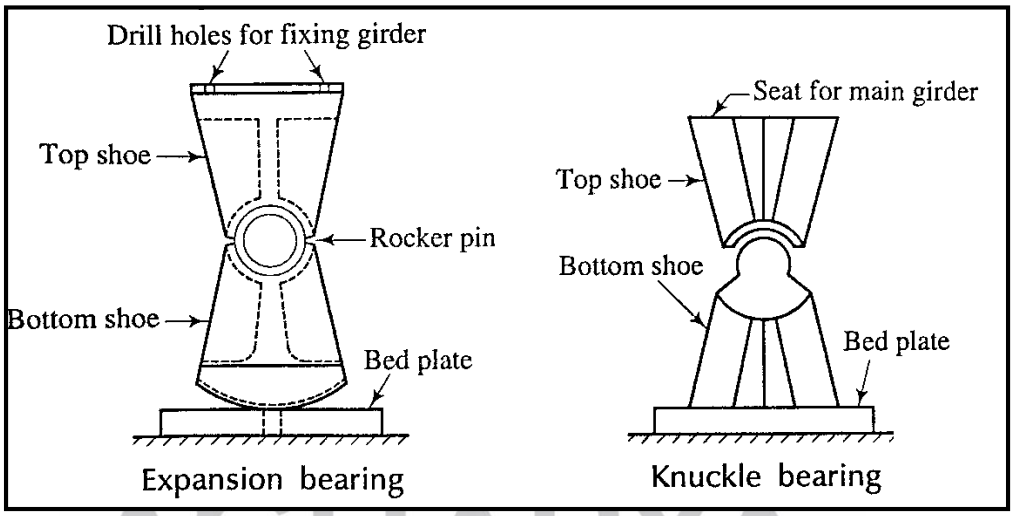
Importance of Bearings

It should remember that the successful functioning of a bridge primarily depends on the design of its bearings. It is observed that faulty design or improper working of the bearings is the main cause of failure of many bridges that have collapsed. The design of bearing to be adopted for a particular bridge will mainly depend on the type of supports, length of the span and the type of superstructure.

Expansion Bearing

In case of expansion bearing, the bottom shoe is given a circular shape. The centre of circular surface coincides with the centre of rocker pin. The bottom shoe rests on the bed plate. The top shoe is provided with drill holes for fixing of the girder.

Fig. shows an expansion bearing. It allows free angular as well as longitudinal movement of the girder and it is useful for girders having small spans.



Knuckle Bearing

In case of knuckle bearing, the top of bottom shoe and bottom of top shoe are given semi circular shapes as shown in fig. The knuckle bearing is adopted when it is desired to provide only for angular movement of the girder which is fixed to the top shoe.

Rocker and Roller Bearing

In case of rocker and roller bearing a rocker pin is provided between the top shoe and the bottom shoe and it is so arranged that the bottom shoe rest on rollers as shoe in fig.. The rollers are cylindrical in shape and they are free to roll on steel bed plate. A rocker and roller bearing is therefore a free bearing which does not but which rolls as well as rocks over a smooth bed plate.

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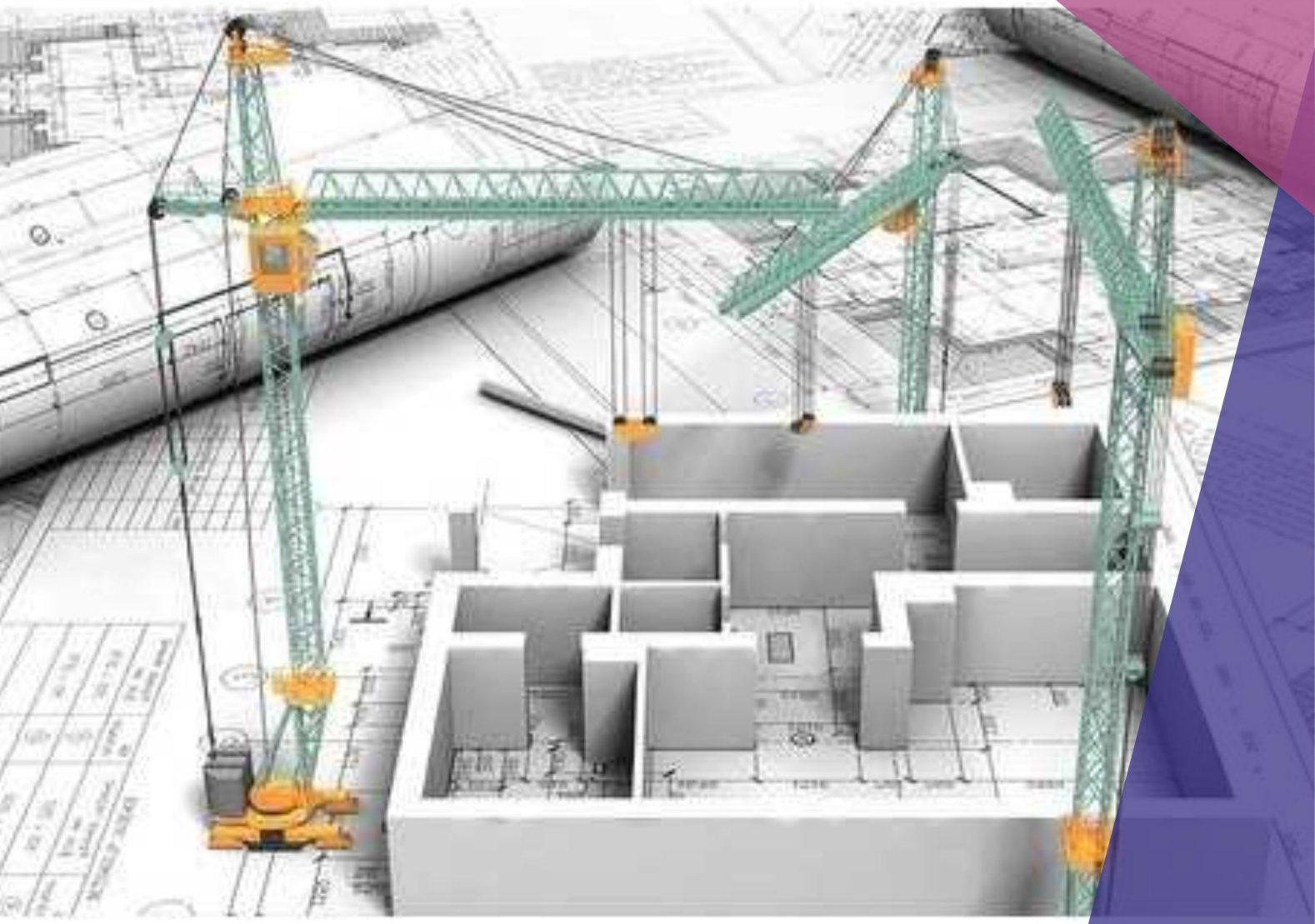


