"DESIGN OF AN EXPRESSWAY"

By

DIVYA MALHOTRA 031605
KUMAR RAJEEV RANJAN 031615

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INFORMATION TECHNOLOGY

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CERTIFICATE

This is to certify that the work entitled, **"Design of an Expressway"** submitted by Divya Malhotra and Kumar Rajeev Ranjan in partial fulfillment for the award of degree of Bachelor of Technology in Civil Engineering of Jaypee University of Information Technology has been carried out under my supervision. This work has not been submitted partially or wholly to any other University or Institute for the award of this or any other degree or diploma.

Dr. R.M.Vasan

Professor & HOD of civil Dept.

Dean of University

Jaypee University of Information Technology

Waknaghat, Solan, Himachal Pradesh, India

ACKNOWLEDGEMENT

The Expressway project marks the culmination of all the concepts assimilated while studying the subject. It has presented us with an opportunity to use the technical know-how imparted to us to a real life project.

Designing of an Expressway involving all the concepts of Highway Engineering, under the guidance of our esteemed mentor Dr. R.M Vasan(H.O.D- CE) not only cleared all our ambiguities but also generated a high level of interest and zest in the subject. We are truly grateful to him.

The prospect of working in a group with a high level of accountability, fostered a spirit of teamwork and created a feeling of oneness, thus motivated us to perform to the best of our ability and create a report of the highest quality.

To do only the best quality work, with utmost sincerity and precision has been our constant endeavor.

Divya Malhotra **Kumar Rajeev Ranjan**

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SYNOPSIS

India is about to embark on a massive scale of Expressway construction. Expressway has been a strong domestic and export market necessitating high speed facilities to move people and goods, there by, facilitating the economic growth and social benefits.

For giving proper direction and focus for the development of high speed facilities, system network planning which supports the current and long term objectives is essential to evolve a Blue Print for such road development for the next two three decades.

While planning for the expressways and high speed facilities, the stress should be laid on:-

1. Maximizing transportation

2. Economic benefits and

3. Minimizing the negative impacts on the people and the environment.

Key local benefits and impacts associated with the different road alternative will have to be identified and sufficient provision for the future expansion of the corridors will have to be made.

The provision of expressway facilities being **capital intensive**, due to paucity of resources, all the traffic corridors may not qualify for immediate capacity augmentation to expressway standards some of them requiring only widening to a multilane cross section. Therefore, **Strategic Planning** is an important part for expressway design and construction. Expressway design means ***"High quality design"*** and safety levels must be considered as ***"enhanced or increased safety through better design"***. Such a staging plan will be governed by a number of factors, such as traffic demands, environmental and right of way problems and economic benefits.

Various design elements and aspects like geometric features, design speeds, grade separations, tunnels and underpasses, toll plaza, entrance and exit ramps, signs and markings, landscaping, service lanes etc. must be properly integrated into the design to achieve optimum safety and performance levels.

Expressways act as a catalyst in the fast development of the area and the entire economy of the region. Hence, the design and safety aspects must be quickly evolved by taking advantage of International experience and expertise and valuable time must not be lost in conducting feasibility studies alone. Since design of various expressway elements are time consuming requiring undivided attention and involve simultaneous consideration of several parameters, computer applications have come as a boon and full advantage should be taken of this.

Need for Expressways

Considering the large traffic volumes on some of the main arterial routes, conventional widening of carriageway may not be able to meet the situation. A possible solution based on the experience in developed countries is to construct such routes as ***Expressway.***

The expressways are designed to meet very high standards of speed and safety. Normally it is a four lane or six lanes divided carriageway where access to highway is controlled and grade crossings are eliminated. A number of facilities such as service stations, rest rooms, restaurants, telephone facilities, emergency services, etc. are provided. The expressways though costly to build bring enormous savings in fuel, wear and tear and in travel time resulting is smooth, fast and safe travel.

A modest beginning has been made by building of taking up the first national expressway between Ahmedabad and Vadodara. Also, Maharashtra government has successfully completed the construction of expressway between Bombay and Pune.

Planning Aspects

The expressways have certain unique characteristics which need to be taken care of in the project planning stage. These large long lasting facilities and have to be panned keeping in view the future requirements of traffic and needs of capacity augmentation. It is important to plan for and to provide land for future expansion of the project. The initial two or four lanes may need to be widened to six or eight lanes in the future or interchanges may need to be added or expanded. The concept of an ultimate design and stage implementation is, therefore, very important.

The high speed roads are meant to provide fast travel for motor vehicles. This requires restricting the usage of facilities to only fast and prohibiting slow moving vehicles, two or three wheelers, etc. from their usage. These roads also tend to attract and stimulate new development of commercial, industrial uses and residential uses particularly near interchanges it is essential to plan for integration of the local traffic with the traffic in the planning stage itself.

Control of access to expressway is of vital importance. Wherever these facilities are existing, special enabling laws and traffic are enacted for this purpose. No comprehensive central legislation is available at present to cater to traffic and access control.

Development of expressways apart from problems of raising of huge resources, are not suited to traditional methods of road construction. These require the use of modern road construction equipments and techniques.Operation and management of modern high speed roads is also a specialized job requiring use of modern management techniques and computerized equipment for safe operation of these facilities.

Recently, there is a concerted effort being made in India towards the planning and design of expressways. A number of studies on expressways have been conducted in the past by various consultants that are mostly concerned with the feasibility studies in terms of economic and financial analysis. Though these studies conducted in a conventional way but do not take into account the concept of sustainability that is increasingly being felt to be incorporated in the planning of expressways.

For the future development of road projects to be carried out in a sustainable basis, effort should be made from the beginning stage only and that starts from the selection of a sustainable alignment. Any proposed alignment option must be studied in terms of:

- **Social Sustainability**
- **Environmental Sustainability**
- **Traffic Sustainability**
- **Economic Sustainability**

The concept has been explained in the following flowchart:

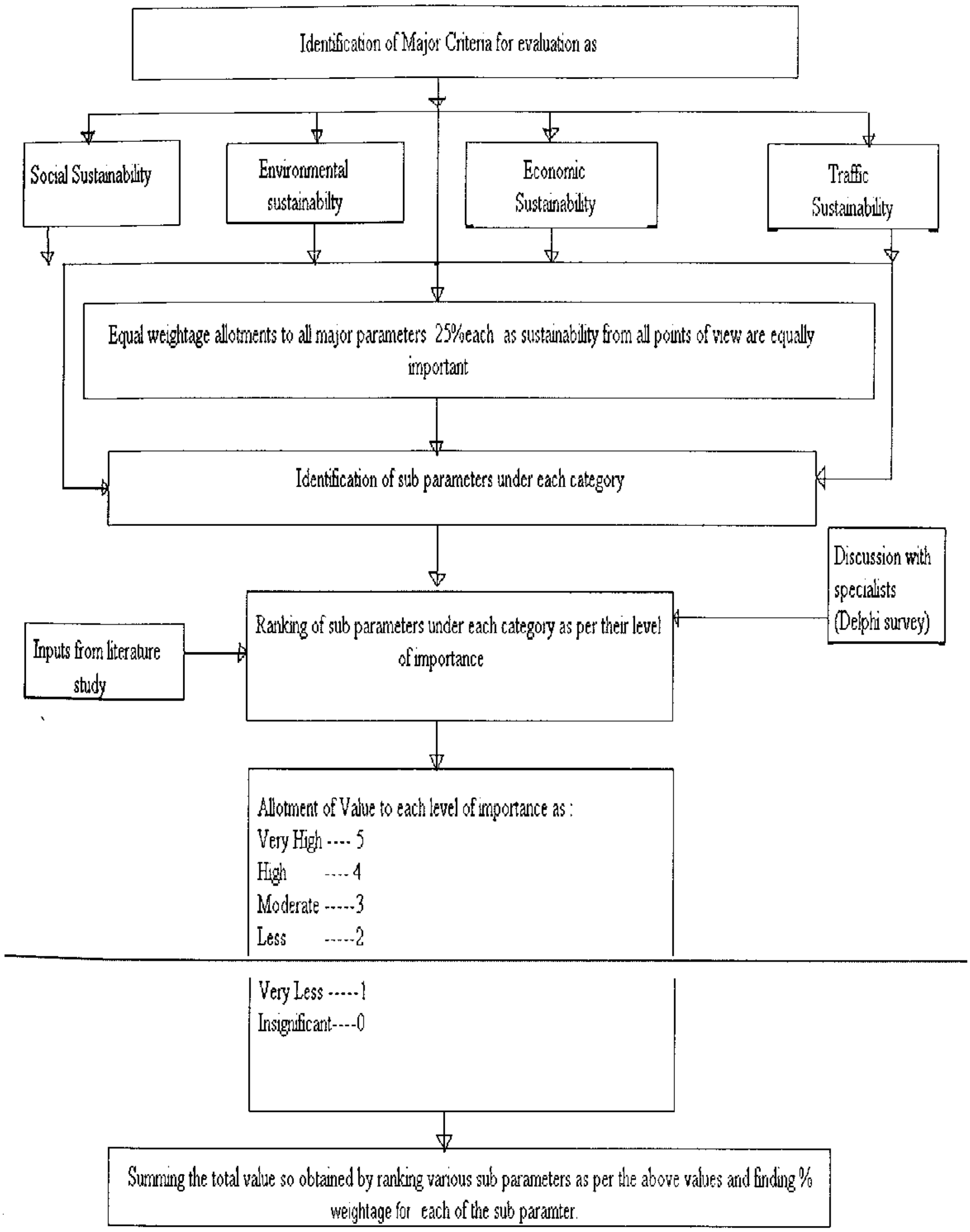

Identification of Major Criteria for evaluation as
Social Sustainability
Environmental sustainabilty
Economic Sustainability
Traffic Sustainability
Equal weightage allotments to all major parameters 25%each as sustainability from all points of view are equally important
Identification of sub parameters under each category
Discussion with specialists (Delphi survey)
Ranking of sub parameters under each category as per their level of importance
Inputs from literature study
Allotment of Value to each level of importance as :
Very High ---- 5
High ---- 4
Moderate -----3
Less -----2
Very Less -----1
Insignificant----0
Summing the total value so obtained by ranking various sub parameters as per the above values and finding % weightage for each of the sub paramter.

Figure 1

ABSTRACT

ECONOMIC GROWTH AND ROAD TRANSPORT:

As India's economy is diversifying and undergoing significant structural changes, road transport is growing at a rapid pace.The motor vehicle fleet has grown at a rate of 10% per year during the past four decades.Road –based passenger movement has grown at a rate of 10% annually whereas freight transport by road has grown at around 9%.

With expectations of an accelerated economic growth in the coming years, these past trends may even be surpassed.Road transport currently accounts for nearly 80% of the total passenger movement and around 60% of the total freight movement.(Reference:Economic Times)

SCOPE OF HIGHWAY ENGINEERING:

The road pavements are generally constructed on small embankments ,slightly above the general ground level , in order to avoid the difficult drainage and maintainance problems.The term road or roadways thus constructed is therefore termed 'highway' and the science and technology dealing with Road Engineering is generally called 'Highway Engineering'.

In nutshell , highway engineering deals with various phases like development, planning, alignment, highway geometric design ,construction ,maintainance, economic considerations, finance and administration.

OBJECTIVE

Objectives of the current project is to make a review of the status of expressways in India - stressing on need and planning aspects of an expressway. Specifications and standards required for designing an expressway have been compiled, which may be followed by the designers of an expressway.

Also , attempts have been made to bring about the various investigations to be carried out and the traffic data to be collected for the design purpose. Detailed description of various design parameters like, axle loading, alignment, intersection and other requirements for an expressway have been presented in the project along with their design examples.

From the considerations of economics and life expectancy, a rigid pavement with DLC sub-base has been considered and a pavement section for an expressway has been designed. Also the typical calculations with respect to geometric considerations have been made.

Concrete mix design has been prepared for M20, M30 and M40 grades of concrete along with their cost analysis.

Finally, computer programs have been developed for design of rigid pavement and design of geometric features of an expressway.

The study of various features of an expressway and their design has presented us with an opportunity to use the theoretical and technical know-how imparted to us to a real life project.

1

INTRODUCTION OF AN EXPRESSWAY

1.1 DEFINITION

An **expressway** is a divided highway for high-speed traffic with at least partial control of access. They are generally provided with grade separations at intersections.

In some jurisdictions, expressways are divided arterial roads with limits on the frequency of driveways and intersecting cross-streets. In other jurisdictions, access to expressways is limited only to grade-separated interchanges, making them the full equivalent of freeways.

Most expressways have speed limits of 45-55 mph (70-90 km/h) in urban areas and 55-70 mph (90-110 km/h) in rural areas. Urban expressways are usually free of private driveways, but occasional exceptions include direct driveways to gas stations and shopping centers at major intersections (which would never be allowed on a true freeway) .

The vast majority of expressways are built by state governments, or by private companies which then operate them as toll roads pursuant to a license from the state government.

Construction of expressways will improve traffic safety and provide faster movement of vehicles with improved riding quality and time. This will lead to reduction in vehicle operating cost and significant reduction in fuel consumption for the vehicle resulting in energy conservation.

Their main function is to provide movement of heavy volumes of motor traffic at high speeds under free-flow conditions. They connect major points of traffic generation and are intended to serve trips of medium and long lengths between residential areas, industrial or commercial concentrations and the central business district.

1.2 TYPICAL CHARACTERISTICS

Expressways have the following typical characteristics:

1. Design speeds: **110 to 160 km/h (usually 120 K.P.H)**
2. **Four-lane** divided highway (2-lane in each direction).
   It can be **6** or **8-lane** also.
3. Grade-separated intersections: Overpasses and Underpasses for roads crossing the expressway.
4. Access Control: Access to expressway is at **grade separations** and at **grade intersections** with traffic-signals.
5. Slow-moving traffic and Pedestrians are not allowed to enter the expressway. (Bicycles, tractors etc.)
6. Highway signs, Lane markings, safety barriers are provided for traffic control.
7. Rest areas and emerging services have to be provided.
8. Road surface: Smooth without potholes and cracks for high speed traffic movement. Pavement construction and maintenance at high standards.

1.3 MAIN FEATURES

1. Exclusion of pedestrians, animals, animal-drawn vehicles, cycles, agricultural tractors and motorized two- wheelers having an engine capacity of less than 50c.c
2. Complete separation of opposite traffic streams by a median
3. Elimination of all crossing at the road level
4. Provision of specially designed inter-changes at reasonably long intervals and the elimination of other accesses.
5. Moderate gradients and gentle curves with adequate sight distances permitting high speeds.
6. Hard shoulders on the outer edge of each carriageway to facilitate parking of vehicles of carriageway.
7. Provision of telephones, servicing and refreshment facilities at convenient intervals.
8. Police and traffic aid posts at convenient intervals.

1.4 DESIGN STANDARDS

1. **Design Speed:**
   a. **Level and Rolling Terrains:** 110 to 160 km/h(usually 120 km/h)
   b. **Mountainous Terrain**: 80 km/h

2. **Ruling Grade:** Upgrade and Downgrade.
   a. **Level and Rolling terrains:** 3 % maximum
   b. **Mountainous terrain:** 6 % maximum

3. **Lane Width:**
   a. Standard 12 ft. (3.6m)
   b. Mountainous roads: 9 to 10 ft. (2.7m to 3.0m)

4. **Paved Shoulders:** 3.5m wide

5. **Median:** 6m.

   Depending upon future requirements for extra lanes.

6. **Side Slopes:** 4:1 OR 6:1 (1 vertical, 4 horizontal) on Soil slopes, steeper slopes on rock cuts.

7. **Median Slopes:** same as Side-slopes.

8. **Cross Slopes on the pavement (Road surface):**

   2 % on lanes, 4% on shoulders.

9. **Marginal Area:** 60 ft. clear area from the edge of the shoulder for protecting vehicles crashing into the ditch.

10. **Right of way:** Total width required to construct the Expressway; 90 m.

11. **Horizontal Curves:** Every curve is designed according to the centre-line of the road.

(i) Minimum radius: 700m

(ii) Desirable radius: 2600m

(iii) Minimum curve length: 240m

Design Elements: (i) Radius

(ii) Super-elevation

(iii) Side friction

12. **Safe Stopping Sight Distance:** To be calculated using the design speed and perception-reaction time of **2.5** seconds

(i) Desirable: 500m

(ii) Minimum: 250m

13. **Interchanges:** Left-turning and Right-turning ramps are designed as horizontal curves at 25 to 30 mph (40 to 50 km/h).

Interchange design speed: (i) Desirable :80 K.P.H
(ii) Minimum:60 K.P.H

Interchange ramp gradient: (i) Desirable : 4 to 5 %.
(ii) Absolute minimum: 60 %

Interchange carriageway : (i) Desirable : 7m
(ii) Minimum: 5.5m

14. **Culverts:** For drainage under the expressway.

15. **Safety Barriers:** Steel guard rails and New Jersey Concrete barriers about 30 inches (75 cm) high provided on curves when the Side Slope is steeper than 4:1, on slopes on Mountainous roads, on medians etc. for preventing the vehicle from leaving the road. Also provided to protect bridge-abutments.

16. **Signs and Markings:** Signs are designed for reading when the vehicles are going at the design speed of speed limit. Lane-marking should be clearly visible. Sometimes, markings are lighted with reflectors. Shoulder line must be clearly visible.

17. **Rest Areas:** Rest areas are provided for comfort and convenience of the highway travelers (drivers and passengers). Generally, they are spaced at 50 to 100 mile (80 km to 160 km). The facilities include:
    - Parking,
    - Restrooms
    - Telephone booths
    - Restaurants
    - Picnic Areas
    - Fuel pumps (Petrol and Diesel)

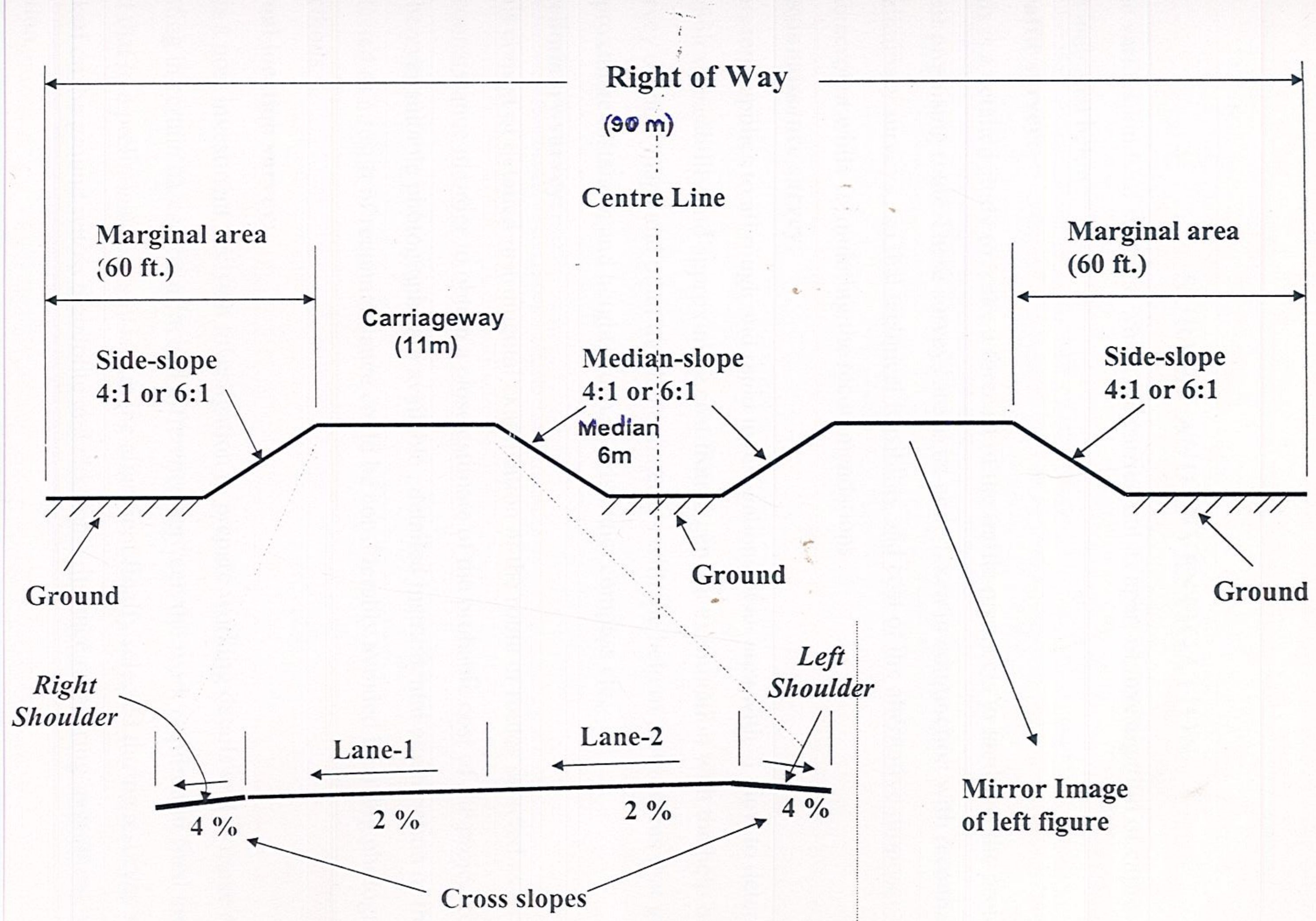
    They have to be provided on both sides of the expressway.

18. **Toll Booth:** For collections of toll charges manually or by electronic-tickets.

1.5 CONCLUSIONS

An **expressway** is a divided highway for high-speed traffic designed to carry large traffic volumes. Speed limits are posted frequently on the sides of the highway and also on all curves. Speeds are reduced on sharp curves. Expressways are intended for providing comfortable driving conditions for long-distance travellers.

Construction of expressways will improve traffic safety and provide faster movement of vehicles with improved riding quality and time. This will lead to reduction in vehicle operating cost and significant reduction in fuel consumption for the vehicle resulting in energy conservation.



CROSS-SECTION OF 4-LANE DIVIDED EXPRESSWAY WITH A MEDIAN DITCH

Figure 1

2

SURVEY AND INVESTIGATION

The various kinds of surveys, which are carried out as apart of investigation of expressway project , are indicated below:

1. **Traffic survey:**

   This is a detailed study to make a forecast of the traffic prospects to facilitate the projection of the most promising route.These surveys are to be undertaken in conjunction with reconnaissance or preliminary surveys., so that technical feasibility and cost of the alternative proposals can be taken into account while formulating the recommendations.

2. **Reconnaissance survey:**

   This term applies to all rough and rapid investigations of an area with a view to determine the technical feasibility and approximate cost from a general examination with the help of contoured survey of India maps and other available materials with the help of instruments that gives an approximate distances and heights such as prismatic compass etc.

3. **Preliminary survey:**

   This consist of detailed instrumental examination of the route or routes selected as a result of reconnaissance in order to obtain a close estimate of the probable cost of the projected route . Wherever suitable photographs are available , detailed instrumental examination of the route selected as a result of reconnaissance could be considerably avoided by using photogrammetric methods.

4. **Final location survey:**

   It is a post investment decision investigation to prepare working details and to make accurate costing in certain cases.The principal difference between the work required in final location survey and that in a preliminary survey is that the alignment finally selected during a survey should be fully staked on the ground with a theodolite and electronic distance measuring instrument or the total station.