Structural Analysis

"All of us do not have Equal Talent.
But, all of us have an Equal Opportunity
to Develop our Talents."
A.P.J. Abdul Kalam

The content of this book covers all PSC exam syllabus such as MPSC, RPSC, UPPSC, MPPSC, OPSC etc.

Rubber Bearing

A rubber bearing consist of layers of rubber plates. The steel plates or wire meshes are introduced between the successive layers and a minimum cover of about 5 mm of rubber is maintained along edges. The steel plates or wire meshes perform two functions:

i. The chance of relative sliding between the rubber plates is avoided and

ii. The crushing of rubber under the load is prevented.

The desired thickness of rubber bearing can be obtained by selecting a proper number of rubber plate. The synthetic rubber like neoprene can be successfully used for preparing rubber bearings so it is also known as neoprene bearings

If a thick rubber bearing is provided at one end and a thin rubber bearing is provided at the other end, the former acts as a free bearing and the latter acts as a fixed bearing.

Neoprene Bearing Pads

Neoprene bearing pads are moulded or cut form a moulded sheet of high grade, new neoprene synthetic rubber compounds. They are economically efficient bearings for pre cast , pre stressed concrete or steel beams in bridges and buildings. They permit a smooth and uniform transfer of load from the beam to the substructure and allow beam rotation at the bearing due to deflection of the beam under load. They also allow lateral and longitudinal movement of the beam caused by thermal forces.

Neoprene pads have no movable parts and thermal expansion and contraction are absorbed to give and take in shear. Neoprene rubber undergoes no marked stiffening at low temperature when the thermal construction of the bridge deck is at maximum. Such stiffening could be deleterious to bearing and structure also. Correctly designed and suitably compounded neoprene bearings can be confidently expected to function efficiently for at least a hundred years.

3. Mild steel
4. Reinforced cement concrete
5. Rubber
6. Tar paper.

The bearings of cast steel, mild steel and tar paper are very common in India. The design of an R.C.C bearing is rather complicated. but its construction is cheaper and speedy. it can be cast as soon as it is ready. The reinforcement in case of R.C.C bearings is usually of spiral type so that bursting tension can be effectively resisted.

As the metallic bearings are expensive in first cost and difficult to maintain the recent trend is to adopt elastometric bearings. An elastomer is either natural rubber or a synthetic material processing characteristics similar to the rubber. The synthetic rubber in common use in chloroprene rubber known as 'Neoprene'. The natural rubber has the following drawbacks:

1. It has only moderate weathering resistance.
2. It is inflammable.
3. It is likely to be attacked by oxygen, ozone, oils and fuels.

Following are the advantages of elastometric bearings:

1. It is possible to increase their resistance against oxygen and ozone by adding antioxidants and antioxonants.
2. The height of this type of bearing is minimum and far less than that of roller or rocker bearing. It thus leads to the reduction in the cost of the approaches.
3. The removal and replacement if required can be carried out easily.
4. They are easy to install, and low in first cost.
5. They do not require positive fixing like metallic bearings.
6. They have better weathering resistance and are flame resistant.
7. They require practically no maintenance.

Buoyancy Pressure

The effect of buoyancy is considered in the design of bridge, only if the strata of soil are permeable or in other words, if the bridge foundation are resting on homogeneous and impermeable strata of soil, on provision is made for buoyancy in the design of bridge. The important facts to be remembered while considering the force of buoyancy are as follows:

- The effects of buoyancy are to be considered in the design of an abutment, especially the abutment of a submersible bridge. In such a case, it is assumed that the filling behind the abutment is washed away or removed by the scouring action.
- For the design of submerged masonry or concrete structure the buoyancy effect through pores is limited to the extent of 15 per cent of the full buoyancy effect.
- For the design of submersible bridges, the full buoyancy effect on the superstructure, piers and abutments is to be considered.
- If member under consideration displaces water only, the reduction in weight due to the buoyancy for that member is taken as equal to the volume of the displaced water.
- If member under consideration displaces silt or sand in addition to water, the reduction in weight due to buoyancy for that member is worked out by taking into account the following two factors,

Centrifugal Forces

When a road or a railway bridge is situated on a curve, the effect due to centrifugal force is to be considered in the bridge design. Following formulas are adopted for the road and railway bridges:

Road Bridges

$$C = \frac{WV^2}{12.95\,R}$$

Dead Load

The dead load indicates the load of structure itself. It depends on various factors such as live load to be carried, length of span, working stresses adopted in the design, etc. It has to be initially assumed for the design purpose. Following two rules are followed:

- The dead load of structure is assumed by reference to suitable empirical formulas or by comparison to similar existing structure.
- After the design is finalized, the actual weight of structure is worked out. If there is appreciable difference between the actual and assumed dead loads, the design is revised accordingly.

Some of the important empirical formulas adopted for various structures are as follows:

Unwin's Formula

$$W = \frac{PLr}{2cf - Lr}$$

Where,

W = Weight of one span in tonnes excluding weight or cross-girders and flooring

P = Load to be carried in tonnes

L = Span in m

r = Ratio of span to depth

f = Working stress in tonnes per cm²

c = Constant which varies from 1200 to 1400 for plate girders and from 1700 to 1900 for trusses.

American Formula for Plate Girders

$$W = \frac{PL}{2.4d}$$

L = span in m.

R.C.C Slab and T Beam Bridges

$$W = 425 + 82\,L$$

Where,

W and L are as above. This formula is adopted for spans from 6 m to 15 m.

DEFORMATION STRESSES

Any bending stress which is developed in a steel member either due to vertical deflection or rigidity of the joints is termed as the deformation stress. The deformation stresses are to be taken into consideration for steel bridges only. The steel bridges are to be designed, manufactured and erected in such a way that the deformation stresses are brought down to a minimum possible level. For the purpose of assumption only, the deformation stresses may be taken as not less than 16 per cent of the live load and dead load stresses. The deformation stresses are to be ignored in case of prestressed girders of steel.

EARTH PRESSURE

The components of bridge which are required to retain earth should be designed for suitable earth pressure. The position of live load on earth causes pressure which is known as the live load surcharge and it should be properly considered in the design of bridge.

The I.R.C. recommends the theory of Coulomb with a slight modification. The height of the centre of pressure above bottom is to be taken as 0.42 of the height of wall above the base instead of 0.33 of that height as per Coulomb's theory. It should also be seen that a bridge structure is designed for a minimum horizontal pressure equivalent to the one exerted by a fluid weighing 4800 N per m^3.

The design of abutments of the railway bridges is based on the Rankine's principles. The use of Rankine's theory may be considered conservative. But the Indian Railways have adopted this theory considering the vital nature of bridge structures.

empirical formulas are, therefore, framed to work out impact factor and it is observed that results obtained by the application of these formulas are fairly accurate.

Following are the commonly used empirical formulas for the impact factor:

For Road Bridges

Road Organization of Great Britain

$$\mathbf{I = \frac{80}{90+1.64\,L\,(n+1)}}$$

Where,

I = Impact factor subject to a maximum of 0.70

L = Span in m and

n = Number of traffic lanes.

Indian Road Congress

- For I.R.C. Class A or B loading

$$\boldsymbol{I = \frac{4.5}{6+L}}$$

{for R.C.C. bridges of spans less than 3 m with a maximum value of 0.50}

$$\boldsymbol{I = \frac{9}{13.5+L}}$$

{for steel bridges of spans less than 3m with a maximum value of 0.545}

Where,

I = Impact factor

L = Span in m.

When the span exceeds 45 m, the impact factors for R.C.C. bridges and steel bridges are taken respectively as 0.088 and 0.154. The curves as shown in fig may be used to determine the impact percentages for the highway bridges designed for the Class A and Class B loading of I.R.C

Where,

I = Impact factor

L = Span in m

n = Number of tracks.

Waddell's Formulas

$$\mathbf{I = \frac{165}{3.28\ n\ L + 150}}$$

Where,

I = Impact factor

L = Span in m

n = Number of tracks.

For electric railways, with 'n' number of tracks, the formula is as follows:

$$\mathbf{I = \frac{120}{3.28\ n\ L + 175}}$$

Indian Railway Board

The Indian Railways treat this as dynamic augment and it is taken as an addition to the live load equivalent to the coefficient of dynamic augment (CDA) or impact factor I multiplied by the live load which gives the maximum bending or shear force in the member under consideration.

The value of I specified now is based on the extensive tests carried out by the Indian Railways and it is applicable for speeds upto 160 kmph on B.G and 100 kmph on M.G.

$$\textbf{Let} \qquad \mathbf{I = 0.15 + \frac{8}{(6+L)}}$$

Where,

L= Loaded length of span in 'm' for the position of the train giving maximum stresses in the member under consideration.

- For depth of fill less than 900 mm

$$I = \left(2 - \frac{d}{0.90}\right) \times 0.50 \times \left(0.15 + \frac{8}{(6+L)}\right)$$

Where,

d = depth of fill in m.

The impact factors for (a) and (b) conditions mentioned above are applicable to both single and multiple track bridges. For multiple track arch bridges exceeding 15 m in span, only two-third impact factor is to be considered.

LIVE LOAD

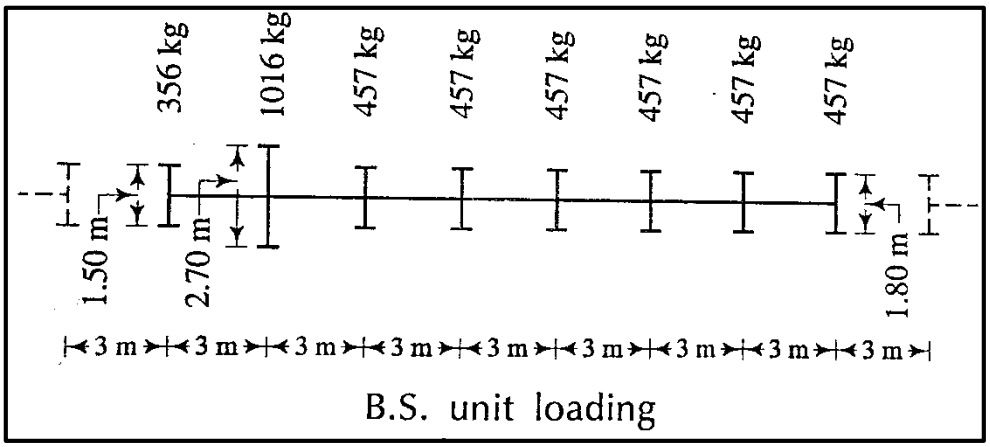
It is evident that maximum live load will depend on the situation of structural member under consideration. In practice, the standard loading are framed for convenience in the design of bridges.

Following are such standard loadings:

For Road Bridges

British Standard or B.S. Unit Loading

Fig. shows the unit loading that is adopted as per B.S. Specifications. The minimum number of units recommended to be taken in the design of all the bridges is 15.



B.S. unit loading

should be checked for Class A loading because under certain conditions, it is likely to get heavier stresses under Class A loading.

Class A loading

The I.R.C. Class A loading is based on the heaviest types of commercial vehicle which is considered likely to run on the Indian roads. Hence, all important permanent road bridges and culverts, which are not covered by Class AA loading, are to be designed for Class A loading.