3

TRAFFIC STUDY

3.1 INTRODUCTION

Traffic engineering is the branch of engineering which deals with the improvement of traffic performance of road networks and terminals.

Institute of traffic engineers, U.S.A defines, "Traffic engineering is that phase of engineering which deals with the planning and geometric design of streets, highways, abutting, and lands and with traffic operation there on as their use is related to the safe, convenient and economic transportation of persons and goods".

3.2 SCOPE OF TRAFFIC ENGINEERING

The basic object of traffic engineering is to achieve efficient free and rapid flow of traffic. The study of traffic engineering may be divided into six major sections:

1. Traffic Studies and analysis
2. Traffic characteristics
3. Traffic Operation- control and regulation
4. Planning and Analysis
5. Geometric Design
6. Administration and Management

3.3 TRAFFIC STUDIES

Traffic studies or surveys are carried out to analyze the traffic characteristics. These studies help in deciding the geometric design features and traffic control for safe and efficient traffic movements. The traffic surveys for collecting traffic data are also called traffic sensus. The various traffic studies generally carried out are:

1. Traffic Volume Study
2. Speed Studies
3. Origin and Destination Study
4. Traffic Flow Characteristics

5. Traffic Capacity Study
6. Parking study
7. Accident Studies or the Traffic Flop

Traffic Volume Study

Traffic volume is the number of vehicles crossing a section of road per unit time at any selected period and used in planning, traffic operation and control of existing facilities and also used in structural design of pavements.

Speed Studies

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

Origin and Destination Study

The origin and destination study is carried out mainly to

(i) plan the road network

(ii) plan the schedule of different modes of transportation for the trip demand of commuters

Traffic Flow Characteristics

Traffic stream generally has the flow and counter flow along a common route unless the stream is separated into pair of one way flows by proper design or regulations.

Traffic Capacity Study

Traffic capacity is ability of a roadway to accommodate traffic volume. It is expressed as the maximum number of vehicles in a lane or a road that can pass a given point in unit time, usually in one hour. i;e. vehicles per hour per lane.

Parking Study

Various aspects to be investigated during parking studies are:

1. Parking Demand
2. Parking Characteristics
3. Parking Space Inventory

Accident Studies

Traffic accidents may involve property damages, personal injuries or even casualties .Therefore traffic engineer has to carry out systematic accident studies to investigate the causes of accidents and to take preventive measures in terms of design and control.

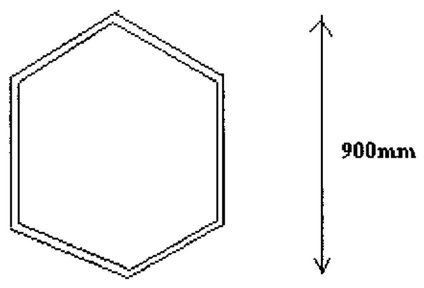
3.4 TRAFFIC SIGNS

Traffic signs have been divided into three categories according to Indian Motor Vehicles Act. These are:

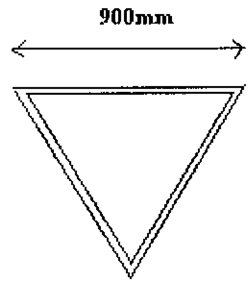
1. Regulatory Signs
2. Warning Signs
3. Informatory Signs

Regulatory Signs

Regulatory signs or mandatory signs are meant to inform road users of certain laws, regulations and prohibitions. These are stop and give way signs, prohibitory signs, no parking and no stopping signs etc.



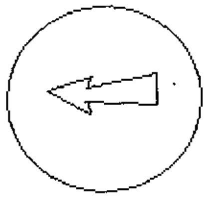
Stop



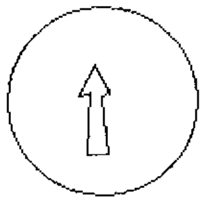
Give way

Warning Signs

Warning signs are used to warn the road users of certain hazardous conditions that exist on or adjacent to the roadway. The warning signs are in the shape of equilateral triangle with its apex pointing upwards. Commonly used warning signs are Right hand curve, left hand curve etc.



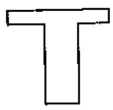
Compulsory Left Turn



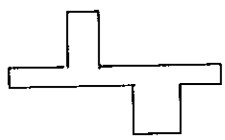
Copulsory Ahead Only

Informatory Signs

These signs are used to guide the road users along routes inform them of destination and distance and provide with information to make travel easier, safe and pleasant. The information signs are Direction information signs, Facility information Signs, Parking Signs and Flood gause.



T- intersection



Major road ahead

3.5 ROAD MARKING

Road markings are made of lines, patterns, words symbols or reflectors on the pavement, kerb sides of islands or on the fixed objects within or near the roadway. The markings are made using paints in contrast with colour and brightness of the pavement or other back ground. Light reflecting paints are commonly used for traffic marking. Different types of marking may be classified as:

1. Pavement Marking
2. Kerb Marking
3. Object Marking
4. Reflector Unit Marking

3.6 ROAD LIGHTING

Lamp post is provided side of the road and the middle of the road for vehicles for proper lighting on the road. Lighting should be in proper manner so that driver can see clearly the vehicle which is coming from onwards. Large lamps with high mountings and wide spacing should be preferred from economy point of view. On straight roads of expressway the lighting may be of the following type:

1. Single Side
2. Staggered
3. Central

4

GEOMETRIC DESIGN

4.1 INTRODUCTION

Geometric design is an aspect of highway design dealing with the visible dimensions of a roadway. It is dictated, within economic limitations, by the requirements of traffic and includes the design elements of horizontal and vertical alignment, sight distance, cross section components, lateral and vertical clearances, intersection treatment, control of access, etc.

The safe ,efficient and economic operation of a highway is governed to a large extent by the care with which the geometric design has been worked out. Efficient and comfortable operation of traffic is possible only if the design elements have been meticulously considered. A well designed highway has to be consistent with economy.

The design engineer has to consider the following points when selecting the design standards for a highway:

i) Adequate geometric design in planning a highway facility ensures that the facility will not become obsolete in the foreseeable future. Hence the volume and composition of traffic in the design year should be the basis of design.

ii) Faulty geometrics are costly, if not impossible to rectify at a later date and so, Due consideration should be given to geometrics design at the initial stage itself.

iii) The design should be consistent and the standards proposed for the different elements should be compatible with one another. Abrupt changes in the design should be avoided.

iv) The design should embrace all aspects of geometrics of the road, including Signs, markings, proper lighting, intersecting, etc.

v) The highway should be considered as an element of the total environment and its location and design should enhance rather than degrade the environment. All its design elements should strive to control pollution.

vi) The design should be so selected that not only the initial cost of construction of the facility, but also the total transportation cost, including maintenance cost and road user cost should be minimized.

4.2 DESIGN CONTROL AND CRITERIA

GENERAL: There are basic design controls and criteria which govern the geometric features of a highway. These are: Topography, traffic, speed capacity, design vehicle and control of access.

TOPOGRAPHY: Topography and physical features play an important role in the location and design of a highway. The various design elements should be related to topographical features if an economical and sound design is to emerge. The Classification of the terrain is normally done by means of the cross slope of the country, the slope approximately perpendicular to the center-line of the highway location. The classification, generally followed is given in Table1:

Classification of the terrain by means of the cross slope of the country

S.No	Terrain Classification	Percent cross slope of country
1	Level	0 to 10
2	Rolling	10 to 25
3	Mountains	25 to 60
4	Steep	Greater than 60

Table 4.1

An extensive survey of 42,000Kms of roads in India as a part of the Road user cost study has classified the terrain as per table 5.2. The quantification of curvature and rise and fall has been on the basis of figure-5.1.

Plan:

Average curvature (CV) of section AB is given by:

$$CV = \frac{\oint 1 + \oint 2 + \oint 3 + \ldots\ldots + \oint n}{\text{DistanceAB (Km)}}$$,expressed in degrees/Km

Longitudinal Profile:

Average rise (RS) of section AB is given by:

$$RS = \frac{h1+h2+h3+\ldots\ldots\ldots hn\ (\text{metres})}{\text{DistanceAB (Km)}}$$, expressed in m/Km

Average fall (FL) of section AB is given by:

$$FL = \frac{h2+h4+\ldots\ldots\ldots\ldots hm\ (\text{metres})}{\text{Distance AB (Km)}}$$, expressed in m/Km

Average rise and fall (RF) of section AB is given by :

$$RF = \frac{h1+h2+h3+\ldots hm+hn\ (\text{metres})}{\text{Distance AB (km)}}$$, expressed in m/Km

Terrain classification suggested in Road user cost study

S.No	Terrain Classification	Rise and Fall (m/km)	Curvature (Deg/km)
1	**Plain**		
	(a) Low curvature	0-15	0-50
	(b) High curvature	0-15	Above51
2	**Rolling**		
	(a) Low curvature	16-30	0-100
	(b) High curvature	16-30	Above101
3	**Hilly**		
	(a) Low curvature	Over 31	0-200
	(b) High curvature	Over 31	Above 201

Table4.2

DESIGN VEHICLE DIMENTIONS:

A "Design vehicle" is a selected motor vehicle, the weight, dimension and operating characteristics of which are used to establish expressway design controls to accommodate vehicles of a designated type. The dimensions and operating characteristics of a vehicle profoundly influence the geometric design aspect such as radii width of pavements, clearances, parking geometrics etc. The weight of axles and the weight of the vehicles affect the structural design of the pavement and structures, as also the operating characteristics of vehicles on grades. Because of its crucial importance, the standardization of the dimensions and weight of design vehicles is the first step in formulating geometric design standards.

Types of design vehicles:

The IRC standard contains only commercial vehicles of the following types:

1. Single Unit Truck.
2. Semi trailer.
3. Truck trailer combination.

Standards of dimension for design vehicle by IRC

Authority	Maximum Width	Maximum Height	Passenger Car	Single Unit Truck	Semi trailer	Truck Trailer	Single Unit Bus
IRC(1983)	2.5	3.8-4.2 (Truck) 4.75 (Double Decker Bus)	----	11.0	16.0	18.0	12.0

Table 4.3

The turning radii for the various IRC design vehicles

Design Vehicle Type	Passenger Car (P)	Ingle Unit Truck (SU)	Semitrailer (large) (WB-50)	Semitrailer full Truck (WB-60)
Minimum turning Radius(m)	7.32	12.8	13.72	13.75
Minimum Inside Radius(m)	4.65	8.61	6.00	6.85

Table 4.4

Axle loads and weights of vehicles: The vehicles maximum axle loads of vehicles as per IRC standard is given below:

Maximum Axle loads (tones)

	Single Axle	Tandem Axle
IRC	10.2	18.0

Table 4.5

The maximum weight of vehicles depends upon the number, configuration and spacing of axles.

Selection of the design vehicle: The selection of the design vehicle for the design of an expressway is governed by the type and volume of traffic that is expected to use the expressway. For instance, the design of a superior facility such as a motorway or an expressway should be based on the largest design vehicle. The design of streets and junctions primarily in residential areas can be done by using the passenger car design vehicle.

DESIGN SPEED:

Speed as design factor. The design of an expressway is largely indicated by the speed, safety and convenience afforded by the facility for travel. Speed is important for economic operation and has great bearing on the safety of the expressway.

"Design Speed" is a speed determined for design and correlation of the physical features of an expressway that influence vehicle operation.The design speed obviously has to be correlated with the terrain conditions and the classification of the expressway.

Suggested design speeds in India for Rural Expressway

(All values in K.P.H)

Plain Terrain		Rolling Terrain		Mountainous Terrain	
Ruling	**Minimum**	**Ruling**	**Minimum**	**Ruling**	**Minimum**
130	110	80	65	50	40
120	100	70	60	40	30

Table 4.6

Suggested design speeds in India

Classification of Roads	Speeds in K.P.H
Expressway	**120**
Highway	100
Arterial	80
Sub Arterial	60
Collector Streets	50
Local Streets	30

Table 4.7

CAPACITY:

Capacity is the maximum flow that can be accommodated in an expressway facility.Early attempts to determine the capacity were made on the basis of the following theoretical formula:

$$C = \frac{1000V}{S}$$

Where, C = Capacity in vehicles per hour lane.

V = Speed in K.P.H.

S = Average spacing in metres between successive moving vehicles.

S = Length of vehicle + Dist. traveled during perception – brake reaction time + breaking dist.

$$= L + \frac{t.V.1000}{3600} + \frac{(V.1000)^2}{(3600^2)} \cdot \frac{1}{2.g.f}$$

$$= L + 0.278\ V.t + \frac{V^2}{254f}$$

Where, S = Spacing between vehicles (m)

L = Length of vehicles (m)

V = Speed in K.P.H

t = Perception-brake reaction time (sec)

f = Coefficient of friction

g = Acceleration due to gravity,(m/sec^2)

Design capacity of Rural Motorway

Type of Carriageway	**Daily Design Capacity PCUs/day**	**Peak Hourly Design capacity Per lane (PCU/hr)**
Dual 2—Lane	33000	1000
Dual 3—Lane	50000	1000
Dual 4—Lane	66000	1000

Table 4.8

Design capacity of multi lane highways in rural areas as per IRC

Type of Highway	**Design capacity PCUs per hr per 3.66m lane**
Freeway, suburban (running speed 65-75K.P.H)	1200
Freeways & expressways with partial control of access and with little interference from cross- traffic, rural(average running speed 75-80 K.P.H)	1000
Major highways with moderate interference from cross traffic and roadsides (average running speed 75-80 K.P.H).	700-900
Major highways with considerable interference from cross traffic and roadsides (average running speed 65-75K.P.H)	500-700

Table 4.9

Suggested design service volume for Indian conditions

Terrain	Curvature (Degrees per Km)	Design Service volume PCU/Day
	Two lane Roads	
1. Plain	Low (0-50)	15000
2. Rolling	High (Above 51)	12500
3. Hilly	Low (0-100)	11000
	High(Above101)	10000
	Low (0-200)	7000
	High (Above201)	5000
	Intermediate lane Roads	
1. Plain	Low (0-50)	6000
2. Rolling	High (Above 51)	5800
3. Hilly	Low (0-100)	5700
	High(Above101)	5600
	Low (0-200)	5200
	High (Above201)	4500
	Single lane Roads	
1. Plain	Low (0-50)	2000
2. Rolling	High (Above 51)	2000
3. Hilly	Low (0-100)	1800
	High(Above101)	1800
	Low (0-200)	1800
	High (Above201)	1400

Table 4.10

In India ,for four-lane expressways, the suggested design service volume are 35,000-40,000 per IRC.

4.3 ALIGNMENT:

Expressways should have smooth-flowing horizontal and vertical alignments. Proper combinations of curvature, tangents, grades, and median types all combine to enhance the safety and aesthetics of expressways. When laying out expressway alignments, consider the following guidelines:

1. **Horizontal Alignment :**

- In rural areas, use large radius curves (desirably R =3000 ft (1000 m)).
- Existing horizontal curves may remain in place provided they have a comfortable operating speed of 65 mph (105 km/h) (level) or 60 mph (100 km/h) (rolling) and there is no history of crashes.

Basic formula for movement of vehicles on curves;

When a vehicle is moving on curved path, it is subjected to an outward force, commonly known as the centrifugal force. In order to resist this force, it is the usual practice to super elevate the roadway cross section.

Let m = mass of the vehicle

v = speed of the vehicle in metres/sec.

R = Radius of the curve in metres.

g = Acceleration due to gravity.

P = Side friction force resisting the centrifugal force =Nμ

N = Normal Force

μ = Coefficient of lateral friction

α = Angle of super elevation

e = Rate of super-elevation, tanα

The centrifugal force : $\frac{mv^2}{R}$

Expressing speed as V in K.P.H. :

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

This equation forms the basis of design of **Horizontal Curves.**

Value of coefficient of lateral friction:

The value of the coefficient of lateral friction depends upon a number of factors, chief among them being the vehicle speed, type and condition of roadway surface, and type and condition of the tyres. IRC recommends the values given in Table.

Coefficient of lateral friction as recommended by IRC

Design speed (K.P.H)	120	100	80	65
Maximum lateral	0.12	0.13	0.14	0.15

Table 4.11

The **IRC recommends** a constant value of 0.15.

Maximum super-elevation value:

As per Indian practice super elevation is calculated on the assumption that it should counteract the centrifugal force developed at **3/4th the design speed**. Thus:

$$e = \frac{0.75V^2}{127R} = \frac{V^2}{225R}$$

In India, the IRC recommendations for hill roads are a maximum value of 0.07 for snowbound areas and 0.10 for areas not affected by snow. In other cases, a value of **0.07** is considered maximum.

Minimum radii of curves:

Equation can be rewritten as:

$$R = \frac{v^2}{127(e+\mu)}$$

Adopting the value of e = 0.07 or 0.0.10 and μ =0.15 as per current Indian Practice, the formula becomes:

R=0.0357V^2 (for plain and rolling terrain)

R=0.0315V^2 (for hill roads which are not snowbound)

R=0.0357V^2 (for hill roads which are snowbound)

PROBLEM: A horizontal curve is to be designed for an expressway in plain terrain. Calculate the ruling minimum and absolute minimum radii. Make suitable assumptions.

SOLUTION:

Assumptions made:

1. Design speed(ruling) = 120 K.P.H
2. Design speed(minimum) = 100 K.P.H (refer Table 7)
3. Maximum super elevation = e= 0.07
4. Coefficient of lateral friction = 0.15

$$R = \frac{v\text{^}2}{127(e+\mu)}$$

Substituting, V=120,e=0.07, μ=0.15

$$R = \frac{120\text{ ^}2}{127(0.07+0.15)}$$

$$= 515.390 \text{ m, say } 515 \text{ m}$$

Thus , the ruling minimum radius is 515 m.

For minimum design speed of V= 100,

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

$$= 357.9 \text{ m, say } 360 \text{ m.}$$

Thus , the absolute minimum radius is 360 m.

PROBLEM : Calculate the super-elevation to be provided for a horizontal curve with a radius 0f 400m for a design speed of 100K.P.H in plain terrain.

SOLUTION:

According to IRC, the super –elevation is calculated on the assumption that it should counteract the centripetal force developed at 3/4th the design speed.

$$\text{Thus, } e = \frac{(0.75\text{ v})\text{^}2}{127R}$$

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

Substituting, V=100, R =400

$$e = \frac{100^2}{225*400} = 1/9 = 0.11$$

But according to IRC practice , the maximum super-elevation allowable is 0.07. Thus , the calculated super –elevation rate is too high and should be restricted to 0.07. The balance of the centripetal force will be taken care of by the friction which is mobilized. Let μ be the coefficient of friction

$$(e + \mu) = \frac{V^2}{127R}$$

$$(0.07 + \mu) = \frac{100^2}{127 *400} = 0.20$$

$$\mu = 0.13$$

which is below the recommended value of 0.15.

2. Vertical Alignment :

a. **Sag Vertical Curves.** Existing sag vertical curves may remain in place if they have a design speed of 50 mph (80 km/h) or greater and do not have a history of crashes. If not, reconstruct the sag vertical curve to a design speed of 70 mph (110 km/h).

b. **Crest Vertical Curves.** Existing crest vertical curves may remain in place if they have a design speed of 55 mph (90 km/h) or greater and do not have a history of crashes. If not, reconstruct the crest vertical curve to a design speed of 70 mph(110 km/h).

Gradients:

Maximum Grades. One of the important considerations in designing an expressway is the gradient. The cost of operation of vehicles, the speed of vehicles and the capacity of an expressway are profoundly affected by the grades provided. On mountainous and steep terrain,
grades are not only influenced by the ability of vehicles to negotiate them, but also by the altitude of a road above the sea level.

In mountainous and steep terrain , successive stretches of exceptional gradients must be separated by a minimum length of 100m having gentler gradient (limiting gradient or flatter).The rise in elevation over a length of 2 km shall not exceed 100m in mountainous terrain and 120 in steep terrain. **At hair pin bends, the gradient is restricted to 2.5%.**

Minimum Gradients for Drainage. Where the drainage of the road is to be effected by means of longitudinal ditches, as in cut sections or hill roads, or along the curbed edge of pavements, a certain minimum longitudinal gradient its necessary for efficient drainage. The values given in Table 5.12 are commonly adopted.

Minimum Gradients for Drainage

S.No	Site Conditions	Minimum Gradient %
1	Longitudinal Drainage along curbed edge of pavements (lined)	0.5
2	Longitudinal Drainage along road side ditches (unlined)	1.0

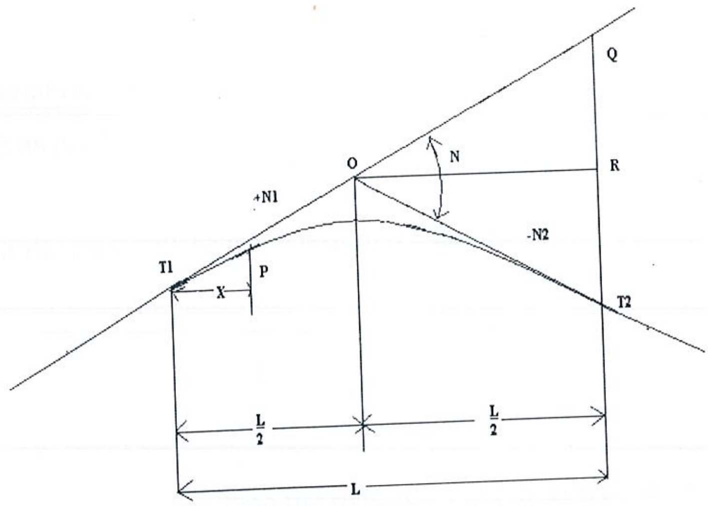
Table 4.12

Vertical curves :

General considerations. Vertical curves should be provided at points of change grade.

The vertical curves serve a number of purposes:

1. They serve as a gradual transition form one gradient to another without discomfort to riders.
2. They eliminate sudden humps and troughs.
3. They provide adequate visibility for stopping and overtaking.



Summit Curve

Figure 4.2

Length of summit curves: The most important consideration in determining the length of the curve is sight distance requirement. The following basic formula can be used to determine the length:

(A) For Safe Stopping sight Distance.

Case I: When the sight distance (S) is less than the length of the curve (L):

$$L= \frac{NS^\wedge 2}{(\sqrt{2h1}+\sqrt{2h2})^\wedge 2}$$

Case II: When the sight distance (S) is greater than the length of the curve (L).

$$L= 2S-\frac{2(\sqrt{h1}+\sqrt{h2})^\wedge 2}{N}$$

In the above formula,

N = difference in slope expressed as an angle in radians or tangent of angle (in decimals).

S = Sight distance in metres.

L = Length of vertical curve, in metres

h1= Height of eye above 6he roadway surface.

h2= Height of object above the road surface.

(B) For intermediate or overtaking sight distance.

$h1 = h2 = 1.2$ as per Indian practice.

Case I: When the length of the curve exceeds the required sight distance, i.e.; L is greater than S.

$$L = \frac{NS^2}{9.6}$$

Case II: When the length of the curve less than the required sight distance, i.e.; L is less than S.

$$L = \frac{9.6}{N}$$

Sag curves (Valley Curves). As per current Indian practice, rider comfort is one of the basic factors in the design of sag curves

α, the radial acceleration, is given by:

$$\alpha = \frac{V^2}{13R}$$

Where, α is in m/sec^2.

V = speed in K.P.H

R = radius in m.