Class B loading

The method of application and other details of class B loading are same as class A loading. It is to be adopted for the design of temporary structures such as timber bridges, etc.

Class 70R loading

This an addition loading which is sometimes specified for use in place of class AA loading. The letter 'R' indicates revised classification and it is based on one of the various other hypothetical vehicles as per revised classification.

For Railway Bridges

Indian Railway Board

The Indian Railway Board, Ministry of Railways, Govt. of India, has specified the standards of live loading to be adopted for three different gauges, namely B.G, M.G, and N.G. The I.R.S Bridge Rules contain various standard in details and they also furnish table giving the equivalent uniformly distributed loads (E.U.D.L) in tonnes on each track and also the impact factor applicable for different spans.

The standards of loading for the Railway Bridges are grouped as follows:

B.G. ……. (a) Main line

(b) Branch line

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Total full length test : 13

Mock test : 16

Total test : 80

at the top of the kerb and of value 7.50 kN per m run should be taken in addition to the pedestrian load of 4.80 kN/m²

LONGITUDINAL FORCES

It is necessary to make suitable provision in the design of road bridge or railway bridge for the longitudinal forces which develop from any one or more of the following causes:

- The braking effect resulting from the application of brakes on the vehicles;
- The frictional resistance offered o the movement of free bearing due to variation in temperature or any other causes;
- The tractive effort caused through the acceleration of the driving wheels of the vehicles or locomotives.

In India, the following rules are observed:

For Road Bridges

The braking effect is computed as follows for working out the longitudinal forces:

For Single Lane and Two- Lane Bridge

It is taken as equal to 20% of the first train load plus 10% of the loads in succeeding trains or parts thereof on any one lane only. For this purpose, the train loads in one lane only are considered. If the entyre first is not on the full span, it is taken as 20% of the loads actually on the span. The allowance for impact is not included in this computation.

For Multi-Lane Bridge

In case of bridges with lanes more than two, it is taken as equivalent to the amount worked out as per provisions in (i) above for the first two lanes plus 5% of the loads on the lanes in excess of two.

For Railway Bridges

The Indian Railway Board Bridge Rules contain tables giving values of longitudinal for different spans and for different standard loadings for different gauges of the Indian

The seismic load is taken as a horizontal force equal to a certain percentage of the weight of structure. The equation to find out the lateral force due to earthquake is as follows:

$$S = xW$$

Where,

S = Lateral force due to earthquake

W = Weight of mass under consideration ignoring reduction due buoyancy or uplift.

x = Seismic Coefficient for the region

For the purpose of determining the seismic coefficient, the country is divided into five zones and table shows the horizontal seismic coefficients to be adopted for different zones according to the type of soil. The zone I consists of areas which are not liable for earthquake damage. The zone V consists of area subject to severe earthquakes. The other zones comprise areas in the intermediate category between the above two extreme cases.

TABLE: Horizontal Seismic Coefficients

No.	Zone no.	Horizontal seismic coefficient		
		Hard soil	Medium soil	Soft soil
1.	I	0.00	0.02	0.02
2.	II	0.02	0.02	0.04
3.	III	0.04	0.05	0.06
4.	IV	0.05	0.06	0.08
5.	V	0.08	0.10	0.12

TEMPERATURE VARIATION FORCES

Due to variation in temperature, the length of a structure is affected. If the change in length of a member due to variation in temperature is restrained, the temperature stresses are developed. But if allowance is kept to accommodate such change in length, the structure will not be subjected to temperature stresses.

g = 9.81 m per sec², the above equation reduces to:

$$P = K \times 9.81 \times 10^3 \times \frac{V^2}{2\ X\ 9.81}$$

$$= 500KV^2$$

The value of V is assumed to vary linearly from zero at the point of maximum scour to the square of the maximum velocity at the free surface of water. For this purpose, the maximum velocity at surface is to be taken equal to √2 times the maximum mean velocity of the current.

The value of constant K will depend on the shape of pipe its value is to be adopted as shown in table.

TABLE: Values of Constant K

No.	Shape of pier	Value of k
1.	Square ended piers	1.50
2.	Circular piers or piers with semi- circular ends	0.66
3.	Piers with triangular cut and ease waters with included angle between the faces as	
	30° or less	0.50
	more than 30° but less than 60°	0.50 to 0.70
	more than 60° and upto 90°	0.70 to 0.90
4.	Piers with cut and ease water of equilateral arches of circles	0.45
5.	Piers with arches of the cut and ease waters intersecting at 90°	0.50
6.	Trestle type piers	1.25

In order to provided for the possible change in the direction of the current of flow, the bridge piers are designed for inclination of 20° on the either side to the existing direction of the current of water.