Since the radial acceleration changes from zero to α in a length of $\frac{L}{2}$, where L = length of the sag curve, the rate of change of radial acceleration C is given by:

$$C = \frac{V^2}{13R} \div \frac{L \times 3.6}{2V}$$

$$= \frac{V^3}{23.4LR} m/\sec^2 \quad \text{.............................. (i)}$$

The recommended value of C for design is 0.6 m/sec^3. Substituting this equation (i) we get,

$$L = \frac{V^3}{14R}, \quad LR = \frac{V^3}{14} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(ii)}$$

For a transition curve of the form of a spiral or a cubic parabola, it can be shown that

$$L = (2RLN)^{\frac{1}{2}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(iii)}$$

Where N = algebraic difference in grades of the straights, expressed as a decimal.

Substituting the value of equation (ii) in equation (iii),

$$L = \left(2\frac{V^3}{14}N\right)^{1/2}$$

$$= \frac{V^{3/2} N^{1/2}}{2.65}$$

The length of the sag curve, depending on the headlight distance at night can be determined for two conditions:

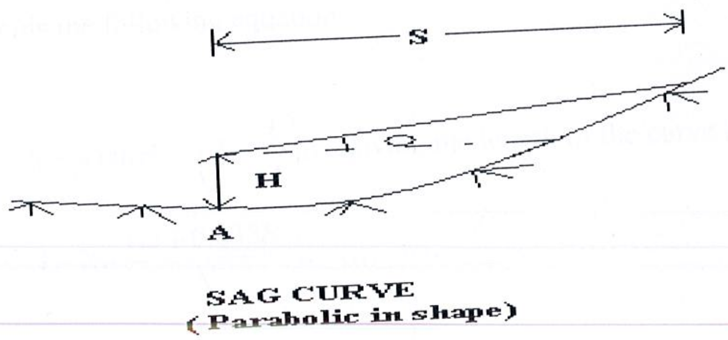
(i) L>S

(ii) L<S, where L is the length of sag curve and S is the headlight distance which should be equal or greater than the stopping sight distance.

Let h be the ht. of the headlight and the beam of headlight inclined at an angle θ

Upwards shown in fig.

Case I: L>S.



(a) L>S

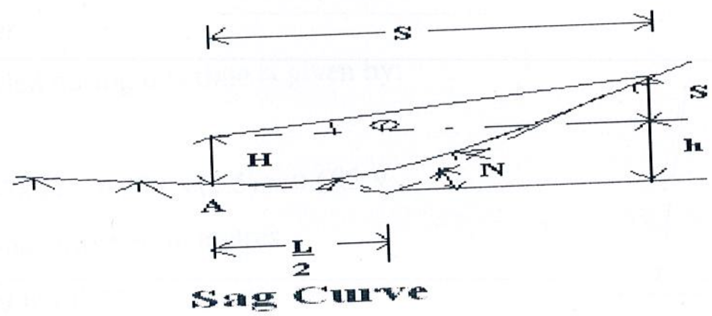
Figure 4.3

The sag curve is assumed to be parabolic in shape, expressed as y=ax^2; $\alpha = \frac{N}{2L}$ Where N is the angle of deviation [= -n1-(+n2)] and L, the total length of the sag curve. Since the sight distance 'S' will be maximum when a vehicle is at A, the lowest point of the sag curve,

$$h + s \tan\theta = \alpha x\text{^}2 = \frac{NS\text{^}2}{2L}$$

$$L= \frac{NS\text{^}2}{2(h + S\tan\theta)} = \frac{NS\text{^}2}{1.5 + 0.035S} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(iv)}$$

Case II: L<S



(b) L<S

Figure 4.4

For this case, consider a vehicle at the beginning of the curve or at the tangent point, for the headlight sight distance which yields the following equation:

$$h + s \tan\theta = \left(S - \frac{L}{2}\right)N, \text{ giving the length of the curve as}$$

$$L=2S-\frac{1.5 + 0.035S}{N} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(v)}$$

4.4 SIGHT DISTANCE

The distance along the road surface at which a driver has visibility of objects, stationary or moving , at a specific height above the carriageway is known as the sight distance. The design of a highway with adequate sight ahead of a travelling vehicle results in safe operation. Sight distance requirements can be considered under two heads:

1. STOPPING SIGHT DISTANCE

It is the distance required by a driver of a vehicle traveling at a given speed to bring his vehicle to a stop after an object on the roadway becomes visible.

As per IRC , a value of 2.5 second is considered reasonable for the perception time and brake reaction time taken together.

The distance traveled during this time is given by:

$$d1 = vt$$

$$= 0.278Vt = 0.278\ V(2.5) = 0.695\ V$$

Where, d1 = distance traveled in metres

v = speed in m/sec

V = speed in K.P.H

t = perception and brake reaction time in seconds = 2.5 seconds

On a level road ,the braking distance is given by:

$$d2 = V^2$$

d2 = braking distance in metres

V = speed in K.P.H

f = coefficient of longitudinal friction between the tyre and the pavement

= 0.35 at 120 K.P.H

Stopping distance is given by = d1 + d2

Following values of stopping sight distance are obtained by above calculations:

Stopping sight distance

Design Speed K.P.H	Safe stopping sight distance (metres)
80	120
90	150
100	180
120	210
130	230
140	260

Table 4.13

2. OVERTAKING SIGHT DISTANCE

As per IRC overtaking sight distance are taken as below:

Overtaking sight distance

Design Speed K.P.H	Safe overtaking sight distance (metres)
80	470
90	550
100	640
120	710
130	750
140	800

Table 4.14

4.5 CROSS-SECTIONAL ELEMENTS

GENERAL

The cross sectional elements in a highway design pertain to those features which deal with its width. They embrace aspects such as right-of-way , roadway width , median , shoulders , camber , side slope , horizontal and vertical clearances etc.

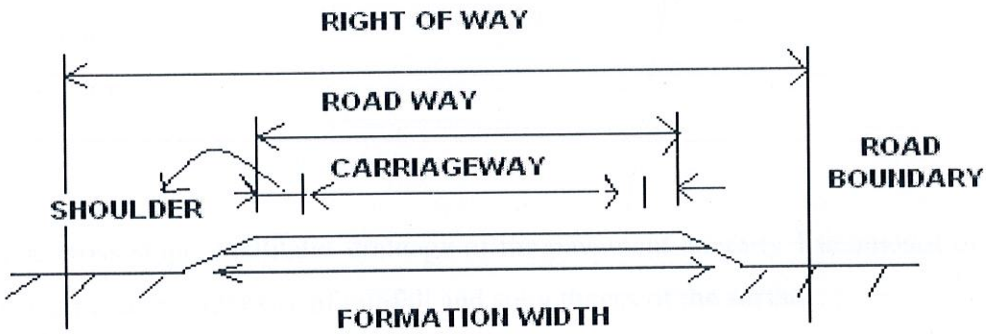
RIGHT-OF-WAY

The road land width is the width of land secured and preserved in public interest for road development purposes.

Right of way

Class of road	Right of	way(metres)
	Normal	Rural
Expressway	90	80-110
National Highway	45	30-60
District Roads	25	25-30

Table 4.15



RIGHT –OF –WAY

Figure 4.4

CARRIAGEWAY WIDTH

The width of traffic lane governs the safety and convenience of traffic and has a profound influence on the capacity of the road.

Expressway -- 3.6m (single lane width)

Highway -- 3.5m (single lane width)

In India, single lane width is generally 3.75m wide, whereas two lane pavements are 7.0 metres wide.For multi-lane pavements, Indian practice is to provide 3.5 metres per lane.

MEDIAN

It is a longitudinal space separating dual carriage-ways. The functions of a carriageway are:

1. to separate the opposing streams of traffic
2. to minimize head-light glare
3. to provide a stopping area in case of emergencies
4. to include space for safe operation of crossing and turning vehicles at intersections at- grade

Expressway - 6.0m

Highway - 5.0m

SHOULDERS

A shoulder is a portion of roadway, contiguous with the traveled way and is intended for accommodation of stopped vehicles, emergency use and lateral support of base and surface courses.

Expressway – 3.5m

Highway -- 2.5m

CAMBER

Also known as cross-slope, facilitates drainage of the pavement laterally.The amount of drainage to be provided depends on intensity of rainfall and smoothness of the surface.

Camber to be provided as per IRC

Type of surface	Camber
Cement concrete	1.7-2.0%
Thin bituminous surfacing	2.0-2.5%
Water bound macadam	2.5-3.0%

Table4.16

Design criteria for Rural Expressway

Design Element				Lanes One-Way
Design Controls	Design Forecast Year			20 Years
	*Design Speed			100 km/h
	Access Control			Partial Control
	Level of Service			B
Cross Section Elements	*Traveled Way Width			2 @ 7.2 m
	Shoulder Width	Right	Total Width	3.0 m
			Paved	3.0 m
		Left	Total Width	1.8 m
			Paved	1.2 m
	Auxiliary Lanes	Lane Width		3.6 m
		Shoulder Width		1.2 m (Paved)
	Cross Slope	*Travel Lane		1.5% for lanes adjacent to crown
		Shoulder		4%
	Median Width	Depressed		Minimum: 15 m
		Flush (Concrete Barrier)		7.0 m
	Clear Zone			
Roadway Slopes	Side Slopes	Cut Section	Front Slope	1V:6H
			Ditch Width	1.2 m
			Back Slope	1V:3H
		Rock Cut		—
		Fill Section		1V:6H to Clear Zone; 1V:3H max. to Toe of Slope
	Median Slopes			1V:6H

Table 5.17

Design criteria for Urban Expressway

Design Element					Construction (Ex-6) One-Way
Design Controls	Design Forecast Year				20 Years
	*Design Speed				Minimum 100 km/h
	Access Control				Full Control
	Level of Service				C
Cross Section Elements	*Traveled Way Width				2 @ 10.8 m
	Shoulder Width	Right	Total Width		3.0 m
			Paved		3.0 m
		Left	Total Width		3.0 m
			Paved		3.0 m
	Auxiliary Lanes	Lane Width			3.6 m
		Shoulder Width			1.2 m
	Cross Slope	*Travel Lane			1.5% for lanes adjacent to crown
		Shoulder			4%
	Median Width	Depressed			Minimum: 16.0 m
		Flush (Concrete Barrier)			7.0 m
		Raised-Curb			N/A
	Clear Zone				
Roadway Slopes	Side Slopes	Cut Section	Front Slope		1V:6H
			Ditch Width		1.2 m
			Back Slope		1V:3H
		Cut Section (Curbed)			1V:20H for 3.0 m: 1V:4H to Top of Slope
		Rock Cut			----
		Fill Section			1V:6H to Clear Zone; 1V:3H Max. to Toe of Slope
	Median Slopes	Depressed			1V:6H
		Raised-Curb			N/A

Table 5.18

5

INTERCHANGES

5.1 INTRODUCTION

An intersection is defined as the general area where two or more highways join or cross, within which are included the roadway and roadside design features which facilitate orderly traffic movements in that area. An intersection leg is that part of any one of the roadways radiating from an intersection which is outside of an area of the intersection proper.

The importance of design of the intersection stems from the fact that efficiency of operation, safety, speed, cost of operation and capacity are directly governed by the design. Since an intersection involves conflicts between traffic in different directions, its scientific design can control accidents and delay and can lead to orderly movement of traffic. Intersections represent potentially dangerous locations from the point of view of traffic safety.

The following principles should be considered in a good intersection design:

1. The number of intersections should be kept to a minimum.
2. The geometric layout should be so selected that hazardous movements by drivers are eliminated. This can be achieved by various techniques such as channelizing and staggering.
3. The layout should follow the natural vehicle paths. Smoothness, in contrast to abrupt and sharp corners, should guide minor streams of traffic into stopping or slowing down positions.
4. The number of conflict points should be minimised by seperating some of the many cutting, merging or diverging movements..

5.2 DEFINITION OF SOME COMMON TERMS

RAMPS:

- A highway ramp (as in *exit ramp* and *entrance ramp*) is a short section of road which allows vehicles to enter or exit a freeway (motorway).

WEAVING:

Is an undesirable situation in which traffic veering right and traffic veering left must cross paths within a limited distance, to merge with traffic on the through lane. In the worst circumstances, a large portion of through traffic must change lanes to stay on the same roadway. Weaving creates both safety and capacity problems..

INTERCHANGE RAMPS:

An interconnecting roadway of a traffic interchange, or any connection between highway facilities at different levels, on which vehicles may enter or leave a designated roadway. It may be in the form of a loop, outer connection or direct connection.

LOOP:

A one-way turning roadway that curves about 270degree to the left to accommodate a right-turning movement.

OUTER CONNECTION:

A ramp used by traffic destined for left-turn movement from one of the through roadways separated by a grade separation structure to the second through roadway.

COMPLETE INTERCHANGE:

A complete interchange has enough ramps to provide access from any direction of any road in the junction to any direction of any other road in the junction.

5.3 AT-GRADE AND GRADE SEPERATED JUNCTIONS:

An intersection where all roadways join or cross at the same level is known as an **At-grade intersection**.

An intersection lay-out which permits crossing manoeuvres at different levels is known as **grade-separated intersection**.

The choice between an at-grade and grade-separated junction at a particular site depends upon various factors such as traffic, economy, safety, delay etc.Grade separated junctions generally are more expensive initially, and are justified in certain situations.

BASIC FORMS OF AT-GRADE INTERSECTIONS:

1. T-junction
2. Y-junction
3. Staggered junction
4. Staggered & skewed junction
5. Cross roads
6. Scissors junction

BASIC FORMS GRADE SEPERATED INTERSECTIONS:

A. Three – leg intersection

1.T interchange

2.Y interchange

3.A practical rotary interchange

B. Four-leg intersection

1. Diamond interchange

2. Half clover leaf interchange

3. Clover leaf interchange

4. Rotary interchange

C. Multi-leg interchange

1. Rotary interchange

5.4 BASIC DESIGN CRITERIA FOR DESIGNING AN INTERSECTION

1. VISIBILITY AT INTERSECTION:

General:

The safety of traffic can be ensured only if the visibility is full and unimpeded along both roads. Any obstructions should be clear of the minimum visibility triangle for a height of 1.2 meters above the roadway.

Minimum visibility distance along major roads at priority intersections of rural highways

Design speed of major road in K.P.H	Minimum visibility distance along a major road (m)
120	200
80	180
65	145
50	110

Table 5.1

2. RADII FOR TURNING SPEEDS:

Minimum radii for intersection curves for various turning speeds

Design turning speed V(KPH)	25	30	40	50	60	65
Side friction factor, f	0.32	0.27	0.23	0.20	0.18	0.16
Assumed minimum superelevation, e	0.00	0.02	0.04	0.06	0.08	0.09
Total e+f	0.32	0.29	0.27	0.26	0.26	0.25
$R = \frac{V^2}{127(e+f)}$	14	28	47	70	96	129
Suggested minimum R(m)	15	27	45	70	95	130

Table 5.2

3. RAMP DESIGN:

3 a. Ramp Types

Ramps have varying shapes, each can be classified into one or more of the types illustrated in **Figure 5.1.**

Types of Ramp

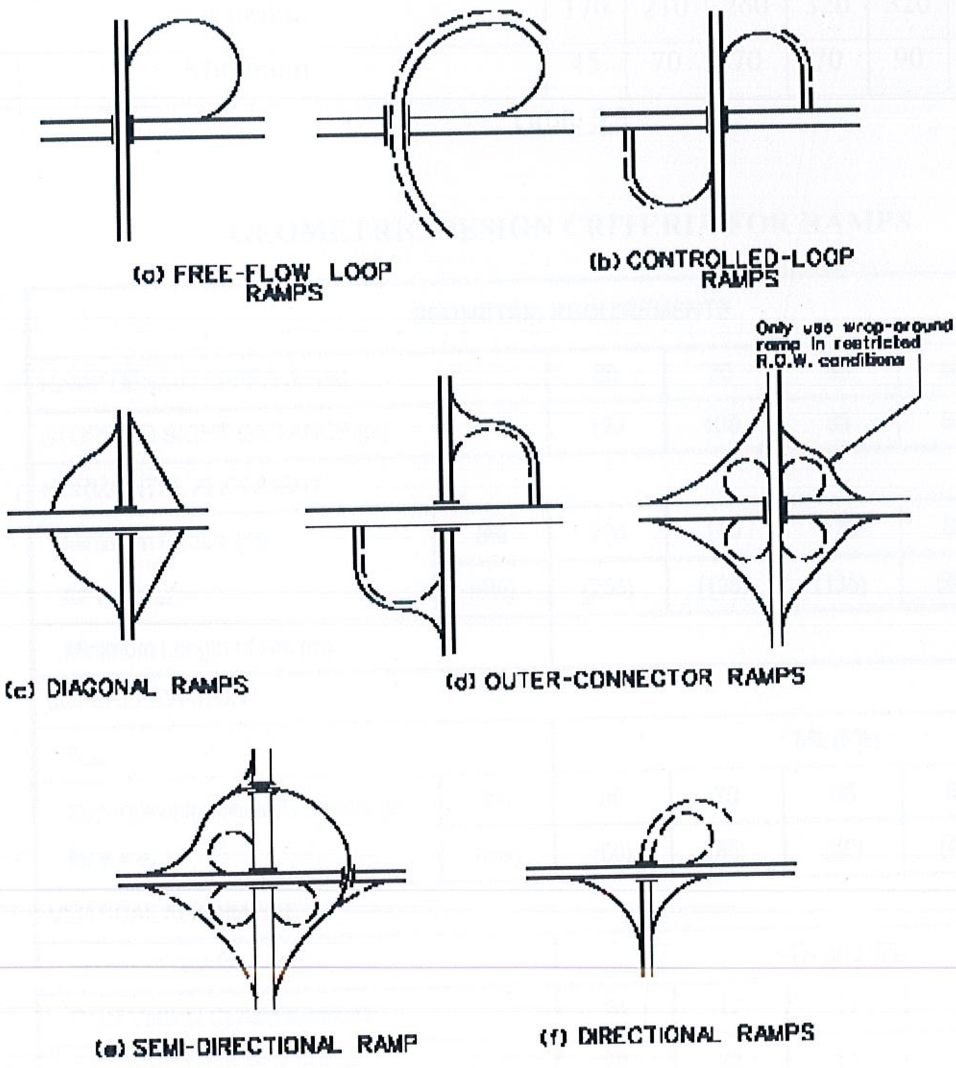


Figure 5.1

3 b. DESIGN SPEED:

Table 5.3. provides the recommended ranges of ramp design speeds based on the design speed of the mainline.

DESIGN SPEED FOR RAMPS

Highway Design Speed K.P.H	80	100	105	115	120	135
Ramp Design Speed K.P.H						
Desirable	70	80	90	100	100	105
Minimum	40	50	50	50	55	65
Corresponding minimum radius, m						
Desirable	170	210	260	320	320	380
Minimum	45	70	70	70	90	130

Table 5.3

GEOMETRIC DESIGN CRITERIA FOR RAMPS

GEOMETRIC REQUIREMENTS						
RAMP DESIGN SPEED (km/h)		80	70	60	50	40
STOPPING SIGHT DISTANCE (m)		129	105	83	64	47
HORIZONTAL ALIGNMENT						
Minimum Radius (m) for $e = e_{max}$	8%	230	180	175	85	50
	(6%)	(255)	(195)	(135)	(90)	(55)
Minimum Length of Arc (m)						
SUPERELEVATION						
e_{max}		8% (6%)				
Superelevation Runoff Lengths (m) for $e = e_{max}$	8%	80	70	65	60	55
	(6%)	(60)	(55)	(50)	(45)	(40)
VERTICAL ALIGNMENT						
Maximum Grades		+4% and -6%				
Crest Vertical Curves K-values		26	17	11	7	4
Sag Vertical Curves K-values		30	23	17	12	8

Table 5.4

3 c. CROSS SECTIONAL ELEMENTS:

1. **Width**. The minimum width of a one-way, one-lane ramp is 9.1 m, which includes a 1.8 m left shoulder (1.2 m paved), an 2.4 m right shoulder (1.8 m paved), and a 4.9 m paved traveled way. This arrangement is illustrated in the ramp cross sections in Figure 5.2.
2. **Cross Slope**. For tangent sections, the 4.9 m traveled way is sloped unidirectionally at 1.5% towards the right shoulder. Shoulder cross slopes, for both the paved and unpaved portions, are typically 4%. The left shoulder is typically sloped away from the traveled way.
3. **Curbs.** If curb and gutter is required, place it on the outside edge of the full-width paved shoulders.
4. **Side Slopes/Ditches**. For the ramp proper, use a side slope of 1V:4H or flatter..

Typical cross-section of a Ramp

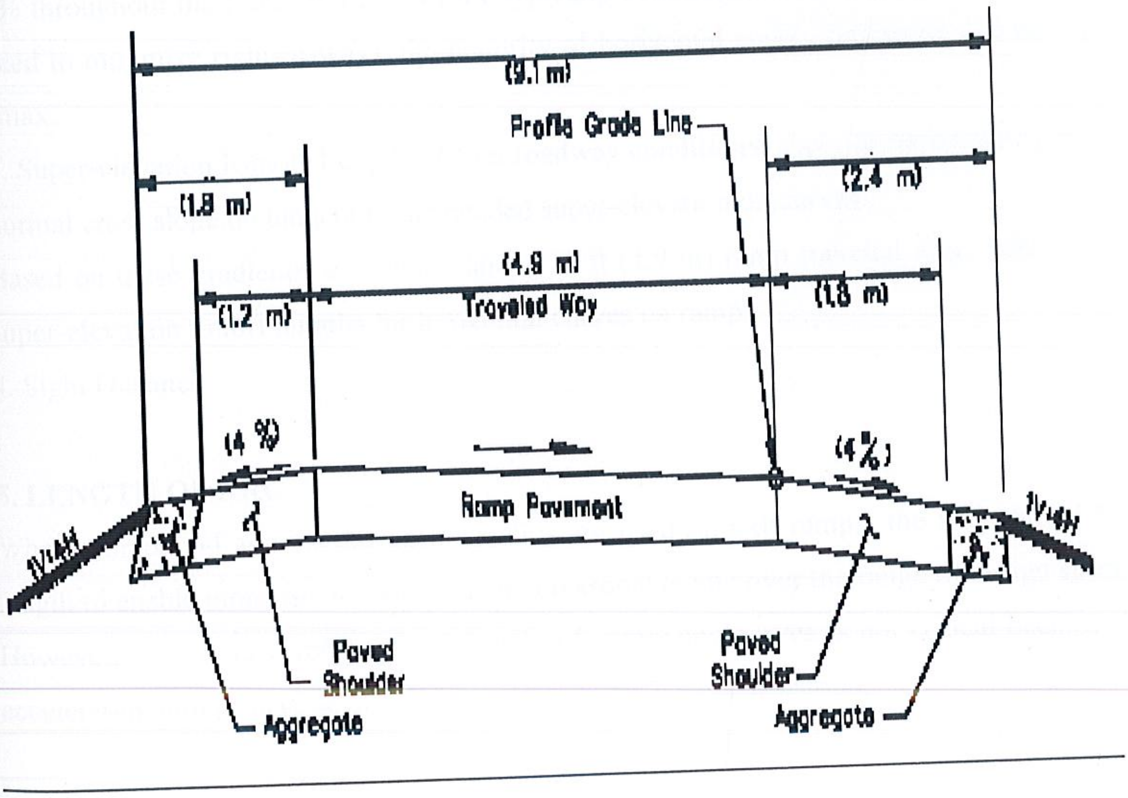


Figure 5.2

4. HORIZONTAL ALIGNMENT

(a) Theoretical Basis

Establishing horizontal alignment criteria for any highway element requires a determination of the theoretical basis for the various alignment factors. These include the side-friction factor (f), the distribution method between side friction and superelevation, the relative longitudinal gradients, and the distribution of the super-elevation runoff length between the tangent and horizontal curve.