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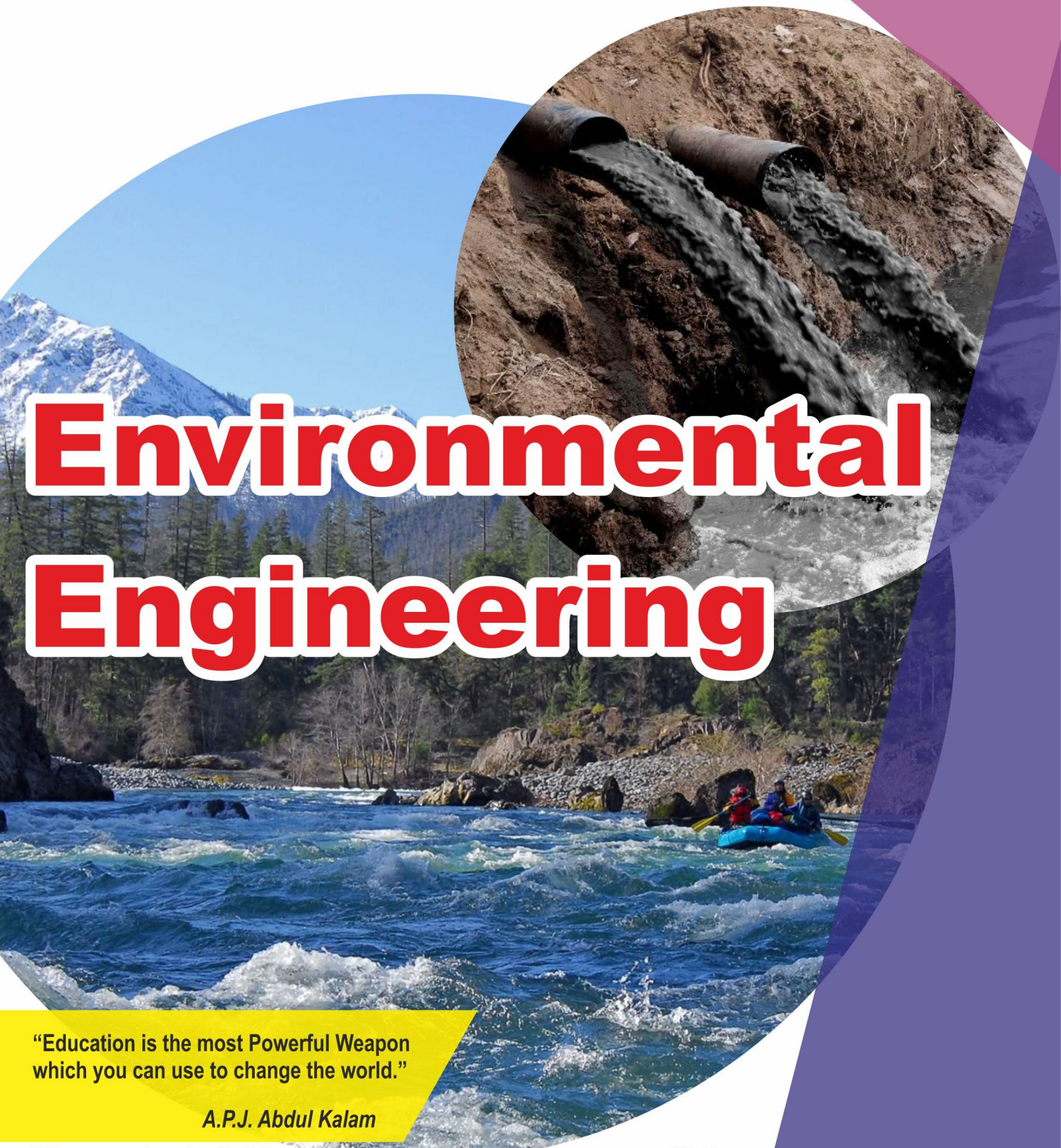


Environmental Engineering

"Education is the most Powerful Weapon which you can use to change the world."

A.P.J. Abdul Kalam

The content of this book covers all PSC exam syllabus such as MPSC, RPSC, UPPSC, MPPSC, OPSC etc.

B.G. bridges	.. .. 1.5 kN/m²
M.G. and N.G. bridges	.. .. 1.0 kN/m²
Foot- bridges	.. .. 0.75 kN/m²

The effect of wind pressure is considered as a horizontal force acting in such a direction that resultant stresses are the maximum for the member under consideration. The other design aspects of wind load are contained in the Indian Railway Board Bridge Rules and they should be followed in the design of all the railway bridges.

DESIGN OF BRIDGE FOUNDATIONS

The design of bridge foundation is made by keeping in mind the forces, load and stresses enumerated above. For bridges with open foundations and well foundations, the permissible increase in the pressure on soil under the various combinations of the various forces, loads and stresses is adopted as follows:

- The maximum bearing pressure due to any combination of forces, load and stresses under buoyancy pressure, centrifugal forces, dead load, earth pressure, impact load, live load, longitudinal forces, temperature variation forces, water pressure should be worked out and it should be seen that this maximum bearing pressure does not exceed the safe bearing capacity of the soil.

- When the effect of seismic load or wind load is considered in addition to the forces, loads and stresses under buoyancy pressure, centrifugal forces dead load, earth pressure, impact load, live load, longitudinal forces, temperature variation forces, water pressure, it should be seen that the maximum bearing pressure on soil does not exceed by 25 per cent of the safe baring capacity of the soil.

- The seismic load and wind load are assumed not act simultaneously.

- For the purpose of design of bridge foundations, the deformation stresses, erection stresses and secondary stresses are ignored.

Extension of Bridge

To provide better substructure to the approaches, the bridge as such is extended into the banks for some distance. The extended portion however may not have the same type of superstructure as the bridge proper.

Gradient

The approaches should not have gradient more than the ruling gradient. Generally, 1 in 30 to 1 in 20 gradients is specified for the approaches.

Joint Walls

The embankments of approaches should be carefully joined with the bridge and it is desirable to construct the joint walls between the approaches and the bridge.

Maintenance

The approaches are to be maintained with special care especially when they are newly constructed. The approach banks and protection works should be such as to involve minimum recurring maintenance expenditure. They should also be reasonably free from flood damages because in such cases, the approach will be put out of use for long periods and will involve high cost in restoration.

Width and Length

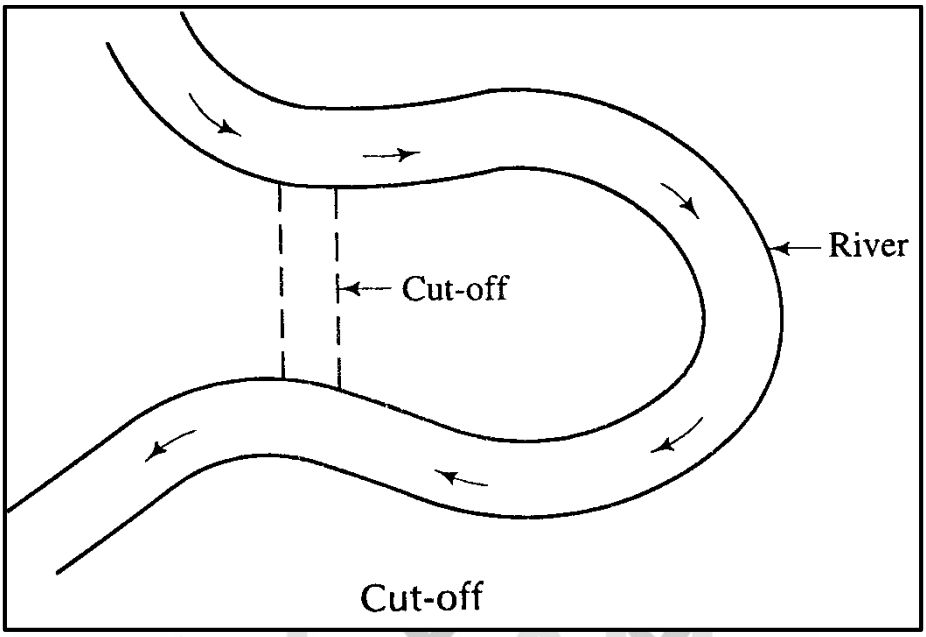
The approaches should normally be made wider than bridge. As per I.R.C. recommendations, the approaches should have at least a minimum straight length of 15 m on either side of a bridge. This minimum length may be increased in cases where it is required to provide minimum sight distance for the design speed. Also, the minimum straight length of the approaches should be surfaced for a width at least equal to the width of roadway on the bridge itself.