(b) Design Controls

The following will apply to the horizontal alignment of ramps:

1. Minimum Curve Radii. **Table 5.4,** provides the minimum curve radii based on ramp design speed, open-roadway conditions, and emax.

2. Super-elevation Rates. For most areas, the maximum super-elevation rate on the ramp is emax = 8%. For areas with snow and ice conditions and/or areas with high congestion, the maximum super-elevation rate is emax = 6%. For two-lane directional roadways within an interchange, use an emax = 6% throughout the State. Because of the typically restricted site conditions for interchanges (e.g., the need to minimize right-of-way), the majority of horizontal curves on ramps will be super-elevated at emax.

3. Super-elevation Runoff Lengths. Open-roadway conditions, apply to transitioning the ramp from its normal cross slope on tangent to the needed super-elevation on curves.

Based on these gradients, e = emax, and a 16 ft (4.9 m) ramp traveled way. Table 5.4, presents the super-elevation runoff lengths for horizontal curves on ramps.

4. Sight Distance

5. LENGTH OF ARC

Where compound arcs of decreasing radius are used on exit ramps, the arcs should have sufficient length to enable motorists to decelerate at a reasonable rate over the range of design speeds, Table 5.5. However, for entrance ramps, the 2:1 ratio of compound curves is not critical because the vehicle is accelerating into a curve with a larger radius or into a tangent section.

ARC LENGTH FOR COMPOUND CURVES

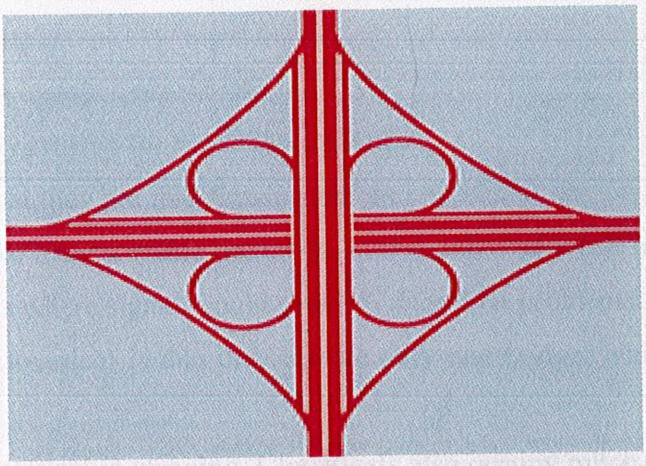
US Customary							
Radius (ft)	100	150	200	250	300	400	500 or more
Minimum (ft)	40	50	60	80	100	120	140
Desirable (ft)	60	70	90	120	140	180	200
Metric							
Radius (m)	30	50	60	75	100	125	150 or more
Minimum (m)	12	15	20	25	30	35	45
Desirable (m)	20	20	30	35	45	55	60

Table 5.5

6. VERTICAL CURVATURE

Design vertical curves on ramps to meet the stopping sight distance criteria based on the ramp design. Table 5.4, provides the K-values for both crest and sag vertical curves. The ramp profile often assumes the shape of the letter S with a sag vertical curve at one end and a crest vertical curve at the other. In addition, design the vertical curvature adjacent to the standard exit and entrance terminals using a design speed of 80 km/h or greater.

CLOVERLEAF INTERCHANGE



A TYPICAL CLOVERLEAF INTERCHANGE

CLOVERLEAF INTERCHANGE

Figure 6.1

6.1 DEFINITION

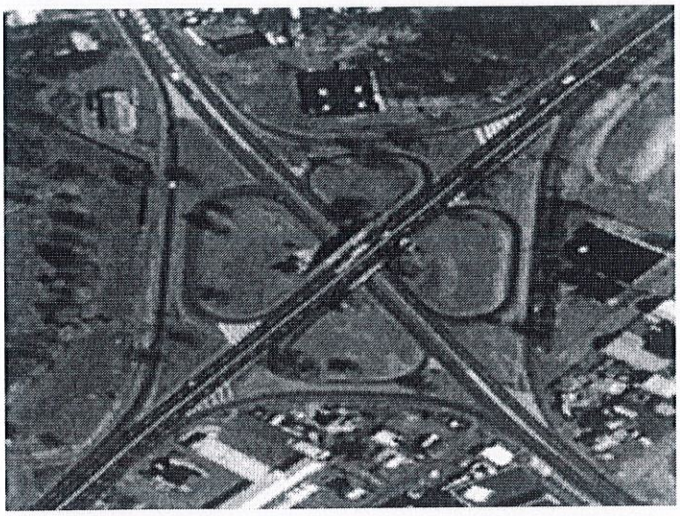
A **cloverleaf interchange** is a two-level interchange in which left turns are handled by loop roads . To go left (in right-hand traffic), vehicles first pass either over or under the other road, then turn right onto a one-way three-fourths loop ramp (270°) and merge onto the intersecting road.

Cloverleaf interchanges, viewed from overhead or on maps, resemble the leaves of a four-leaf clover.They were originally created for busier interchanges .

Their chief advantage is that they are free-flowing and do not require the use of such devices as traffic signals. This not only make them a viable option for interchanges between freeways but they are also used for very busy arterials where signals could present congestion problems.

The major advantage of cloverleaf is that they require only one bridge, which makes such junctions cheap if land is plentiful.

A major problem with cloverleaf is **weaving** .Cloverleafs also occupy much more land than any other kind of interchange.



CLOVERLEAF INTERCHANGE

Figure 6.2

6.2 ADVANTAGES

1.Through traffic on both roads is unimpeded.

2.Only one structure is required.

3.Left-turning traffic has a direct path.

4.It is very simple to use and does not confuse the drivers.

6.3 DISADVANTAGES

1.Relatively large area is needed.

2.The carriageway area required is also higher than a rotary interchange.

3.Weaving manoeuvres are involved , some of them on the roadway of the structure and some underneath the structure.

4.The weaving capacity is limited to about 1200PCUs/hour, but may be increased by providing an ancillary lane.

5.The U-turns are long and operationally difficult.

6.Loop design speeds have to be low, and speeds above 50 KPH are likely to increase the cost.

7.Right –turning traffic has extra distance.

8.The capacity of the loop is also restricted.

A capacity of 800-1200 veh. per hour is almost the limit.

6.4 PROBLEM.

1. First, the loop ramps must go around 270 degrees of rotation. To build the loop ramps, a trade-off must be made for size vs. utility. A ramp with a much larger radii can be taken at higher speeds and thus move more traffic, but takes up a lot more real estate. A smaller loop takes up less space at the cost of slower speeds;

2. The second problem with cloverleaf interchanges is the weaving that occurs. The basic problem is that two types of traffic is switching lanes in the middle of the interchange: traffic that has just entered from the right from the first loop ramp, and traffic that is about to exit to use the second ramp. Both of these streams of traffic must switch places between the right lane of the through highway and the auxiliary entrance/exit lane. In addition, the entering traffic is trying to accelerate to merge into the through traffic, while the exiting traffic must slow down to negotiate the tight turn on the loop ramp.

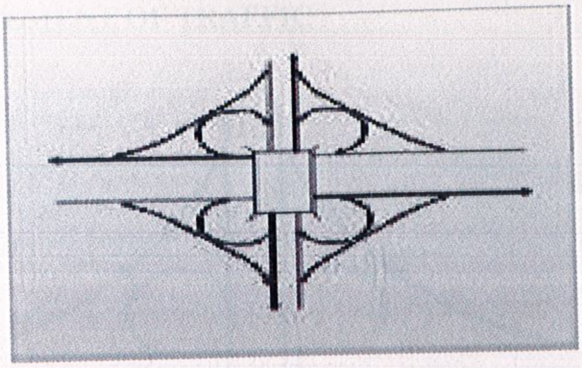
SOLOTIONS:

Cloverleaf or partial cloverleaf designs may be used in lieu of a diamond when development or other physical conditions prohibit construction in a quadrant, or where heavy left turns are involved. A continuous flow design is required where two major facilities intersect. In this case, a full cloverleaf interchange is the minimum design that can be used. The designer should consider collector-distributor roads in conjunction with cloverleaf interchanges to minimize weaving. However, full cloverleafs have deficiencies which need to be addressed before being chosen as the interchange type. Principle disadvantages are:

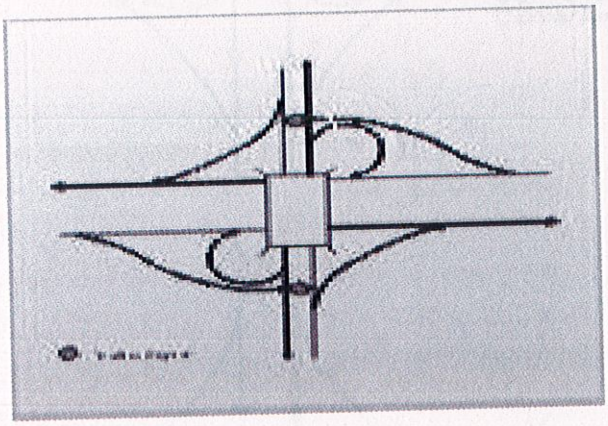
- Large trucks may not be able to operate efficiently on the smaller curve radii on the associated loop ramps.
- Loop ramps are limited in capacity.

The full cloverleaf weaving maneuver is objectionable when are relatively the sum of traffic volumes on two adjoining loops approaches about 1,000 vehicles per hour, interference occurs, which results in a reduction in the speed of the mainline traffic. For these reasons, full cloverleafs are discouraged.

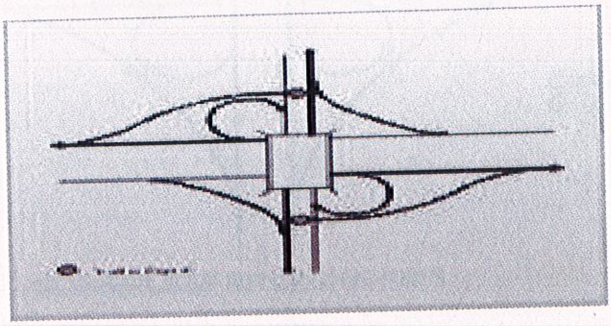
6.5 TYPES OF CLOVERLEAF INTERCHANGE



Full Cloverleaf Interchange



Partial Cloverleaf A Interchange



Partial Cloverleaf B Interchange

<u>Figure 6.3</u>

6.6 DIRECTION OF MOVEMENT OF TRAFFIC

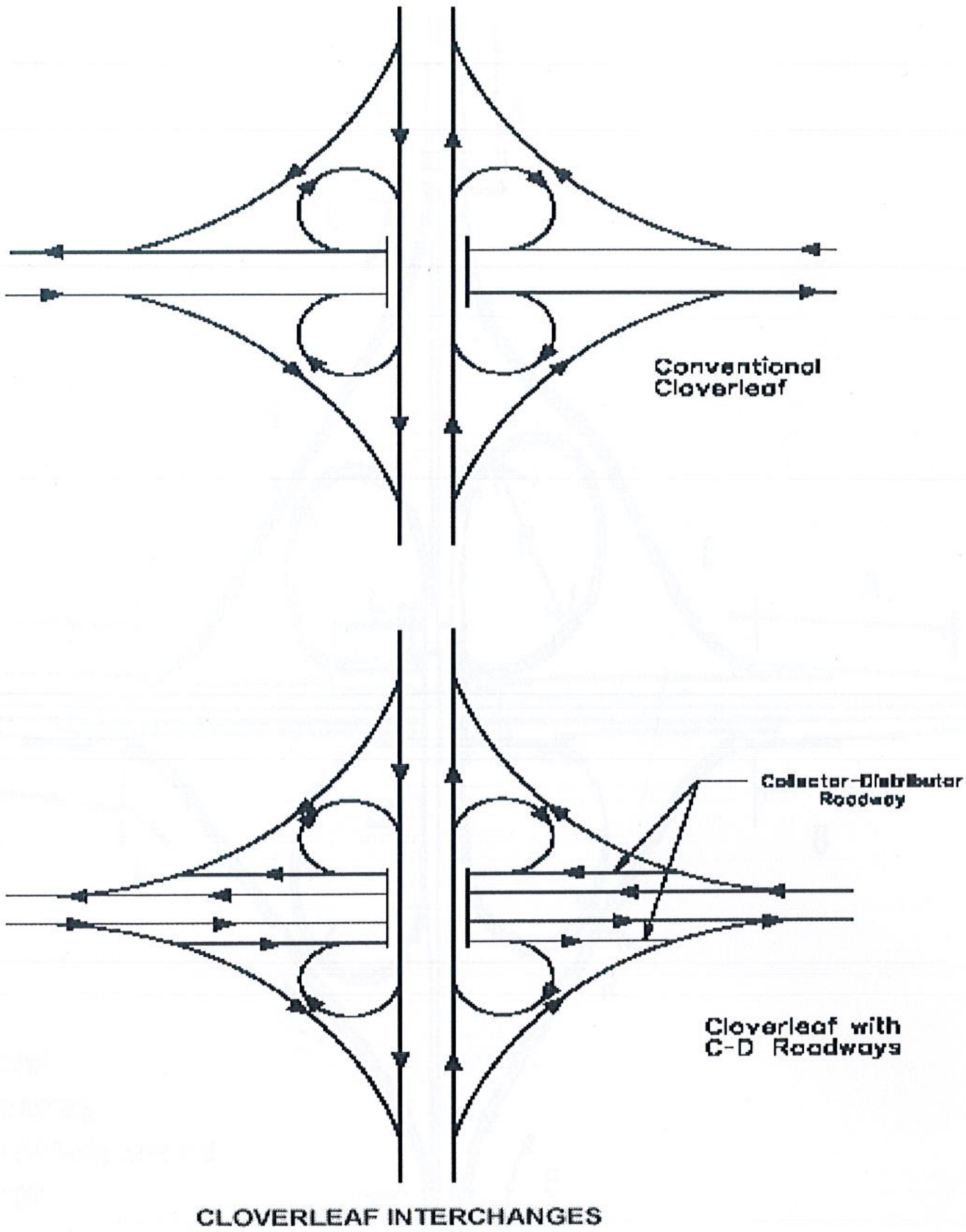


FIGURE SHOWING THE DIRECTION OF MOVEMENT OF TRAFFIC

<u>Figure 6.4</u>

LAYOUT OF CLOVERLEAF INTERCHANGE

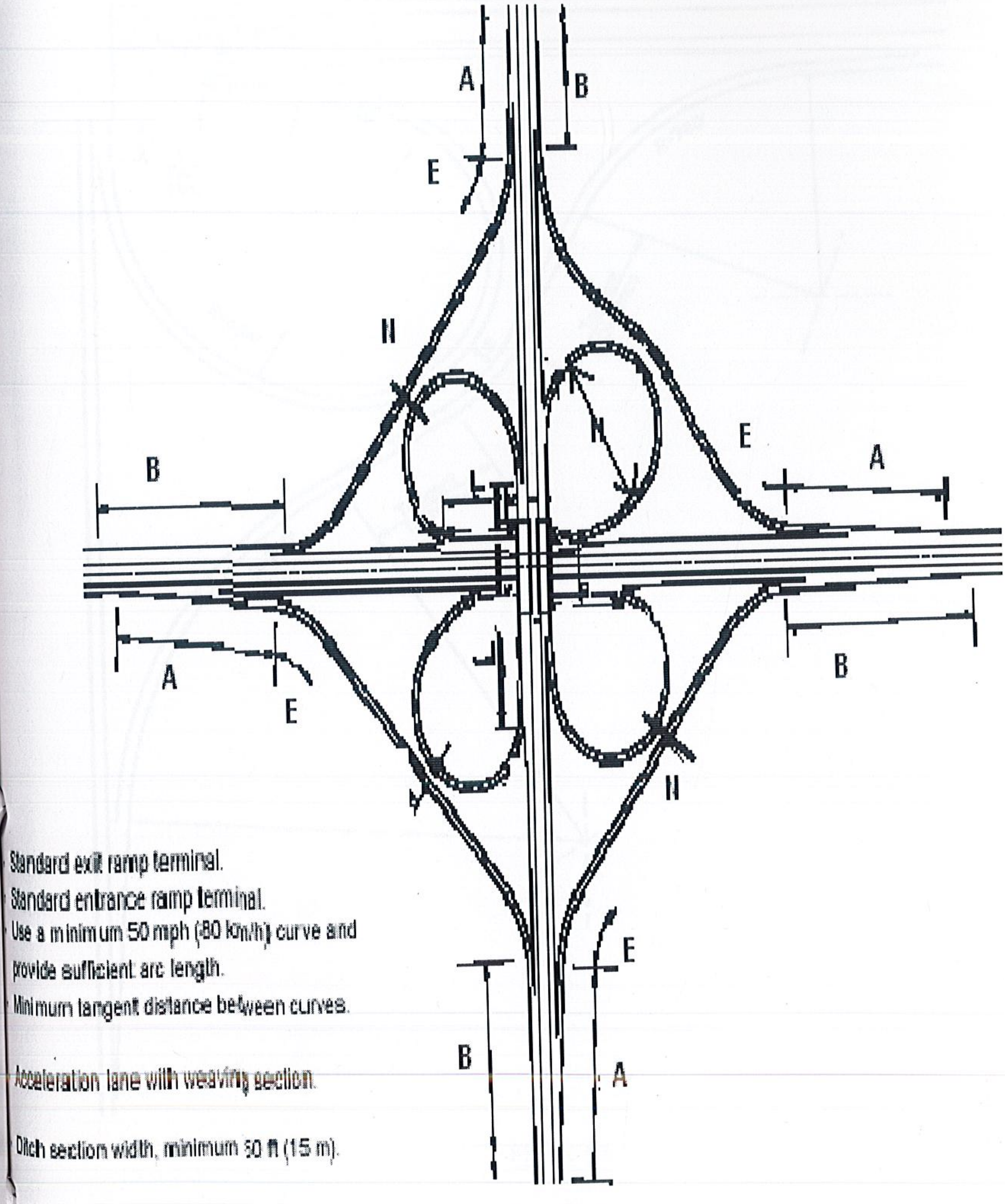


Figure 6.5

LAYOUT OF CLOVERLEAF QUADRANT DESIGN

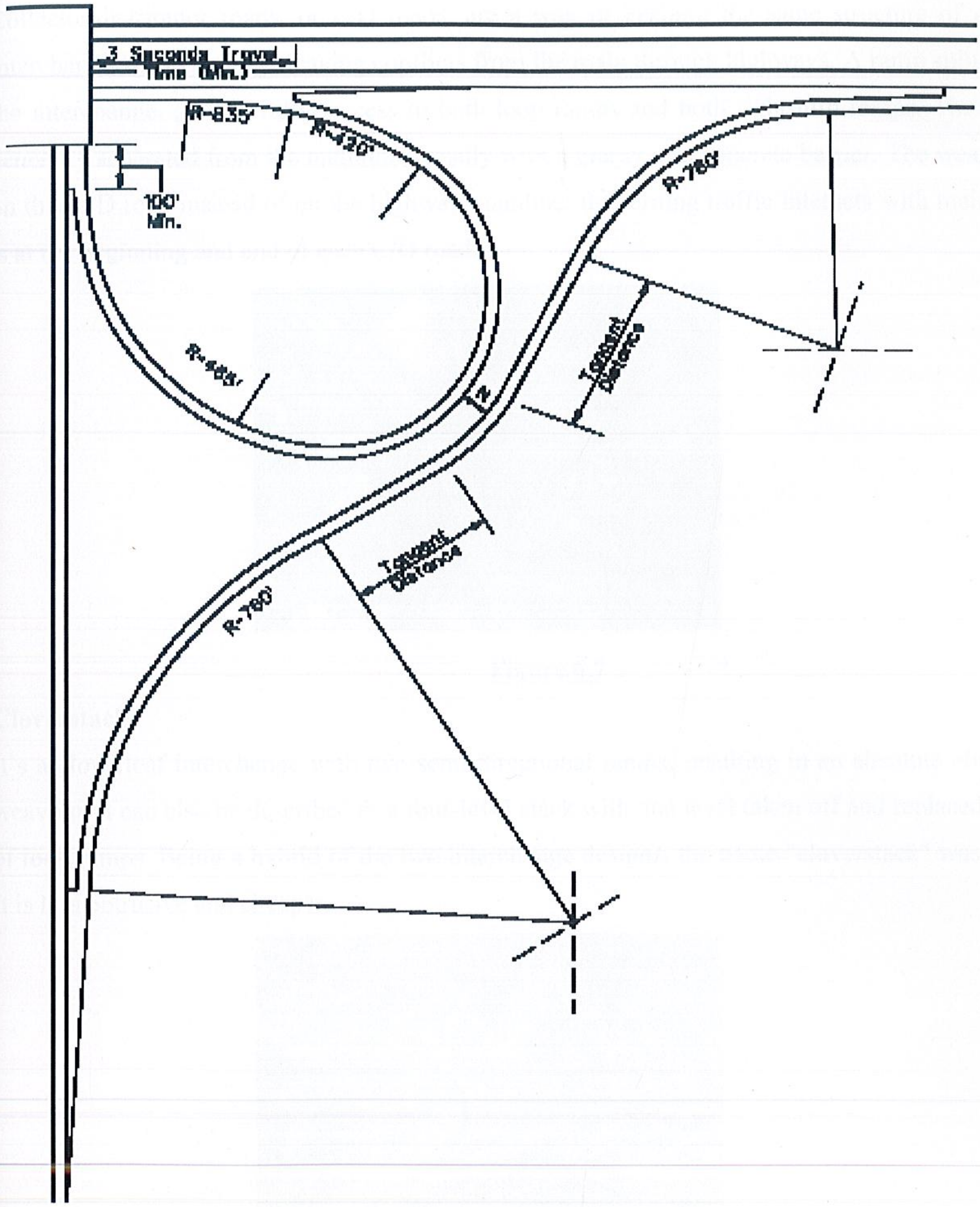


Figure 6.6

6.7 FACILITIES USED ON AN INTERCHANGE

Collector/Distributor Roads:

Collector/distributor roads, or C/D roads, are a way of keeping the same structure of a cloverleaf interchange but removing weaving conflicts from the main through highways. A ramp splits off before the interchange, giving traffic access to both loop ramps and both right-turn ramps. These lanes are generally separated from the mainline, usually with a grassy or a concrete barrier. The weaving occurs on this C/D road instead of on the highway mainline; the turning traffic interacts with mainline traffic is at the beginning and end of each C/D road.

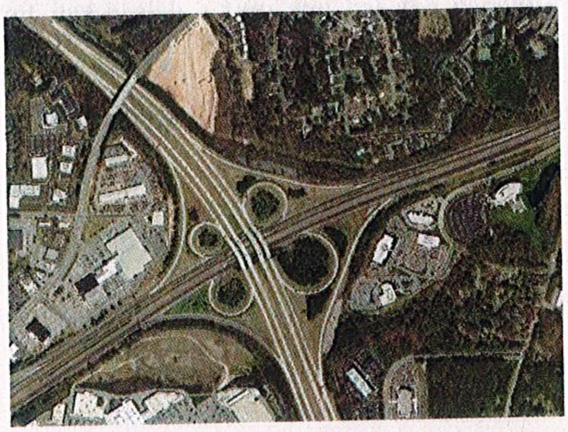


Figure 6.7

Cloverstack:

It's a cloverleaf interchange with two semi-directional ramps, resulting in an absolute elimination of weaving. It can also be described as a four-level stack with one level taken off and replaced with a pair of loop ramps. Being a hybrid of the two interchange designs, the name "cloverstack" was given to it. It is less obtrusive and cheaper.

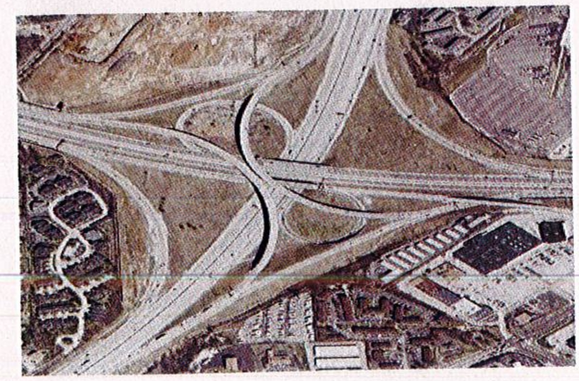


Figure 6.8

7

CONCRETE PAVEMENT DESIGN

7.1 DEFINATION

Concrete pavements are made of Portland cement concrete- either plain , reinforced or prestressed concrete.They are those which are characterized by their flexural strength or rigidity.

The rigid pavement has a slab action and has the capability of transmitting the wheel load stresses through the wider area below.The rigid pavements are usually designed and the stresses are analysed using the elastic theory, assuming the pavement as an elastic plate resting over an elastic or viscous foundation.

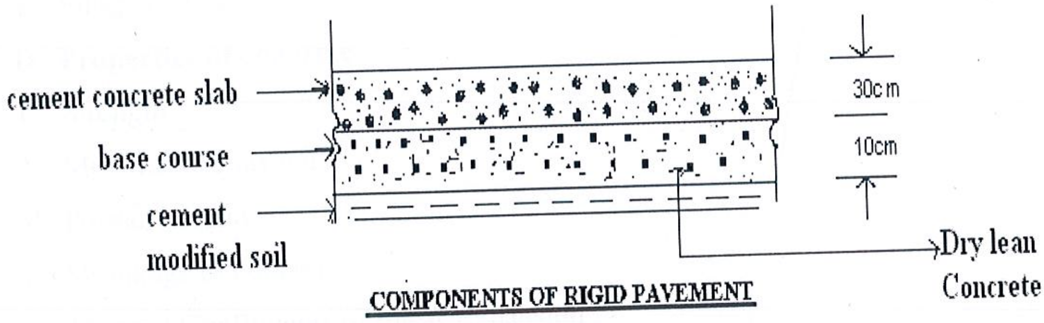


Figure 7.1

7.2 FACTORS AFFECTING CONCRETE PAVEMENT DESIGN:

A. Design period

B. Loading

1. Wheel Load
2. Axle load spectrum
3. Directional distribution of traffic
4. Traffic growth rate
5. Repetition of loads
6. Tyre pressure and area of contact
7. Impact
8. Location of load with respect to slab

C. Properties of subgrade

1. Subgrade strength

D. Properties of concrete

1. Strength
2. Modulus of Elasticity
3. Poisson's ratio
4. Shrinkage of concrete
5. Thermal Coefficients of linear Expansion

E. External conditions

1. Temperature changes
2. Friction between slab and subgrade

F . Joints

1. Arrangements of joints

G. Reinforcement

1. Provision or omission of reinforcement
2. Continuous reinforcement

A. Design period :

Concrete pavements have a long life, which varies from 30 to 40 years. But it is customary to design concrete pavements for a design period of **20 years.**.

B. Loading:

1. Wheel load--

The wheel load induces stresses in the slab. For highway pavements, the wheel can be single or dual. The rear axles can be single or tandem axles.

The standard axle load used in highway design is **82 KN**. The wheel load then becomes **41KN.** The legal axle load in India is **10.2 tonnes.**

According to IRC ,the design wheel load is taken as **5100kg.**

2. Traffic growth rate--

The rate of growth of commercial traffic ,should be established. accurately on the basis of historical trends or applying a suitable elasticity coefficient to the rate of growth of an important economic indicator and if not a **rate of 7.5%** may be adopted.

3. Repetitions of loads--

The number of passes of commercial vehicles during the design period is given by the following formulae:

$$N = \frac{365 * ADT(CV)[(1+r)^n - 1]}{r} * f1 * f2$$

Where,

N = Number of passes of commercial vehicles during the design period

n = design period in years

ADT(CV) = Average daily commercial vehicles in both directions in the year the road is opened to traffic

R = annual rate of growth in decimals(eg. 7.5% = 0.075)

f1 = factor to account for directional distribution of traffic(may be 0.75 for two lane roads and 0.5 for divided carriageways of four lanes or more)

f2 = factor to account for concentration of commercial vehicles in the extreme lane(may be 0.75 for four lane divided carriageway and 0.6 for six lane divided carriageways ;the value of f2 is 1.0 for two lane roads)

4. Tyre pressure and area of contact--

The contact area is generally assumed to be circular , though in reality it tends to be elliptical. If P is the wheel load, the radius of contact area is thus given by:

$$a = \left(\sqrt{\frac{P}{P1 * \Pi}} \right)$$

Where,

a = radius of contact (cm)

P = total load on tyre (Kg)

P1 = tyre pressure (Kg/cm2)

According to **IRC 'a' is taken as 15 cm** and **tyre pressure ranging from 6.3 to 7.3kg\cm2.**

5. Impact--

Load safety factors for various classes of roads

1. For interstate and other multilane projects where there will be uninterrupted traffic flow and high volumes of traffic --------**1.2**
2. For highways and arterial streets where will be moderate volumes of truck Traffic --------**1.1**
3. For roads, residential streets and other streets that will carry small volumes of truck traffic --------**1.0**

Table 7.1

6. Location of load with respect to slab:

Three positions of loading are generally considered for estimating the stresses in a slab, in the conventional method of design . They are as foll:

(1) **Interior loading:**

It produces tensile stresses at the bottom of the slab.

(2) **Edge loading:**

It produces tensile stresses at the bottom of the slab parallel to the edge, and another small tensile stress at the top of the slab

(3) **Corner loading:**

It producs tensile stresses at the top of the slab, parallel to the bisector of the angle.

C. **Properties of subgrade**

1. **Subgrade strength**

Since the wheel loads are ultimately transferred to the subgrade through the pavement, the supporting power of the subgrade enters into pavement design.The subgrade supporting capacity is measured in terms of the modulus of subgrade reaction, K. **Minimum K value of 5.5 kg/cm2** is specified for rigid pavements.

Reaction of subgrade under concrete slab

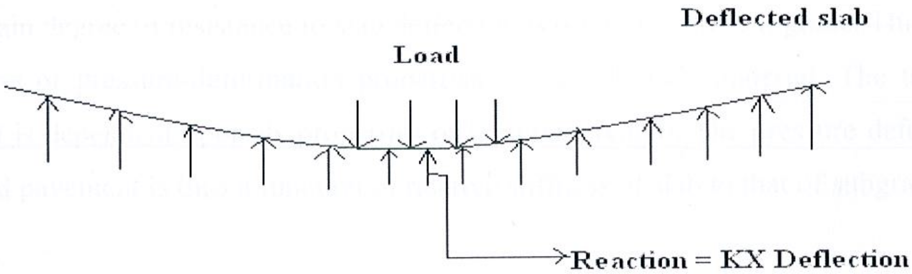


Figure 7.2:

D. Properties of concrete

1. **Modulus of Elasticity**
2. **Poisson's Ratio**

They vary with concrete materials and strength .The former increases with increase in concrete strength and the latter decreases with increase in the modulus of elasticity.

E = 3*10^5 Kg/cm2

μ = 0.15

E. External conditions

1. **Temperature Change**

Changes in temperature gradient through the slab, will cause differential expansion or contraction between the top and bottom of the slab.The slab then tends to warp, but its own weight and the friction at the load transferring devices restrain the warping.As a consequence , stresses are induced in the slab. The linear expansion or contraction of the slab due to temperature changes, is restricted because of the friction between the slab and the subgrade. This also causes stresses in the slab. Coefficient of thermal expansion of concrete is taken as $\infty = 10 * (10^{-6})$ per degree for design purposes.

2. Friction between the slab and the sub-base

7.3 ANALYSIS OF STRESSES

A. Relative Stiffness of Slab to Sub-grade:

A certain degree of resistance to slab deflection is offered by the subgrade. This is dependent upon the stiffness or pressure-deformation properties of the subgrade material. The tendency of the slab to deflect is dependent upon its properties of flexural strength. The pressure deformation characteristics of rigid pavement is thus a function of relative stiffness of slab to that of subgrade.

Westergaard's equation of Radius of Relative Stiffness:

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

Here,

l = radius of relative stiffness ,cm

E = modulus of elasticity of cement concrete ,Kg/cm2

μ = Poisson's ratio for concrete = 0.15

h = slab thickness , cm

K = subgrade modulus , kg/cm3

Westergaard's equation for highway pavements:

$$S_i = \frac{0.316\,P}{h^2} [4\log_{10}(l/b) + 1.069]$$

$$S_e = \frac{0.572\,P}{h^2} [4\log_{10}(l/b) + 0.359]$$

$$S_c = \frac{3P}{h^2}\left[1-\left(\left(a\sqrt{2}/l\right)^{0.6}\right)\right]$$

Where,

Si ,Se, Sc = Stress due to interior , edge and corner loading , resp Kg/cm2

h = slab thickness , cm

P = wheel load , kg

a = radius of wheel load distribution , cm

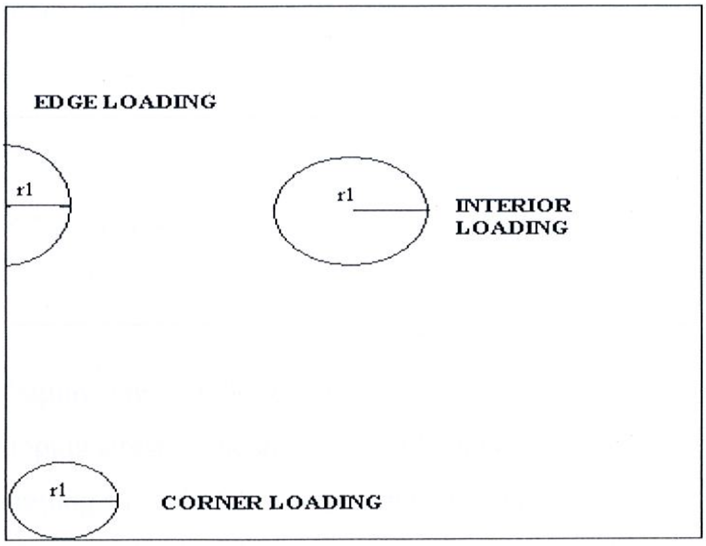
l = radius of relative stiffness , cm

b = radius of equivalent distribution of pr. at the bottom of the slab, cm

$= \sqrt{(1.6a^2+h^2)} - (0.675 \cdot h)$,when $a \le 1.724h$

and

$= a$,when $a \ge 1.724h$



LOADING POSITIONS FOR RIGID PAVEMENT DESIGN

Figure 7.3:

B. Temperature stresses:

Changes in temperature of the slab causes the slab to curl upwards or downwards, thus inducing stresses.

(a) Wraping stresses

(b) Frictional stresses

As per Bradbury's formulae:

$$St(e) = \frac{Cx * E * e * t}{2}$$

$$= Cy \frac{* E * e * t}{2} \quad \text{(whichever is higher)}$$

$$St(c) = \frac{E * e * t}{3(1-\mu)} \sqrt{(a/l)}$$

$$St(t) = \frac{E * e * t}{2} [Cx + \mu Cy / 1 - \mu^2]$$

$$Sf = \frac{W * L * f}{2 * (10^4)}$$

Where,

St(e)= Wraping stress in the edge region , kg/cm2

St(t)= Wraping stress in the interior region , kg/cm2

St(c)= Wraping stress in the corner region , kg/cm2

Sf = unit stress developed in cement concrete pavement,kg/cm2

E = modulus of Elasticity , Kg/cm2

C = Bradbury's coefficient

μ = Poisson's ratio=0.15

e = thermal coefficient of concrete per degree celcius.

t = temp. diff. b/w the top and bottom of the slab in degree Celsius

W = unit weight of concrete ,kg/cm3

f = coefficient of subgrade resistant

L = slab length,m

B = slab width,m

C. **Design of joints:**

1. **Spacing of expansion joints:-**
2. **Spacing of contraction joints:-**
3. **Design of dowel bars:-**
4. **Design of tie bars:-**

1. Spacing of expansion joints:-

The max. spacing recommended :

For 25mm wide expansion joints is 140m.(rough foundation)

For slab thickness upto 20cm expansion joints is 90m.(smooth foundation) For slab thickness 25cm expansion joints is 120m.(smooth foundation

$$Le = \frac{\delta'}{100*C(T2-T1)}$$

Where,

$$\delta' = Le*C*(T2-T1)$$

Where,

δ' = max. expansion in a slab of length Le with a temp. rise of T1 to T2.

C = thermal expansion of concrete per degree rise in temperature.

2. Spacing of contraction joints:-

Acc to **IRC :**

Max. contraction joint spacing

In reinforced slabs=13m for 15cm thick slab with steel reinforcement of 2.7kg/m2

and 14m for 20cm thick slab with steel reinforcement of 3.8kg/m2.

In unreinforced slabs=4.5m

(a)When reinforcement is not provided-

$$Lc = \frac{2Sc*(10^4)}{W*f}$$

(b)When reinforcement is provided-

$$Lc = \frac{200*Ss*As}{b*h*W*f}$$

Where,

Lc = slab length or spacing in contraction joints,m

h = slab thickness,cm

f = coeff. of friction(1.5 max)

W = unit weight of cement concrete,kg/m3(2400)

Sc = allowable stress in tension in cement concrete,kg/cm2(0.8)

As = total area of steel,cm2

b = slab width,m

Ss = allowable tensile stress,kg/cm2 (1400)

3. Design of dowel bars:-

$$Ld = 5d \sqrt{\left(\frac{Ff}{Fb} * \frac{Ld+1.5\delta}{Ld+8.8\delta} \right)}$$

Where,

Ld = total length of embedment of dowel bar,cm

d = diameter of dowel bar,cm

δ = joint width,cm

Ff = permissible flexural stress in dowel bar,kg/cm2

Fs = permissible flexural stress in dowel bar,kg/cm2

Fb = permissible bearing stress in dowel bar,kg/cm2

4. Design of tie bars:-

$$Lt = \frac{d* Ss}{2*Sb}$$

Where,

Lt = total length of tie bar

Ss = allowable stress in tension,kg/cm2(1400)

Sb = allowable bond stress in concrete,kg/cm2

d = diameter of tie bar,cm

EXAMPLE OF DESIGN OF CONCRETE PAVEMENT FOR AN EXPRESSWAY

8 lane Expressway with heavy over-loading:

Design Data:

1. Number of commercial vehicles per day : 3000(both directions)
2. Period of construction : 4years
3. Axle load distribution:

Load(T)	Percent
3-16	98
18	2

3. Sub-grade CBR : 10
4. Design period : 20 years after completion
5. Traffic growth rate : 7% per annum
6. Concrete st.-28 days compressive st. : 40MPa
7. Temperature variation : 20° C

Design Solution:

Step 1 : Assume load factor of 1.2

Step 2 : Number of commercial vehicles per day : 3000

Step 3 : Traffic growth rate : 7%per annum

Step 4 : Design period: 20 years after completion

Step 5 : Period of construction : 4 years

Traffic after completion = 3000*(1.07^4)

= 3930 commercial vehicles per day

Step 6 : Axle load distribution:

3-16T : 98%

18T : 2%

Step 7 : Number of repetitions of vehicles during design period:

$$N = \frac{365 * ADT(CV)[(1+r)^n - 1]}{r} * f1 * f2$$

F1 = 0.5

F2 = 0.75

n = 20

ADT(CV)=3930

N = 365 * 3930 [(1.07)^20 -1] *0.50*0.75

= 14.7 million

= 14 *(10^6)

Number of repetitions of axle, with average 2 axle per vehicle

3-16T : 14.7*(10^6) * 0.98 * 2 = 28.81 *(10^6)

18T : 14.7*(10^6) * 0.02* 2 = 58800

Step 8 : Soil support value

CBR : 10

K : 5.54 Kg/cm^3(from the following figure)

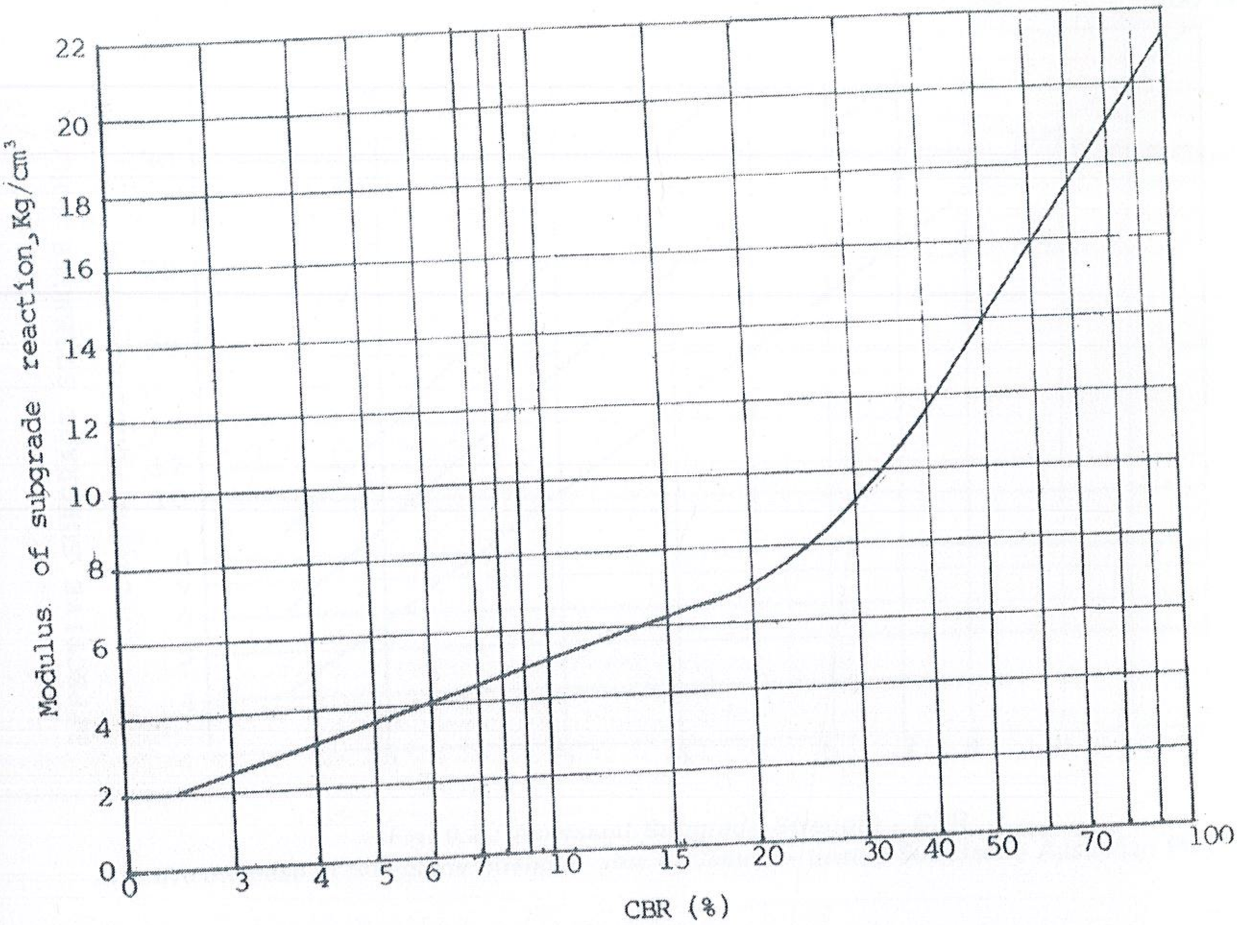


Fig. 8.5: Relationship between Modulus of Subgrade Reaction and CBR.