RIVER TRAINING WORKS

Objects

It is found that in most parts of our country the rainfall is concentrated during a small period of about 3 to 4 months of monsoon only. The variation in river discharge is to

This chord-channel connecting two portions of bend is called the natural cut-off as shown in fig. and it may be made artificially to make the river flow straight. The cut-off reduces the length to be crossed. It thus shortens the distance for navigation and reclaims some useful land or property.

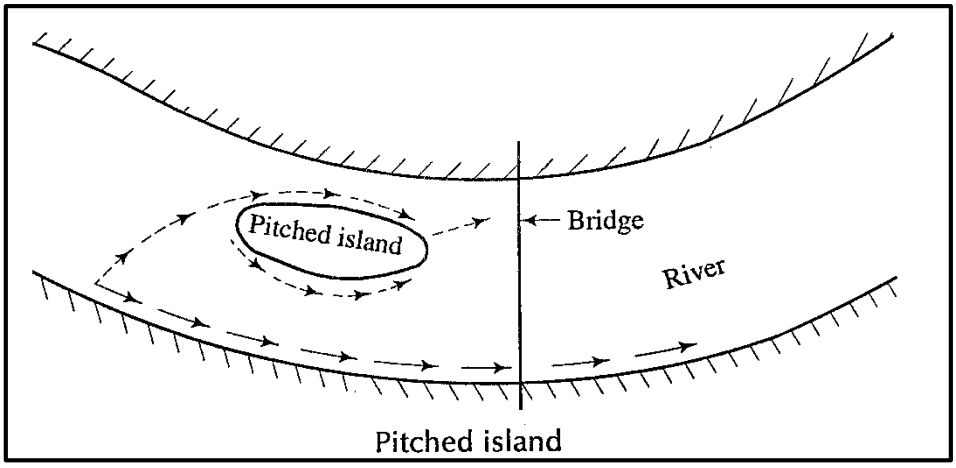


Embankments

They are constructed parallel to the river bank and upto a height of about 12 m. Depending upon the position of the embankments, they are classified in the following two categories:

Marginal Embankments

These embankments are constructed as close to the bank as possible so as to provide adequate waterway during the monsoon. They protect the marginal land from inundation caused by the floods. They are also referred to as the dykes and they are designed to retain water upto the maximum anticipated H.F.L. without the possibility of overtopping and with a view to resist all external pressures. They are also provided with necessary freeboard, bed with, top width and adequate slopes. The side slopes of these banks which are facing towards the river water are pitched with stones to bear the wave action of water.



When the depth of water around the island becomes sufficiently more, it attracts the current of water from the other side of the bank and thus, the concentration of the current at the other side bank is reduced as shown in fig. The dotted arrows shows the path of water flow after the construction of pitched islands.

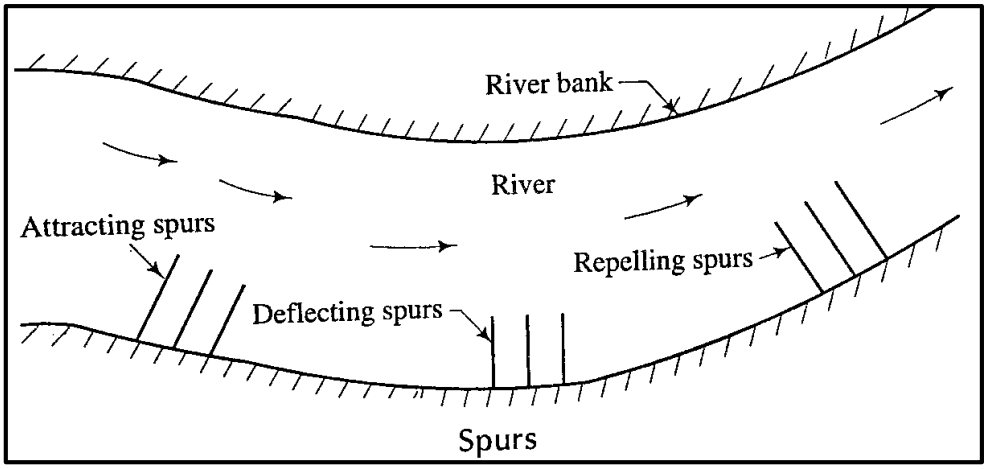
Pitching of Banks

The river bank in the required length of river is cut to a stable uniform slope from 1:1 to 2:1 depending upon the material of the bank and then, the pitching or revetment is done with the help of boulders, concrete or brick blocks, brushwood, growing forest or the natural growth of grass. Thus, the river bank are made safe from the caving action of water. The bank revetment also exerts an attracting influence by drawing the river water towards it on account of deep scour formed at the toe of bank. The river channel is, in this way, held permanently at the pitched banks.

Spurs

These are also referred to as the groynes or transverse dykes and they indicate structures, built transverse to the river flow, extending from the river bank towards the river. They serve the following purposes:

- They attract, deflect or repel the flow of water along a desired course.
- They contract the wide river channel.
- They form a pool of nearly still water along a particular bank.



BRIDGE INSPECTION

The main aims of bridge inspection are assurance of safety, economic planning and protection of national wealth.

Following are the main objectives of bridge inspection:

- Budgeting of available funds.
- Identification of actual sources of deficiencies at the earliest possible stage.
- Planning of classification of bridges, maintenance, repair and reconstruction activities, traffic regulations, etc.
- Providing information to the researchers, designers and construction agencies regarding performance of materials, design criteria, construction techniques and new areas requiring research, development and standardization.

The existing system of bridge inspection in India is based on the manual for Maintenance and Inspection of Bridges published in IRC: SP:18-1978 by Indian Road Congress. The frequency of inspection is recommended as once in a year.

BRIDGE ARCHITECTURE

The essential consideration of a bridge is its functional utility. But at the same time, it is desirable to make the bridge design aesthetically pleasing by observing some of the

Light and Shade

The role of light and shade on bridge at night is certainly a matter of expression. The highways and bridges within city limits should be provided with diffused lights so that a vehicle driver can put off his vehicle light well ahead before reaching the bridge and can enjoy the ride over the bridge.

Line and edges

The eye of an observer appreciates the lines and edges employed in the bridge structure. It is therefore essential that all line and edges are in good order to contribute to the pleasure imparted by a bridge view.

Proportioning

The span and depth of the bridge should be suitably proportioned. The main dimensions and choice of spans are however largely determined by the functional and economic considerations. But a variation within reasonable limits is permissible to achieve an attractive design. In all cases, a bridge should look as effortless as possible and not too heavy. A well proportioned bridge not only looks attractive but also expresses a sense of achievement.

Railings

The railings on bridge should be provided with such design that an open view is seen while crossing or driving over the bridge. The solid parapets may be used only for the single span, minor bridges and culverts.

Simplicity

The best bridge design should always exhibit a certain simplicity. The unnecessary ornamentation is meaningless in modern times because those who pass over or under the bridge usually travel at a speed and take pleasure in the general effect of the design.

depth of cover provided below reinforcement and degree of quality control. No concrete is made absolutely impermeable to water or air. For highway bridges, dense concrete prepared from ordinary Portland cement is found quite impermeable to provide adequate protection to steel. Also, the drained water falling on a structural part of a bridge may cause deterioration of structural steel.

Rectification

(i) The superstructure of steel bridges should be periodically cleaned and painted.

(ii) Adequate clearance between steelwork and brickwork should be provided.

(iii) To prevent rusting of the hidden parts, thicker sections should be used instead of thinner sections while designing.

(iv) Sufficient numbers of drainage holes should be provided to avoid collection of rain and dirt at through sections.

Other defects of bridge are as follows:

(i) Expansion joint distress

(ii) Cracks in metalwork

(iii) Damaged structural members

(iv) Foundation settlement and movement

(v) Loose connections; etc.

MAINTENANCE OF BRIDGES

After the bridge is constructed, it is absolutely necessary to inspect it at regular intervals and to maintain it in such condition that it functions properly. The damage to a bridge structure may be either due to faulty design or improper construction or the aging of the material. It may also occur due to external factors like floods, storms or accidents.

It is absolutely necessary that every part of the bridge structure is kept under constant observation. For this purpose, a periodic or routine inspection followed by detailed technical examination, wherever necessary, is essential. The technical inspection, should be entrusted to specially selected and trained personnel. Thus, the above-mentioned maintenance work can broadly be grouped into the following two categories:

- Detailed inspection
- Routine inspection

Detailed Inspection

The detailed or in-depth inspection involves the visual examination of all superstructure and substructure elements. It is carried out in the following two categories:

General

A check- list of items is inspected either visually or with the aid of standard instruments in the general inspection. It is carried out once in 2 years.

Major

It requires close examination of elements with the aid of access facilities. It is conducted at intervals of 5 to 6 years or even at smaller intervals depending upon the design of structure. The structural analysis of bridges is done by experienced bridge design engineers soon after the occurrence of calamities such as floods and earthquakes or the passage of high intensity loadings.

The trouble spots to be checked up during the detailed inspection are as follows:

- Behaviour of expansion joints
- Cracks in metalwork
- Damaged structural members
- Deterioration and cracks in concrete
- Excessive vibrations

TESTING AND STRENGTHENING OF BRIDGES

After the construction work of a bridge is completed and before it is opened for traffic, it is necessary to the bridge for its stiffness and strength.

The testing of bridge is usually carried out with the help of a deflectometer under various condition of loading. The deflectometer records the deflection automatically and it is placed on the platform of instrument trestle. For taking readings of the instrument, an observation platform, which is entirely independent of the instrument platform, is constructed on another trestle.

The loads are allowed to stand, to move slowly and to run at maximum speed on the bridge. From the set of readings obtained, the strength and stiffness of bridge are computed.

The present-day sudden explosion of heavy road traffic has posed the problem of testing and strengthening the existing bridges. It is quite clear that the weakest bridge on a particular route will be the deciding factor for the capacity of road or highway.

Following are the methods which are applied to work out the safe bearing capacity of an existing bridge:

- Correlation method
- Load testing
- Theoretical method.

Each of the above method will now be briefly discussed.

Correlation Method

The behaviour of another existing bridge with identical specification and other similar details is studied and its safe bearing load is then correlated to the bridge under consideration.

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Total full length test : 13

Mock test : 16

Total test : 80

Other Material

In this case, the cofferdam is constructed to enclose the space around the damaged pier and water is taken out. A thick cement concrete casing can then be provided or the old pier may be driven in the space between the old pier and the cofferdam to strengthen the foundation of the damaged pier.