Step 9 : Sub –grade: provide 150 mm lean concrete

Step 10 : Adjusted soil support value

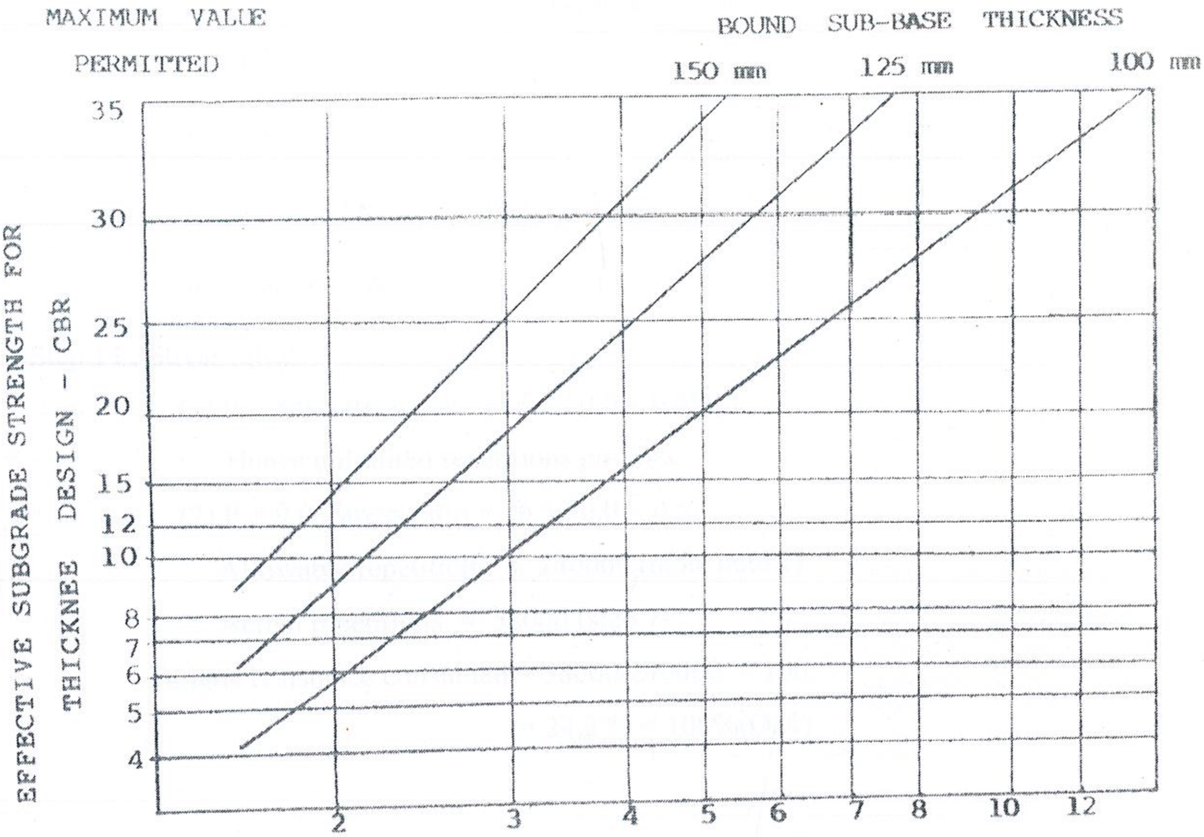


Fig. 9.2 : Assessed Subgrade Strength - CBR
Effective Increase in Sub-grade Strength - due to Cement - treated Sub-Base - Australian Practice

From fig: 9.2CBR: 35

$K = 10$ Kg/cm^3 (from fig 8.5)

Step 11 : Assume pavement thickness of 28 cm

Step 12 : Concrete compressive strength at 28 days :40 MPa

(F'c28)

Concrete flexural strength at 90 days

F'c28 = 10 (F90 - 1)

F90 = F'c28/10 + 1

40/10 + 1 = 5 MPa

Step13 : From curves of edge load stress for P=8,

Load safety factor 1.2,

fe = 24.5 Kg/cm^2

For P = 9.0, load safety factor 1.2

fe = 26.5 Kg/cm^2

Step 14 : Stress ratio

(1) P = 8.0 ,Stress ratio = 24.5/50.0 = 0.49< 0.5

Hence unlimited repetitions possible

(2) P = 9.0 ,Stress ratio = 26.5/50.0 = 0.53

Allowable repetitions = 240000 (table below)

Actual repetitions = 58000 (step 7)

Fatigue resistance consumed = 58000/240000 * 100

= 24.2 % < 100%(O.K)

Stress ratios and allowable repetitions

Stress ratio	Allowable Repetitions	Stress Ratio	Allowable Repetitions
0.51	4,00,000	0.71	1,500
0.52	3,00,000	0.72	1,100
0.53	2,40,000	0.73	850
0.54	1,80,000	0.74	650
0.55	1,30,000	0.75	490
0.56	1,00,000	0.76	360
0.57	75,000	0.77	270
0.58	57,000	0.78	210
0.59	42,000	0,79	160
0.60	32,000	0.80	120
0.61	24,000	0.81	90
0.62	18,000	0.82	70
0.63	14,000	0.83	50
0.64	11,000	0.84	40
0.65	8,000	0.85	30
0.66	6,000		
0.67	4,500		
0.68	3,500		
0.69	2,500		
0.70	2,000		

FIG 7.6

Step 18 : Assume contraction joint spacing of 4.5 m

L= 4.5 m = 450 cm

$$l = \left[\frac{E\,(h^3)}{12(1-\mu^2)\,K} \right]$$

= 86.6 cm

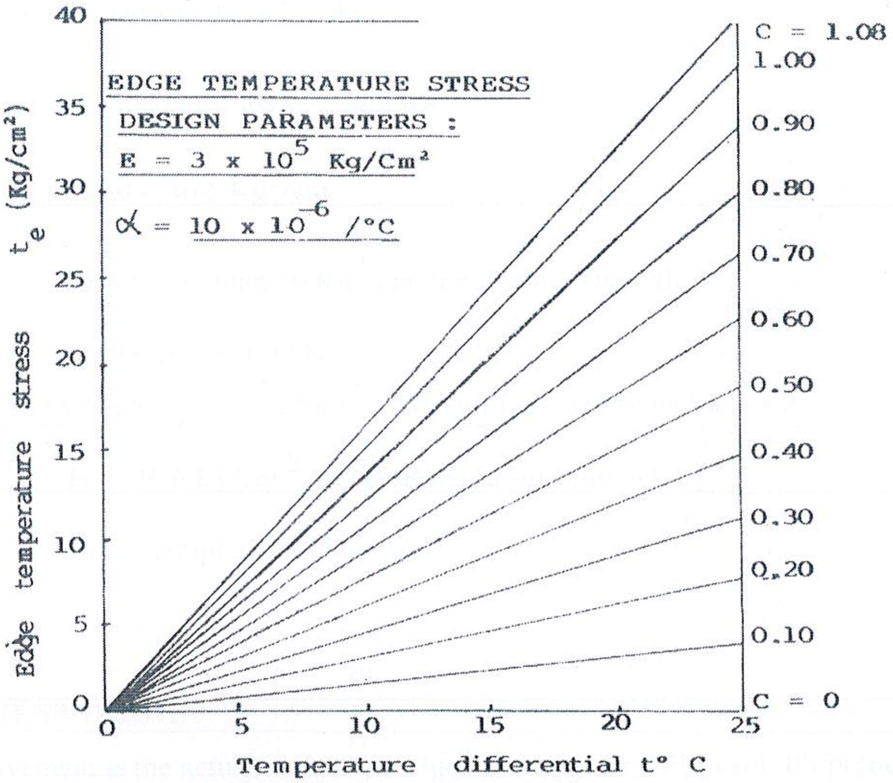


Fig 9.5: Design chart for calculation of edge temperature stress

Chart for determination of coefficient C

L/l or W/l	C	L/l or W/l	C
1	0.000	7	1.030
2	0.040	8	1.077
3	0.175	9	1.080
4	0.440	10	1.075
5	0.720	11	1.050
6	0.920	12	1.000

L = length of slab. W = width of slab. l = Radius of relative stiffness (see para 9.2.2)

L/l = 5.2

From fig: , C= 0.72

And edge temperature stress for temperature differential of

20degree C = $22 Kg/cm^2$

Step 15 : Edge load stress(for P = 8.0 T) = 24.5 Kg^2/cm

Temperature stress = 22.0 Kg^2/cm

Total = 46.5 Kg^2/cm

This is less than 50 Kg^2/cm, the flexural strength.

Hence design is O.K

Step 16 : Corner load stress for P = 8.0, and Load safety factor = 1.2

Fc = 26.6 Kg/cm^2 (O.K) (Refer design curves)

Hence adopt 28 cm thick slab.

7.4 PAVEMENT DESIGN

The road pavement is the actual surface on which the vehicles will travel. It's purpose is two fold, to provide friction for the vehicles and to transfer normal stresses to the underlying soils. The design process can be split up into different areas. These are as follows:

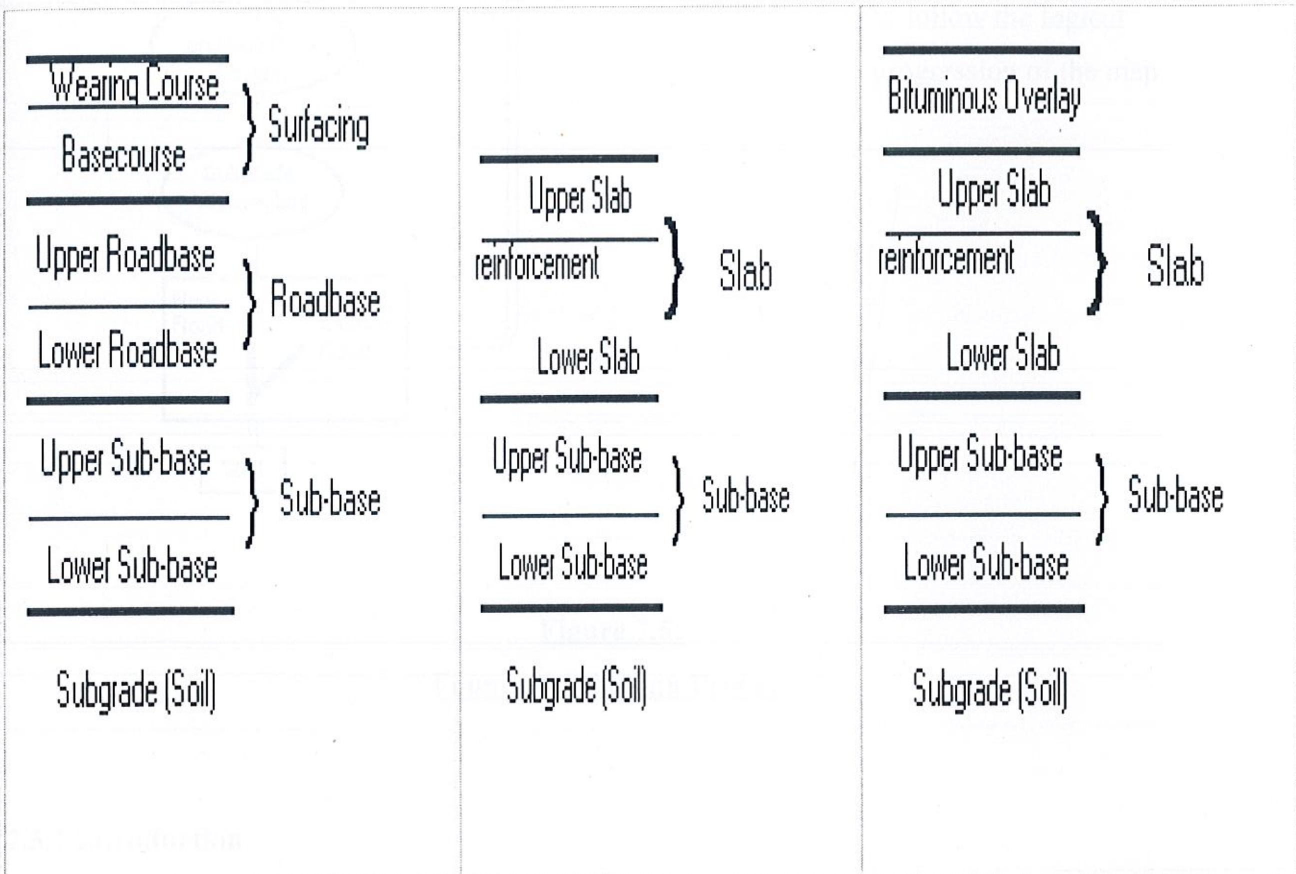
- **Foundation Design** - That is the design of the Subgrade and sub-base
- **Thickness Design** - That is the design of the actual road surface

7.4.1 Introduction

There are four types of pavement currently in use at present:

- **Flexible** - pavements with a bitumen bonded surfacing and roadbase.

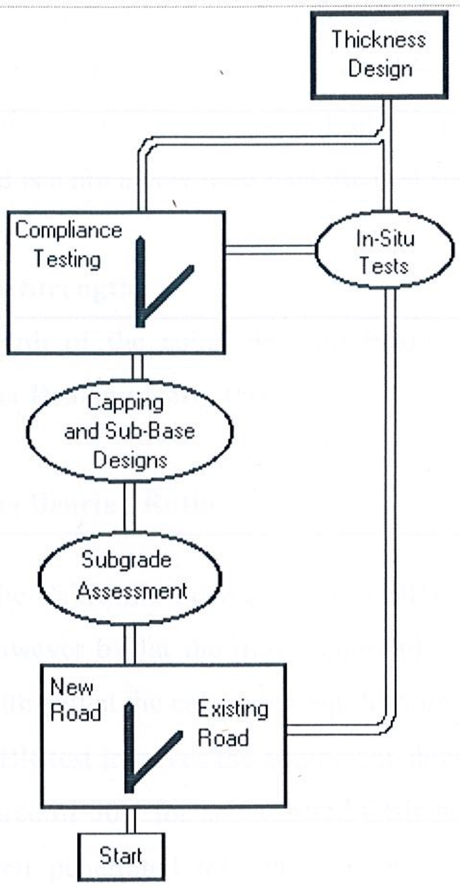
- **Flexible Composite** - The surfacing and upper road base are bituminous on a lower roadbase of cement bound material
- **Rigid** - Pavements with a concrete surface slab which can be un-reinforced, joint reinforced or continuously reinforced.
- **Rigid Composite** - continuously reinforced concrete slab with a bituminous overlay.



Flexible | **Rigid** | **Rigid Composite**

Figure 7.4 - Pavement Types

7.5 Pavement Design - Foundation Design



The map alongside can be used as a guide to the process of Foundation Design.

It is highly recommended to follow the logical progression of the map

Figure 7.5:

Foundation Design Process

7.5.1 Introduction

The main purpose of the foundation is to distribute the applied loads to the underlying subgrade, without causing distress to either the foundations, the overlying layers or the subgrade.

The critical condition for a pavement foundation is whilst carrying the construction traffic as, whilst the repetitions are low, the stresses are applied direct to the foundation. Standard foundation design is thus to design for the construction traffic.

7.5.2 Assessment Methods

The first step in the design of the foundations depends on the situation that is causing the design.

If the road is new then the first step is the assessment of the subgrade on which the road is to be built. This is described in the next section and is essential to the design. If this is not carried out correctly then the information on which the designs are based may be incorrect.

If the road is a not a new road then the first step is the assessment of the existing foundations.

Subgrade Strength

The strength of the subgrade (soil below the pavement) is assessed using a test known as the **California Bearing Ratio test.**

California Bearing Ratio

- The California Bearing Ratio (CBR) is a measure of the supporting value of the subgrade. It is however by far the most commonly used in Pavement Design. The CBR test should be used with soil at the calculated equilibrium moisture content .
- CBR test involves the equipment shown below. The plunger is then seated into the soil using a force of 50N for an expected CBR below 30% or 250N for greater than 30%. The plunger is then penetrated into the soil at a constant rate of 1mm/min and the forces recorded at penetration intervals of 0.25mm. The total penetration should not exceed 7.5mm. These results are then compared to a standard curve for a value of 100% CBR. The forces on the standard curve are 13.2kN at 2.5mm penetration and 20.0kN at 5.0mm penetration. The CBR is then a simple ratio of the corresponding values and where a difference between the value at 2.5mm and 5mm occurs, the higher value is taken.

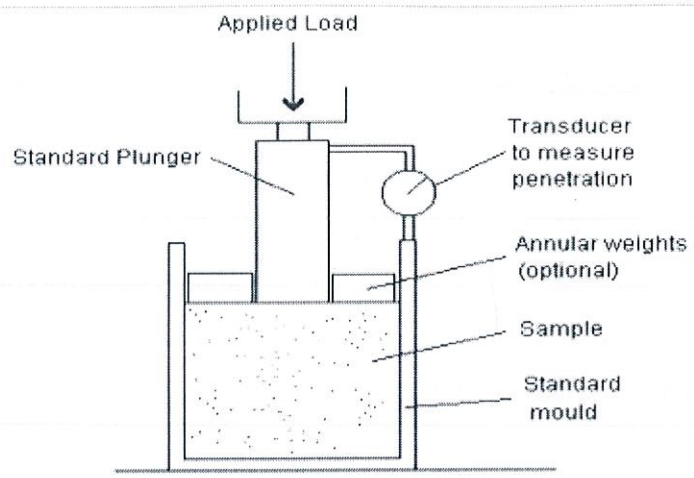


Figure 7.6:

California Bearing Ratio Equipment

The first factor affecting the performance of the subgrade is the moisture content..The importance of the moisture content is demonstrated by the variation of the CBR values as shown below. This is a plot of a typical soil sample values of CBR against moisture content. Thus the soil sample should have the moisture content reassessed after the test is performed and compared to the desired value.

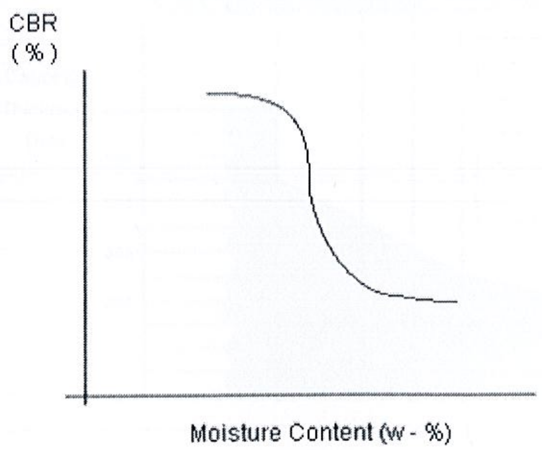


Figure 7.7:

California Bearing Ratio Vs Moisture content

Standard practice is to assess the soil at the optimum moisture content.This is done using the procedure below-

- Plot the dry density of the soil against moisture content.
- This will give you the optimum moisture content, that is the peak of the curve.
- Plot the CBR against moisture content graph

The CBR value carried forward to the design is that at the optimum moisture content.

7.5.3 Capping & Sub-base Design

Once the CBR value has been determined, it is then possible to design the actual capping and Sub-base layers. Capping is used to protect weak subgrades by using a relatively cheap material between the subgrade and sub-base

It is not practical to build on a layer whose CBR value is less than 15%. It is therefore necessary to improve this value either by capping or increasing the thickness of the sub-base. The chart below shows the two alternatives, each of which are equally effective and which is used depends on cost and construction restrictions.

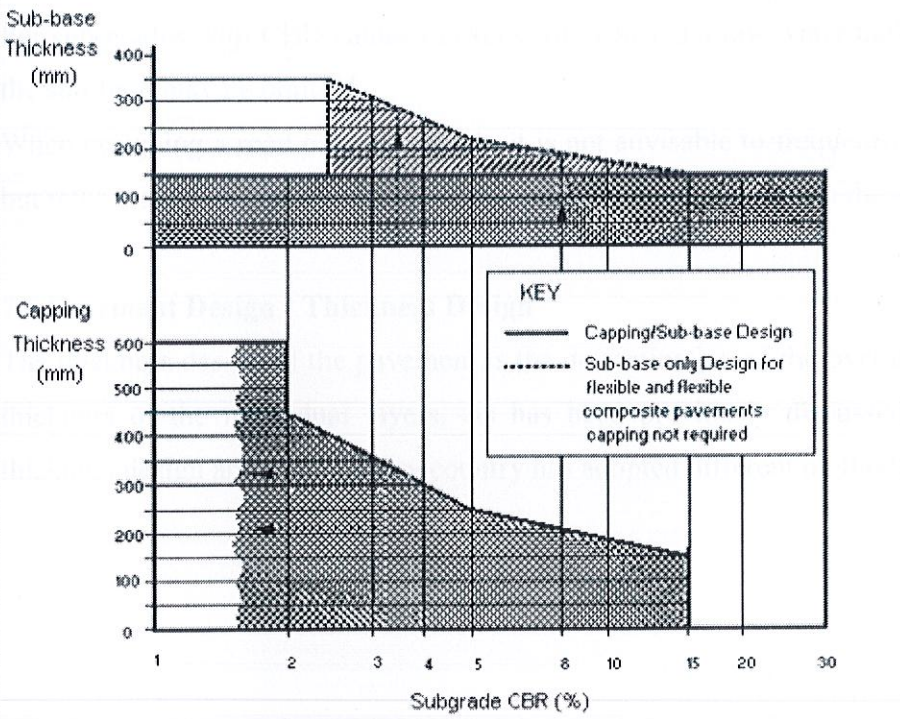


Figure 7.8:

Capping and Sub-base Thickness Design

In exceptional circumstances where the CBR value falls below 2%, a value below which the subgrade would deform under construction traffic, there are several options open to the designer:

- The material can be removed and replaced with a more suitable material. The thickness replaced is typically between 0.5m and 1.0m. Irrespective of the quality of the new material a CBR value of just under 2% should be assumed for the sub-grade.
- For cohesive soils, it may be possible to treat the soils using lime. The sub-base and capping is again designed assuming a sub-grade CBR of just under 2%.
- For a reasonably permeable soil the drainage system may be lowered and the results monitored. The main foundation should then be designed assuming the achievable conditions.

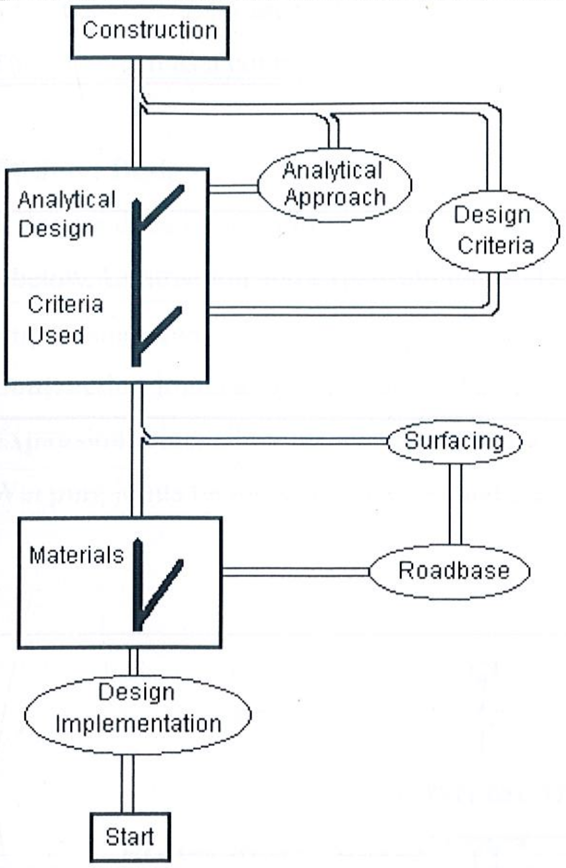
For sub-grades with CBR values of 15% and above the sub-base should have a standard thickness of 150mm, a value determined as the minimum practical for spreading and compaction.

For sub-grades with CBR values in excess of 30% and a low water table or hard rock sub-grades then the sub-base may be omitted.

When designing a road of some length, it is not advisable to frequently vary the foundation thickness but rather select an appropriate value for each significant change in the sub-grade properties.

7.6 Pavement Design - Thickness Design

The thickness design of the pavement is the determination of the overall thickness of the road and the thickness of the individual layers. As has been previously discussed, there are many methods of thickness design and nearly every country has adopted different methods.



The map alongside can be used as a guide to the process of Thickness Design.

It is highly recommended to follow the logical progression of the map

Figure 7.9:

Thickness Design Process

At this point, it is necessary to have ascertained the vehicle loading on the road surface. This is not an indication of the total traffic flow nor is it intended to design the road layout. It is solely relevant to the engineer and used to design the pavement thickness. This is covered in more detail and hopefully somewhat better explained on the traffic loading page. Thus you should now have two pieces of information, the CBR value and a vehicle loading in the left hand lane (right hand lane outside the UK) in millions of standard axles (msa).

7.7 Reinforcement Design

As can be seen from the design chart the thickness of the concrete slab is dependent on the area of reinforcement used. Normal design procedure is to produce a design for each of the four curves shown, that is the different areas of reinforcement. The area of reinforcement is generally 0.3% of the total cross sectional area. However if cracking is to be prevented then the area is increased to 0.6%. This is known as a continuously reinforced pavement.

7.8 Joint Design

There are three types of joint, expansion contraction and warping. Typical designs are shown in Figure 7 below. Contraction and expansion joints are called Transverse joints and the warping joint is a longitudinal joint.

Contraction joints allow the slab to shorten as it's temperature drops.

Expansion joints allow the slab to expand as it's temperature increases above that at which it was cast.

Warping joints tie the slabs together and can be thought of as hinges in the slab.

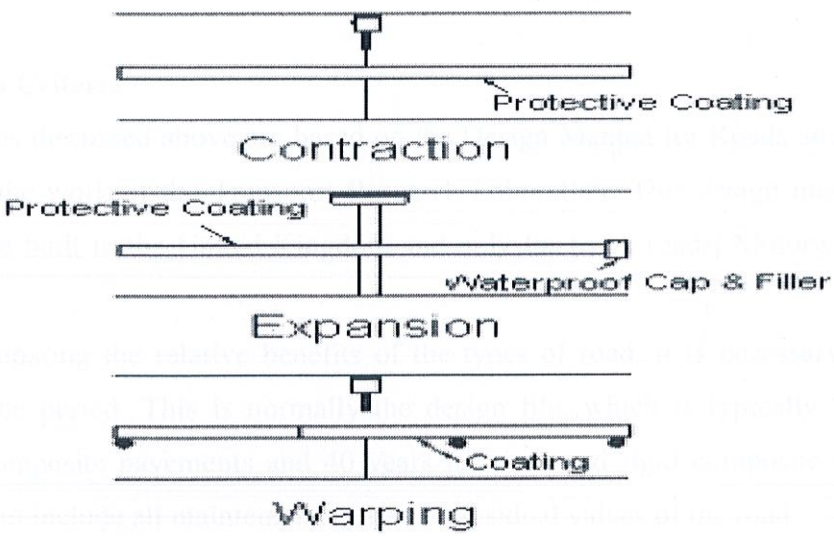


Figure 7.10:

Pavement Joint Types

At the contraction joint, there is a crack inducer so that if cracking does occur then it is in the area of reinforcement.