Strengthening of Bridge Superstructure

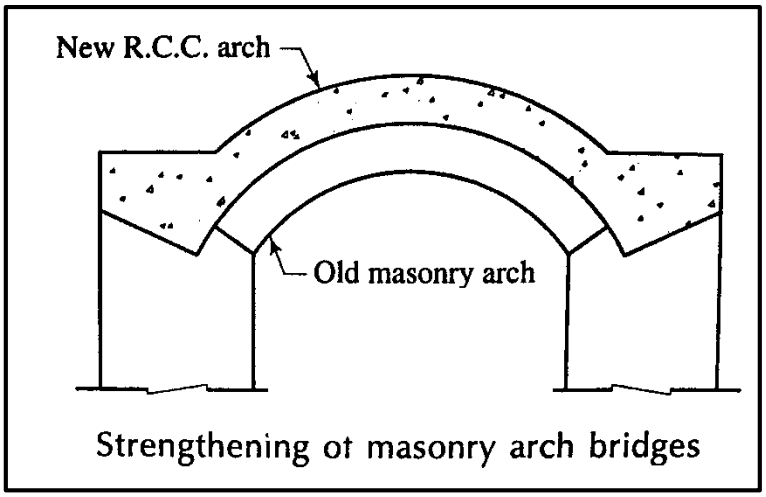
The bridge superstructure is to be strengthened by keeping in mind the type of bridge to be handled. The strengthening techniques adopted for some of the common types of bridge superstructure are as follows:

Continuous Bridges

These bridges are strengthened by methods similar to those of single span without any remarkable variation. But care must be taken to see that when a span is being strengthened, the adjacent span is not weakened.

Masonry Arch Bridges

For masonry arches, the simplest way of strengthening is to remove the filling above the arch and cast an R.C.C. slab on top of the roughened extrados, effectively keyed into the abutments as shown in fig. This method is adopted when the existing section is sound and can continue to contribute strength. The new R.C.C. arch serves as a supplementary section only.



Strengthening of masonry arch bridges

Suspension Bridges

These bridges are normally strengthened by the additional suspension requirements such as extra cables with fasteners.

Qu5 Fixed plate bearing plates are suitable for spans upto

a) Less than 6 m

b) 12 m

c) 18 m

d) 24 m

TEST YOUR SELF

Qu6 Generally, a culvert has span less than

a) 3 m

b) 6 m

c) 9 m

d) 12 m

Qu7 Height of bridge is kept _____ above high flood level

a) 1.2 to 1.5 m

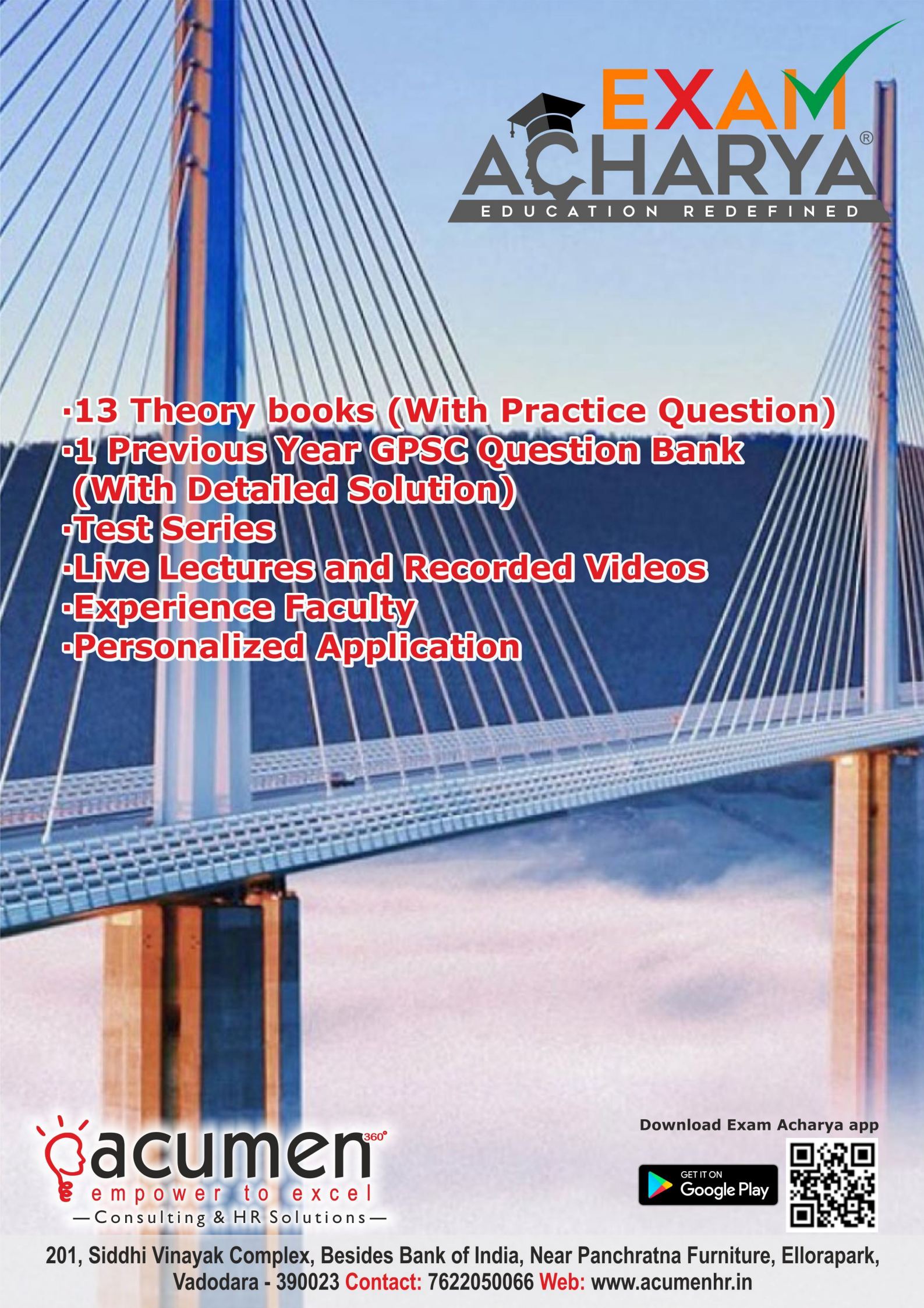
b) 1.8 to 2.1 m

c) 2.2 to 2.5 m

d) More than 2.5 m

Answer

1-(b), 2-(d), 3-(b), 4-(a), 5-(b), 6-(b), 7-(a)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