Joint Spacing- The spacing of the joints depends on the type of pavement you wish to design.

- **UnReinforced Concrete (URC)** For a URC pavement, the joint spacing is dependent on the slab thickness. For slabs thicker than 230mm contraction joints should be every 5m. For slabs under 230mm thick contraction joints should be every 4m. Expansion joints should replace every third contraction joint, ie. at a spacing of 12m or 15m.
- **Jointed Reinforced Concrete** For contraction joints this is generally at a standard distance of 25m, unless there is $500mm^2/m$ of reinforcement when the spacing is taken from the design chart. For expansion joints, replace every third contraction joint with a expansion joint. For example a pavement with contraction joint spacing of 25m has an expansion joint spacing of 75m.

7.9 Design Criteria

The designs discussed above are based on the Design Manual for Roads and bridges, which in turn is based on the work of the Transport Research Laboratory. This design manual is only applicable to roads to be built in the United Kingdom and only for trunk roads, Motorways and other multi-laned roads.

When comparing the relative benefits of the types of road, it is necessary to compare both over a similar time period. This is normally the design life, which is typically 20 years for flexible and flexible composite pavements and 40 years for rigid and rigid composite pavements. As such, it is necessary to include all maintenance costs and residual values of the road.

7.10 Analytical Design

The design charts presented above are based mainly on empirical results and full scale experiments. Some work however has included an analytical approach to the design. This is based on the stresses and strains induced in the pavement by an applied wheel loading. It is however very complicated and rarely used and as such is not covered in these pages.

Problem:

Using the same example as in the traffic analysis page, that is a design loading of 5.13 millions of standard axles (msa), calculate the following:

1. Given the following soil test data suggest appropriate capping and sub-base layers for the road:

Moisture Content (%)	Bulk Density (Mg/m^3)	CBR (%)
5.0	1.575	23.0
7.5	1.844	20.0
10.0	2.189	5.2
12.5	2.132	2.1
15.0	2.082	1.0

2. If the road were to be constructed using a flexible pavement design, suggest appropriate thicknesses for the wearing course, base course and roadbase layers.
3. If the road were to be constructed using a rigid pavement design, suggest appropriate thicknesses for the concrete slab. Comment on the amount of reinforcement and the spacing of the expansion and contraction joints.

Solutions:

Subgrade Assesment

The first step is to determine the California Bearing Ratio at the optimum moisture content. To find the optimum moisture content, it is necessary to plot the dry density against moisture content. This is done in the table below:

- **Moisture Content** - Given in the question
- **Bulk density** - Given in the question
- **Dry Density** - Given by **Bulk Density/(1+moisture content)**
- **CBR** - Given in the question

Moisture Content	Bulk Density (Mg/m^3)	Dry Density (Mg/m^3)	CBR (%)
5	1.575	1.500	23
7.5	1.844	1.715	20
10	2.189	1.990	5.2
12.5	2.132	1.895	2.1
15	2.082	1.810	1.0

Plot of Dry density Vs Moisture Content -

From the plot, it can be seen that the optimum moisture content is approximately 10.3%.

Plot of CBR vs moisture content -

From the plot, it can be seen that the CBR at the optimum moisture content is approximately 4.5%. This value is then carried forward to the capping and sub base design.

CBR design value = 4.5%

Capping and Sub Base Design

From the design chart for Capping and Sub-base design, Figure 11 , it can be seen that there are 2 design options:

1. Use a standard **Sub-base of 150mm** and thus use a **280mm capping** thickness.
2. Use no capping and have a **Sub-base thickness of 250mm**

Pavement Design - Design Chart

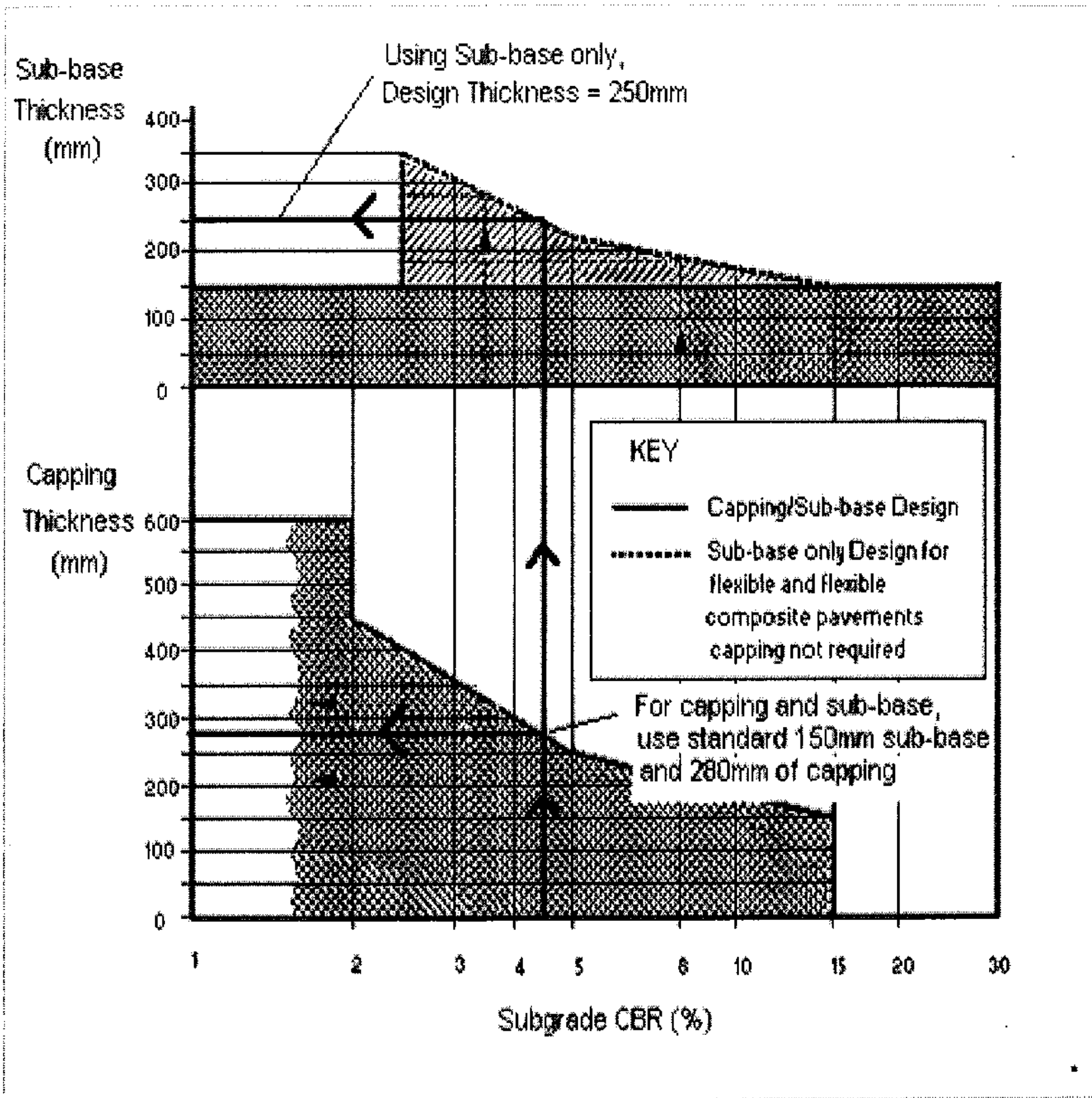


Figure 7.11 - Capping and Sub-base Design

Pavement Thickness - Design Charts

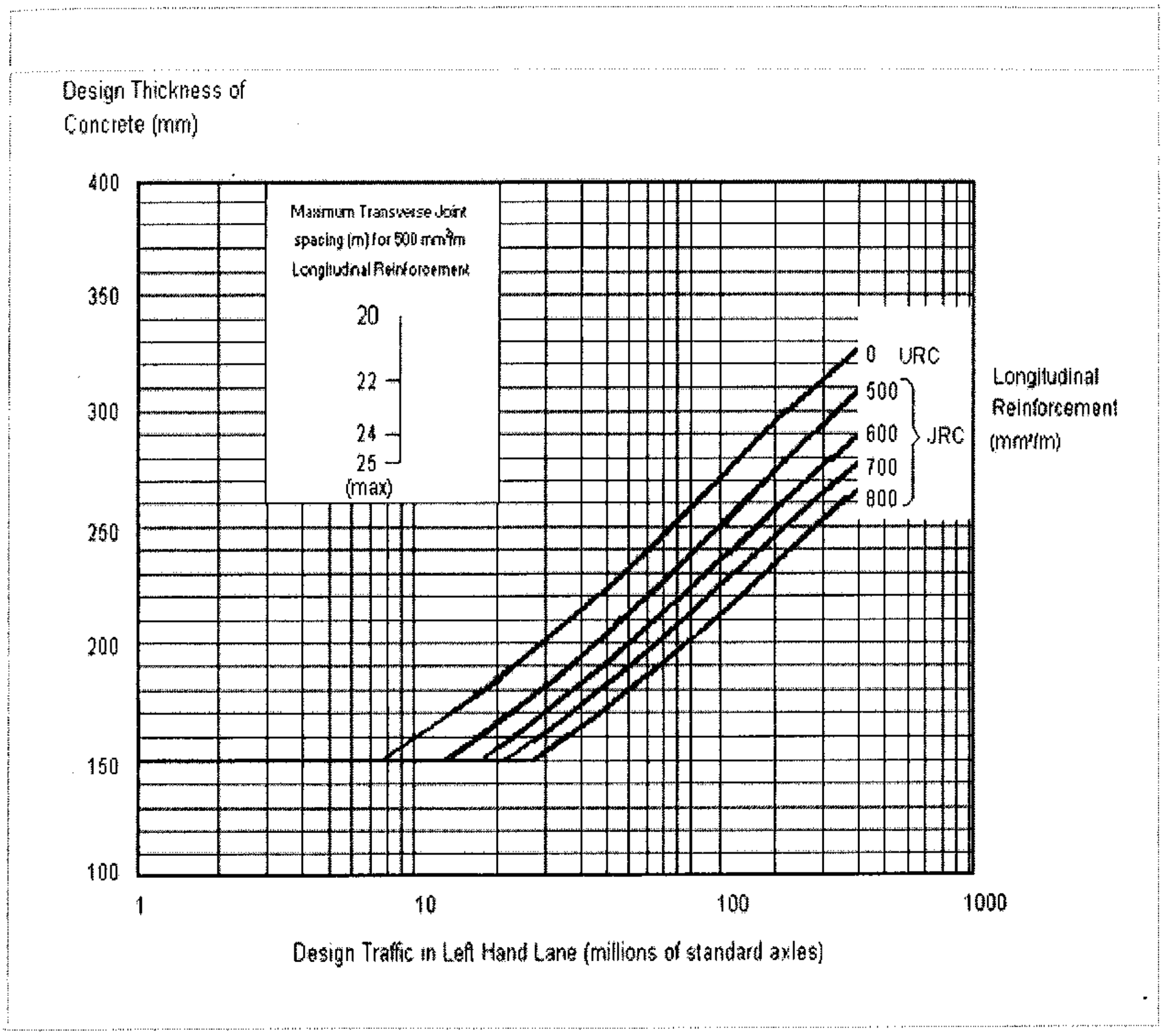


Figure7.12

Design Thickness for Rigid Pavements

8

USE OF FLY ASH IN CONCRETE FOR EXPRESSWAY

Fly ash is divided residue resulting from combustion of pulverized bituminous coal or sub bituminouscoal (ignite) in thermal power plants. It consists of inorganic mineral constituents of coal and organic which is not fully burnt. It is generally grey in colour, refractory in nature and has a fineness 4000 to8000sq.cm per gram and posses pozzolanic characteristics. Flyash is extensively used in cement/conretein developed countries for quite a long time in India this practice started comparatively late.

8.1 Advantage of concrete using PPC(Flyash based)

- Reduced Heat of Hydration
- Better Workability
- Higher long term strength
- Better Performance in Aggressive Environment
- Environmental Aspects

8.1.1 Reduced Heat of Hydration

Blended cement concrete does not develop heat as rapidly as normal portland cement concrete. This reduction of heat hydration is specially usefull incase of mass concrete used for roller compacted concrete structures like dams and road bases and sub bases. In some cases, it can also satisfy the requirements of flow heat cement.

8.1.2 Better Workability

Inclusion of Flyash for a given amount of cementious material in concrete reduces the water demand and improves workability significantly. Placeability of the concrete improves and concrete containing flyash shows reduced segregation and bleeding.

8.1.3 Higher long term strength

Flyash has good potential for as (i) cement replacement and (ii) pre filling material in concrete. The results of research work show that Flyash significantly improves the long term strength of the concrete.

Use of Flyash as cement Replacement

Function of the Flyash as cement replacement material has been studied and investigated by a number of research agencies. The investigation revealed that optimum percentage of substitution of Flyash for cement varies with the w/c ratio of the concrete. The higher quantities of cement can be replaced in case of lower w/c ratios and vice versa. One of the experiments was conducted using seven different batches of concrete, having w/c ratios of 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9 and results studied. In order to replace the exact amount of cement with the Flyash, the percentages are expressed based on absolute volumes, by taking their respective specific gravities into consideration. Moreover, the same level of workability was maintained in control mixes by choosing different aggregate/cement ratios.

Flyash as Pore filling Material in Concrete

Function of Flyash as Pore filling material has been studied and investigated. It has been observed that compressive strength of the concrete increases due to pore filling effect of the Flyash. In this case, the Flyash is considered just as a filler material, like coarse and fine aggregates. While the coarse aggregates gives body to the concrete, the fine aggregate fills in the mix. Flyash is assumed to fill the voids in the mixture of fine aggregate and cement. In order to verify the above assumption, the actual w/c ratios excluding Flyash for all the mixes are calculated and shown in Table-8.1 The quantities of Flyash as filler material are calculated and are expressed as percentages by volume of the concrete. These values are also shown in Table-8.1.

Flyash concretes attain better strengths at 90days than 28days.This leads us to deduce that, when the cement is partially replaced with Flyash, the remaining cement particles will slowly increase their volumes and occupy the extra space available, as each particle has to get hydrated deep into its core. Hence, when more and more cement is replaced with Flyash, the remaining cement particles have to get hydrated deep into their cores, in order to expand to occupy the whole extra space available to them. Consequently, more time is required for this. The increase in strength at

90 days also reveals better bonding among the cement and Flyash particles. Flyash is increased the compressive strength increases in all the concretes having the same actual w/c ratio. Here, Flyash is acting as filler material. As the quantity of Flyash is increased, more and more pores get filled and thereby the compressive strength increases. This clearly manifests the pore filling effect of the Flyash in the concrete.

8.1.4 Better performance in Aggressive Environment

- **Sulphate Resistance**

  Use of flyash has beneficial effects on the permeability of concrete. Flyash combines with the alkalis and calcium hydroxide released during the hydration of cement and thus reduces the potential for Gypsum and ettringite formation.

- **Acid Resistance**

  Concrete made of blended cement with Flyash has better resistance to acid attack as compared to normal Portland cement Concrete.

- **Resistance against Carbonating, Chloride Attack**

  Even trace amounts of chloride can trigger and accelerate corrosion if moisture and oxygen are present. A dense concrete with low permeability and low water cement ratio is recommended for providing resistance against carbonation and chloride attack. Investigation have revealed that permeability of concrete made with

  appropriate amounts of suitable pozzolana(Flyash) can be as low as 1/10th or 1/100th of that comparable concrete of equal strength made without pozzolana.

- **Protection against Corrosion Reinforcement**

  Addition of Flyash reduces the alkalinity of the concrete and hence promotes the corrosion of reinforcement in reinforced concrete structures such as bridges, pavements etc.

8.1.5 Environmental Aspects

Investigation shows that one tonne of Portland cement production discharges 0.87 tonne of CO_2 into the atmosphere. To compensate for the total CO_2 discharged into the atmosphere because of worldwide cement production every year, barren land area 1.5times that of India's total territory should be afforested. Since CO_2 is major contributer to the greenhouse effect and global warming of the planet, the developed countries are considering very severe regulations and limitations on CO_2 emissions.

On one hand, utilization of Flyash in cement/concrete minimizes the above referred CO_2 emission problem to the extent of its production in cement concrete; on the other hand it reduces the accumulation of Flyash which if unutilized poses environmental threat. By conserving partially the natural resources for the extended use in future, blended cement concretes in harmony with the concept of sustainable development.

Batch	% of Replacement	Actual w/c ratio	% of Flyash by volume of concrete	28days strength(Mpa)	90 days strength (Mpa)
A	0	0.30	0.00	34.08	34.44
	50	0.60	9.72	33.04	38.23
	60	0.75	11.67	24.59	37.54
	70	1.00	13.61	18.30	25.49
B	0	0.40	0.00	31.85	32.06
	40	0.67	5.36	25.04	36.54
	50	0.80	6.70	15.83	33.98
	60	1.00	8.04	14.22	19.87
C	0	0.50	0.00	20..74	22.22
	30	0.71	2.89	22.82	26.81
	40	0.83	3.84	17.63	23.11
	50	1.00	4.81	13.70	21.78
D	0	0.60	0.00	13.33	20.23
	25	0.80	2.08	12.74	22.22
	35	0.92	2.91	11.41	18.67
	45	1.09	3.74	10.74	18.22
E	0	0.70	0.00	11.92	19.11
	20	0.88	1.39	11.11	18.08
	30	1.00	2.09	10.37	17.78
	40	1.117	2.79	8.00	15.56
F	0	0.80	0.00	10.52	18.22
	15	0.94	0.89	90.4	16.67
	25	1.06	1.48	8.89	15.41
	35	1.23	2.07	7.85	13.56
G	0	0.90	0.00	9.92	15.78
	5	0.95	0.26	5.19	11.56
	15	1.06	0.77	5.78	10.44
	25	1.20	1.29	4.30	8.96

Figure 8.1 (Ref. handbook of kadiyali)

9

DESIGN MIX CONCRETE

9.1 INTRODUCTION

The scientific methods based on experiments and past experiences to determine the proportions of ingredients of concrete, such that the mix is workable in its hardened state and has a required strength and durability in its hardened state, are known as **MIX DESIGN METHOD**. The concrete thus produced is known as **DESIGN MIX CONCRETE**.

Usually the concrete mix is designed for its compressive strength.

This design mix concrete produced should be of required quality strength and durability.

Data for mix design:

The following basic data are required to be specified for design of a concrete mix:-

1. Characteristic compressive strength of concrete at 28 days(fck)
2. Degree of workability desired
3. Limitations on water-cement ratio and the minimum cement to ensure the adequate durability
4. Type and maximum size of an aggregate to be used
5. Standard deviation of compressive strength of concrete.

Grades of concrete (As per IS:456)

Grade designation	Specified characteristic compressive strength at 28 days, N/mm^2
M10	10
M15	15
M20	20
M25	25
M30	30
M35	35
M40	40

Table 9.1

9.2 COMPACTION FACTOR:

$$\text{Compaction factor} = \frac{\text{mass of partially compacted concrete}}{\text{mass of fully compacted concrete}}$$

9.3 TARGET STRENGTH OF CONCRETE (at 28 days):

$$fck' = fck + (t*s)$$

where,

fck' = target average (mean) compressive strength

fck = characteristic compressive strength at 28 days

s = standard deviation

t = a statistical value depending upon the accepted proportion of low results and the number of tests.

Values of 't' for a large number of tests

Accepted proportion of low results	Value of t
1 in 5	0.84
1 in 10	1.28
1 in 15	1.50
1 in 20	1.65
1 in 40	1.86
1 in 100	2.33

Table 9.2

Suggested values of standard deviation

Grade of concrete	Standard degree	deviation of control	for different ,N\mm^2
	Very good	good	fair
(1)	(2)	(3)	(4)
M15	2.5	3.5	4.5
M20	3.6	4.6	5.6
M25	4.3	5.3	6.3
M30	5.0	6.0	7.0
M35	5.3	6.3	7.3
M40	5.6	6.6	7.6
M45	6.0	7.0	8.0
M50	6.4	7.4	8.4
M55	6.7	7.7	8.7
M60	6.8	7.8	8.8

Table 9.3

9.4 SELECTION OF WATER –CEMENT RATIO:

If the 28 days strength of cement is known, water- cement ratio may be selected from the following

graph :

Relation between compressive strength and w/ c ratio of concrete

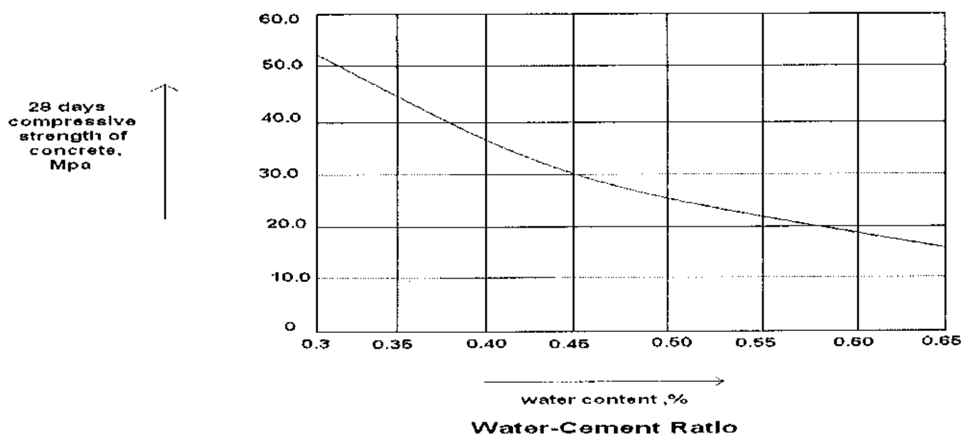


Figure 9.1

Approximate sand and water contents per cubic meter of concrete for grades upto M 35**

Nominal maximum size of aggregate(mm)	Water content per cubic meter of concrete(kg)	Sand as percent of total aggregate by absolute volume
10	208	40
20	186	35
30	176	33
40	165	30

Table 9.4

**Note:

This table is used for concrete grades upto M35 and is based on following conditions:

1. crushed coarse aggregates , confirming to IS:383-1970
2. fine aggregates consisting of natural sand confirming to grading zone III of table
3. water –cement ratio of 0.6 (by mass)
4. workability corresponding to compacting factor of 0.80

Suggested coarse aggregate grading

Zone	percent 40mm	passing 20mm	Sieve size 10mm	4.75mm	Maximum size of aggregate (mm)
I	100	34-40	16-18	0	40
II	100	40-45	18-20	0	
III	100	45-53	20-25	0	

Table 9.5

Grading limits of fine aggregate (IS: 383)

Is sieve(mm)	Grading Zone I	Grading Zone II	Grading Zone III	Grading Zone IV
10	100	100	100	100
4.75	90-100	90-100	90-100	95-100
2.36	60-95	75-100	85-100	95-100
1.18	30-70	55-90	75-100	90-100
600micron	15-34	35-59	60-79	80-100
300 micron	5-20	8-30	12-40	15-50
150 micron	0-10	0-10	0-10	0-15

Table 9.6

Adjustments of values in water cement and sand % for other conditions

Change in condition stipulated	(Adjustments required in) Water content	% , sand in total aggregate
1	2	3
For sand confirming to grading zone I, zone III or zone IV as IS: 383-1970.	0	+1.5% for Zone I -1.5% for Zone III -3.0% for Zone IV
Each 25mm increase or decrease in slump	+3%	0
Each 0.05 increase or decrease in free water cement ratio	0	+1%
For rounded aggregate	-15kg/m^3	-7%

Table 9.7

ESTIMATION OF AIR CONTENT:

Approximate amount of entrapped air to be expected in normal(non-air-entrained) concrete is given in the following table-

Approximate air content

Nominal maximum size of aggregate ,mm	Entrapped air, as percentage of volume of concrete
10	3.0
20	2.0
40	1.0

Table 9.8

CALCULATION OF CEMENT CONTENT:

The cement content per unit volume of concrete may be calculated from the free water-cement ratio and the quantity of water per unit volume of concrete. The cement content so calculated should be checked against the minimum cement content for the required.

Minimum cement content required in cement concrete to ensure durability under specified conditions of exposure (As per IS:456)

Exposure	Plain	concrete	Reinforced	Concrete
	Minimum cement content (kg/m^3)	Minimum water-cement ratio	Minimum cement content (kg/m^3)	Minimum water-cement ratio
Mild	220	0.7	250	0.65
Moderate	250	0.6	290	0.55
severe	310	0.5	360	0.45

Table 9.9

CALCULATION OF AGGREGATE CONTENT:

With the quantities of water and cement per unit volume of concrete and ratio of fine to total aggregate already determined, total aggregate content per unit volume of concrete may be calculated from the following formulae:

$$V = (W + C/Sc + 1/p * fa/Sfa) * 1/1000 \text{ ....(1)}$$

And

$$V = (W + C/Sc + 1/1\text{-}p * fa/Sca) * 1/1000 \text{........(2)}$$

Where,

V = absolute volume of fresh concrete, which is equal to gross volume(m^3) minus the volume of entrapped air

W = mass of water(kg) per m^3 of concrete

C = mass of cement(kg) per m^3 of concrete

Sc = specific gravity of cement

p = ratio of fine aggregates to total aggregates by absolute volume

fa,Ca = total masses of fine aggregate and coarse aggregate(kg) per m^3 of concrete respectively

Sfa,Sca = specific gravities of saturated surface dry fine aggregate and coarse aggregate respectively.

MIX DESIGN OF CONCRETE

The mix design of a concrete mix of grade **M20** is prepared utilizing the data given below:

1. Design stipulations:

   a. Characteristic compressive strength required in the field at 28 days-- 20 N/mm^2

   b. Maximum size of aggregate -- 20mm(angular)

   c. Degree of workability -- 0.90compaction factor

   d. Degree of quality control -- good

   e. Type of exposure -- mild

2. Test data for materials:

   a. Cement used – Portland cement grade 33 satisfying the requirements of IS:269-1989

   b. Specific gravity of cement -- 3.15

   c. Specific gravity

      1. Coarse aggregates -- 2.60

      2. Fine aggregates -- 2.60

   d. Water absorbtion

      1. Coarse aggregates -- 0.5% , 2. Fine aggregates -- nil

   e. Free moisture

      1. Coarse aggregates -- nil , 2. Fine aggregates -- 2%

   f. Sieve analysis

1. Coarse aggregate:

IS sieve sizes, mm	Analysis aggregate (percent	of coarse fraction passing)	Percentage different	of fractions		Remark
	I	II	I	II	Combined	
			60%	40%	100%	Confirming
20	100	100	60	40	100	to table 2 of
10	0	71.20	0	28.5	28.5	IS:383-1970
4.75	--	9.40	--	3.7	3.7	
2.36	--	0	--	--	--	

Table 9.10

2. Fine aggregate:

IS sieve sizes, mm	Analysis of fine aggregate fraction (percent passing)	Remark
4.75 mm	100	Confirming to grading
2.36 mm	100	Zone III ofv table 4 of
1.18 mm	93	IS:383-1970
600 micron	60	
300 micron	12	
150 micron	2	

Table 9.11

3. TARGET MEAN STRENGTH OF CONCRETE:

For a tolerance factor of't '= 1.65 from table 9.2 and standard deviation's '= 4.6 from table 9.3

fck' = fck + t*s

fck' = 20 + 4.6*1.65 = 27.6 N/mm²

4. SELECTION OF WATER –CEMENT RATIO:

The free water –cement ratio required for the target mean strength of 27.6 N/mm² , from figure9.2 is

0.50. This is lower than the maximum value of 0.65 prescribed for mild exposure from table 9.9.

Relation between compressive strength and w/ c of concrete

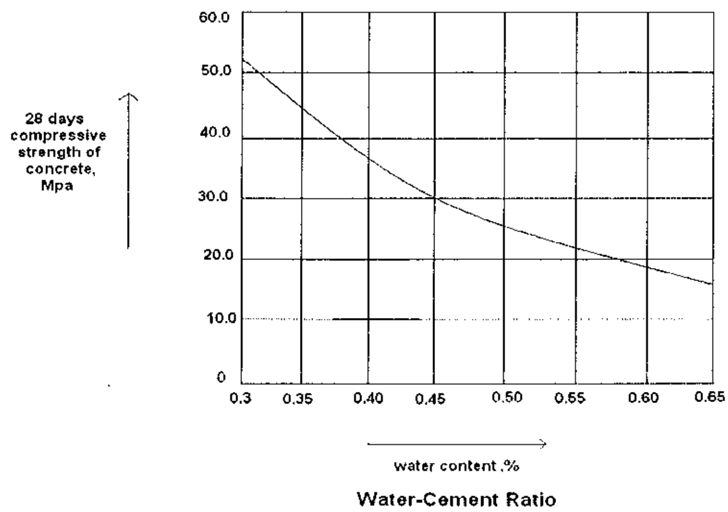


Figure 9.2

5. SELECTION OF WATER AND SAND CONTENT:

From table 9.4, for 20mm nominal maximum size aggregate and sand confirming to grading zoneIII –

from table 9.5, water content per cubic meter of concrete = 186 kg and sand content as percentage of

total aggregate by volume = 35 %

For changes in values of water-cement ratio, compacting factor and sand belonging to zone III, the following adjustment is required:

Change in condition (refer table 7)	Adjustments Water content,%	required in percentage sand in total aggregate
For decrease in water-cement ratio by (0.60-0.50) = 0.1	0	-2.0
For increase in compacting factor (0.90-0.80) = 0.1	+3	0
For sand confirming to zoneIII of table 4 of IS:383-1970	0	-1.5
Total	3%	-3.5

Table 9.12

Therefore ,

Required sand content as a percentage of total aggregate by absolute volume

= 35-3.5 = 31.5%

Required water content = 186 + (186*3)/100

= 186 + 5.58

= 191.6 litres/m^3

6. DETERMINATION OF CEMENT CONTENT:

Water – cement ratio = 0.50

Water = 191.6 liters = 191.6 kg

Cement = 191.6/0.50 =383 kg/m^3

This cement content is adequate for mild exposure condition, according to **table 9.9.**

7. DETERMINATION OF COARSE AND FINE AGGREGATE CONTENT:

From **table 9.8**, for the specified maximum size of aggregate of 20mm,the amount of entrapped air in the

wet concrete is 2%.

Taking this into account and applying equations **(1) & (2)**

0.98m^3 = (191.6 + 383/3.15+1/0.315* fa/2.60) *1/1000

and

0.98m^3 = (191.6 +383/3.15+1/0.685* Ca/2.60) *1/1000

Therefore, fa = 546 kg/m^3

Ca = 1187 kg/m^3

The mix proportion then becomes:

Water	Cement	Fine aggregates	Coarse aggregates
191.6 lit.	383 kg	546 kg	1187 kg
or 0.50	1	1.42	3.09

Table 9.13

8. ACTUAL QUANTITIES REQUIRED FOR THE MIX PER BAG OF CEMENT:

The mix is 0.5:1:1.42:3.09 (by mass). For 50 kg of cement, the quantities of materials are worked out as below:

a. Cement = (1 *50) = 50kg
b. Sand = (1.42 * 50) =71kg
c. Coarse aggregate = (3.09 *50) = 154.5kg

(Fraction I = 92.7kg,

Fraction II = 61.8kg)

d. Water

1. For w/c ratio of 0.50, quantity of water

= 25lit

2. Extra quantity of water to be added for absorption in case of coarse aggregate , at 0.5 % by mass

= 154.5 * (0.5/100) = (+)0.77 lit.

3. Quantity of water to be deducted for free moisture present in sand , at 2% by mass

= 71* (2/100) = (-)1.42lit

4. Actual quantity of water to be added

= 25 +0.77 -1.42 = 24.35 litres

5. Actual quantity of sand required after allowing for mass of free moisture

= 71 + 1.42 = 72.42 kg

e. Actual quantity of coarse aggregate required:

1. Fraction I = 92.7-0.46 = 92.24kg

2. Fraction II = 61.8-0.31 = 61.49kg

Therefore,

The actual quantities of different constituents required for the mix are:

	Water	**= 24.35kg**
	Cement	**= 50.00kg**
	Sand	**= 72.42kg**
Coarse aggregate:	**Fraction I**	**= 92.24kg**
	Fraction II	**= 61.49kg**

MIX DESIGN OF A CONCRETE

The mix design of a concrete mix of grade **M40** is prepared utilizing the data given below:

1. Design stipulations:

   a. Characteristic compressive strength required in the field at 28 days-- 40 N/mm^2

   b. Maximum size of aggregate -- 40mm (angular)

   c. Degree of workability -- 0.90compaction factor

   d. Degree of quality control -- good

   e. Type of exposure -- mild

2. Test data for materials:

   a. Cement used – Portland cement grade 33 satisfying the requirements of IS:269-1989

   b. Specific gravity of cement -- 3.15

   c. Specific gravity

      1. Coarse aggregates -- 2.60

      2. Fine aggregates -- 2.60

   d. Water absorption

      1. Coarse aggregates -- 0.45% , 2. Fine aggregates -- nil

   e. Free moisture

      1. Coarse aggregates -- nil , 2. Fine aggregates -- 2%

   f. Sieve analysis

      1. Coarse aggregate:

IS sieve sizes, mm	Analysis aggregate (percent	of coarse fraction passing)	Percentage different	of fractions		Remark
	I	II	I	II	Combined	
			60%	40%	100%	Confirming
20	100	100	60	40	100	to table 2 of
10	0	71.20	0	28.5	28.5	IS:383-1970
4.75	--	9.40	--	3.7	3.7	
2.36	--	0	--	--	--	

Table 9.14

2. Fine aggregate:

IS sieve sizes, mm	Analysis of fine aggregate fraction (percent passing)	Remark
4.75 mm	100	Confirming to grading
2.36 mm	100	Zone III of table 4 of
1.18 mm	93	IS:383-1970
600 micron	60	
300 micron	12	
150 micron	2	

Table 9.15

3. TARGET MEAN STRENGTH OF CONCRETE:

For a tolerance factor of ' t '= 1.65 from table 9.2 and standard deviation 's '= 6.6 from table 9.3

fck' = fck + t*s

fck' = 20 + 6.6*1.65 = 50.89 N/mm²

4. SELECTION OF WATER –CEMENT RATIO:

The free water –cement ratio required for the target mean strength of 50.89 N/mm², from figure9.3 is 0.32. This is lower than the maximum value of 0.65 prescribed for mild exposure from table 9.9.

Relation between compressive strength and w/ c of concrete

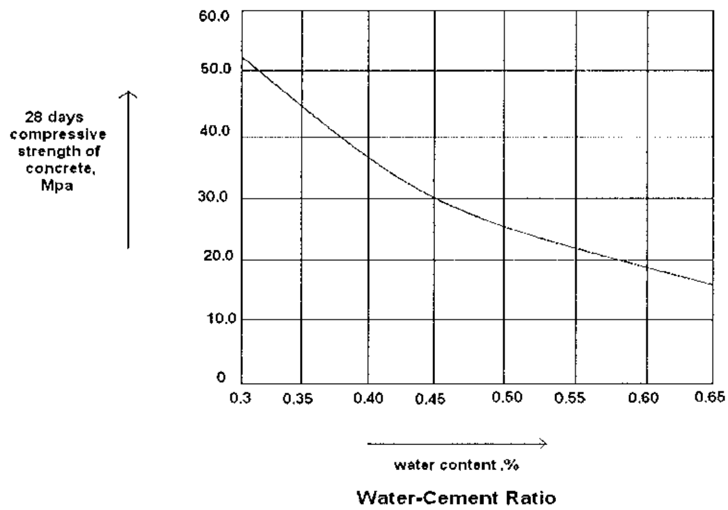


Figure 9.3

5. SELECTION OF WATER AND SAND CONTENT:

From table 9.4, for 40mm nominal maximum size aggregate and sand confirming to grading zoneIII from table 9.5, water content per cubic meter of concrete = 165 kg and sand content as percentage of total aggregate by volume = 30 %

For changes in values of water-cement ratio, compacting factor and sand belonging to zone III, the following adjustment is required:

Change in condition (refer table 7)	Adjustments Water content,%	Required in percentage sand in total aggregate
For decrease in water-cement ratio by (0.60-0.32) = 0.28	0	-6.4
For increase in compacting factor (0.90-0.80) = 0.1	+3	0
For sand confirming to zoneIII of table 4 of IS:383-1970	0	-1.5
Total	3%	-7.9

Table 9.16

Therefore ,

Required sand content as a percentage of total aggregate by absolute volume

= 30-7.9 = 22.1%

Required water content = 165 + (165*3)/100

= 169.95 litres/m^3

6. DETERMINATION OF CEMENT CONTENT:

Water – cement ratio = 0.32

Water = 169.95 liters = 165.95 kg

Cement = 165.95/0.32 = 531 kg/m^3

This cement content is adequate for mild exposure condition, according to **table 9.9.**

7. DETERMINATION OF COARSE AND FINE AGGREGATE CONTENT:

From **table 9.8**,for the specified maximum size of aggregate of 40mm,the amount of entrapped air in the wet concrete is 1%.

Taking this into account and applying equations **(1) & (2)**

V = 1-.01 = 0.99m^3

0.99m^3 = (169.95 + 531/3.15 + 1/0.221* fa/2.60) *1/1000

and

0.99m^3 = (169.95 + 531/3.15 + 0.4937 Ca) *1/1000

Therefore, fa = 374.41 kg/m^3

Ca = 1319.5 kg/m^3

The mix proportion then becomes:

Water	Cement	Fine aggregates	Coarse aggregates
169.95 lit.	531 kg	374.4 kg	1319.5 kg
or 0.32	1	0.7	2.48

Table 9.17

8. ACTUAL QUANTITIES REQUIRED FOR THE MIX PER BAG OF CEMENT:

The mix is 0.32:1:0.7:2.48 (by mass). For 50 kg of cement, the quantities of materials are worked out as below:

a. Cement = 50kg

b. Sand = 35kg

c. Coarse aggregate = 124kg (Fraction I = 74.4kg, Fraction II = 37.2kg)

d. Water

1. For w/c ratio of 0.32, quantity of water
   = 22lit
2. Extra quantity of water to be added for absorption in case of coarse aggregate ,at 0.45 % by mass
   = 124 * (0.45/100) = (+)0.558 lit.
3. Quantity of water to be deducted for free moisture present in sand , at 2% by mass
   = 35 * (2/100) = (-)0.7lit
4. Actual quantity of water to be added
   = 22 +0.558-0.7 = 21.858 litres
5. Actual quantity of sand required after allowing for mass of free moisture
   = 50 + 0.7 = 50.7 kg

e.Actual quantity of coarse aggregate required:

1.Fraction I = 74.4 - 0.334 = 74 kg

2.Fraction II = 37.2 – 0.223 = 37 kg

Therefore,

The actual quantities of different constituents required for the mix are:

Water = 21.858kg

Cement = 50.00kg

Sand = 50.7kg

Coarse aggregate: Fraction I = 74kg

Fraction II = 37kg

CONCLUSION

After calculating these values we will design the pavement for an Expressway which is economically feasible. The data from mix design are calculated from several experiments and tests which are carried out in quality control or in design office with several parameters and finally we get the water content, cement, coarse aggregate and sand quantities for requiring for designing an Expressway

10

COST ANALYSIS

ANNUAL EXPRESSWAY COST

Assuming land cost according to previous case study of Ahmedabad –Vadodra expressway = 1.50 crore for 1km land. (Assumed data)

Estimated life = 100yrs.

Earthwork Total Cost = 15lakhs.

Estimated life = 40yrs.

Pavement Concrete Cost Calculation:

According to IS:383 -1970 concrete required for 1km pavement is 5040m^3

Then our assumed ratio is ~~1:2:3.~~ 0.5 : 1 : 1.42 : 3.09

Lets we assume that,

~~X+2x+3x~~ = 5040 = 0.5x + 1x + 1.42x + 3.09x

X = 840 tonnes for cement. (Assumed as a base)

According our design proportion,

Water $=840\times 0.5 = 420$tonnes

Fine Aggregate $= 1.255\times 840 = 1192.8\,tonnes$

Coarse Aggregate $= 3.285\times 840 = 2595.6\,tonnes$

For **pavement concrete** of thickness 30cm concrete required is,

$$\text{Volume}= 1000\times\frac{30}{100}\times 7m\text{\^{}}3 = 2100m\text{\^{}}3$$

According to IS: 383-1970, the rate of aggregate of Type-I is 165 Rs. /m^3 and Type-II is225 Rs.

Type-I $= 2100\times 165 = 3,46{,}500$ Rs.

Type-II $= 2100\times 225 = 4,72{,}500$ Rs.

Total Cost = 8, 19,000 Rs.

According to IS: 383-1970 cost of sand /m^3 is 200 Rs.

$$\text{Sand Cost} = 2100 \times 200 = 420000 Rs.$$

$$\text{Water Cost} = 420 \times 100 \times 10 = 420000 Rs. \text{(water Rate = 10/kg assumed)}$$
$$\text{Cement required} = 840 \times 100 = 84000 kg$$

$$\text{No of cement bags} = \frac{84000}{50} = 1680 bags$$
Cement rate/ Bag = 152 Rs.

$$\text{Rate of cement} = 1680 \times 152 = 255360 Rs$$

Total Cost for pavement concrete = 819000 + 420000 + 420000 + 255360
= 1, 91, 4360 Rs.

Calculation for Dry Lean Concrete:

Thickness = 10 cm (Design value).

Then our assumed ratio is 1:2:3.

Lets we assume that,

X+2x+3x = 1060

X = 177 tones for cement. (Assumed as a base)

$$\text{No of Bags} = \frac{17700}{50} = 354 Bags$$

$$\text{Rate of cement} = 354 \times 152 = 53808 Rs$$

$$\text{Volume of Concrete} = 1000 \times \frac{10}{100} \times 7 m\text{^}3 = 7000 m\text{^}3 \text{ for 1 km.}$$

$$\text{Coarse Aggregate Cost} = \frac{819000}{3} = 273000 Rs$$

Sand Cost $= \frac{420000}{3} = 140000 Rs$

Water Cost $= 140000 Rs$, (Assume Rate of water = 10/ kg)

Total Cost = 140000 + 140000 + 273000 + 53808 = 606808 Rs

Total pavement cost in construction = 606808 Rs + 1, 91, 4360 Rs

= **25, 21,168** Rs.

Now Total Expressway Cost = Total Cost in Pavement construction + Maintenance Cost + land Cost + Earthwork.

= 25, 21, 168 + 1, 50,000 + 1, 50, 00000 +15, 00000 =

= **1, 91, 71168** Rs.

The total cost of Expressway for 1 km is 1, 91, 71168 Rs.

11

DRAINAGE CONSIDERATION

For design of an expressway, drainage pattern also plays a vital role while construction of roads. The main objectives of drainage is to prevent the road pavement from entry of excess of water, and preventing the ground underneath from getting saturated upto a depth of about 1 m below the top of the sub-grade, at all times. There are two types of drainage problems generally occurred in roads like **surface drainage** and **sub–surface drainage** problems but surface drainage problem is relatively less.

SURFACE DRAINAGE

The most essential components of surface drainage is to have 'Camber' on the pavement surface, slopes on the roadsides shoulders, and properly designed roadside ditches.

SUB-SURFACE DRAINAGE

In the case of sub-surface drainage we provide cement modified sub-grade of thickness 10-15cm below the DLC sub-base to prevent from 'Capillary effect' which causes cement pavement to show cracks under the loads on the paving concrete.

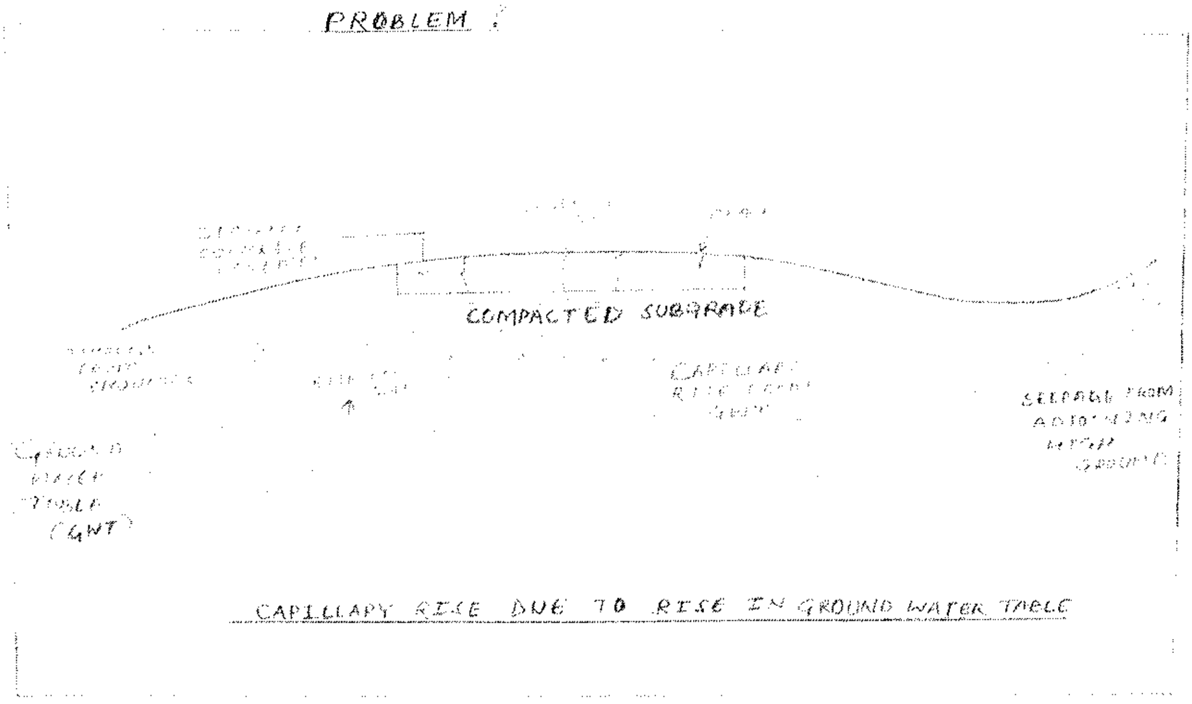


Figure 11.1

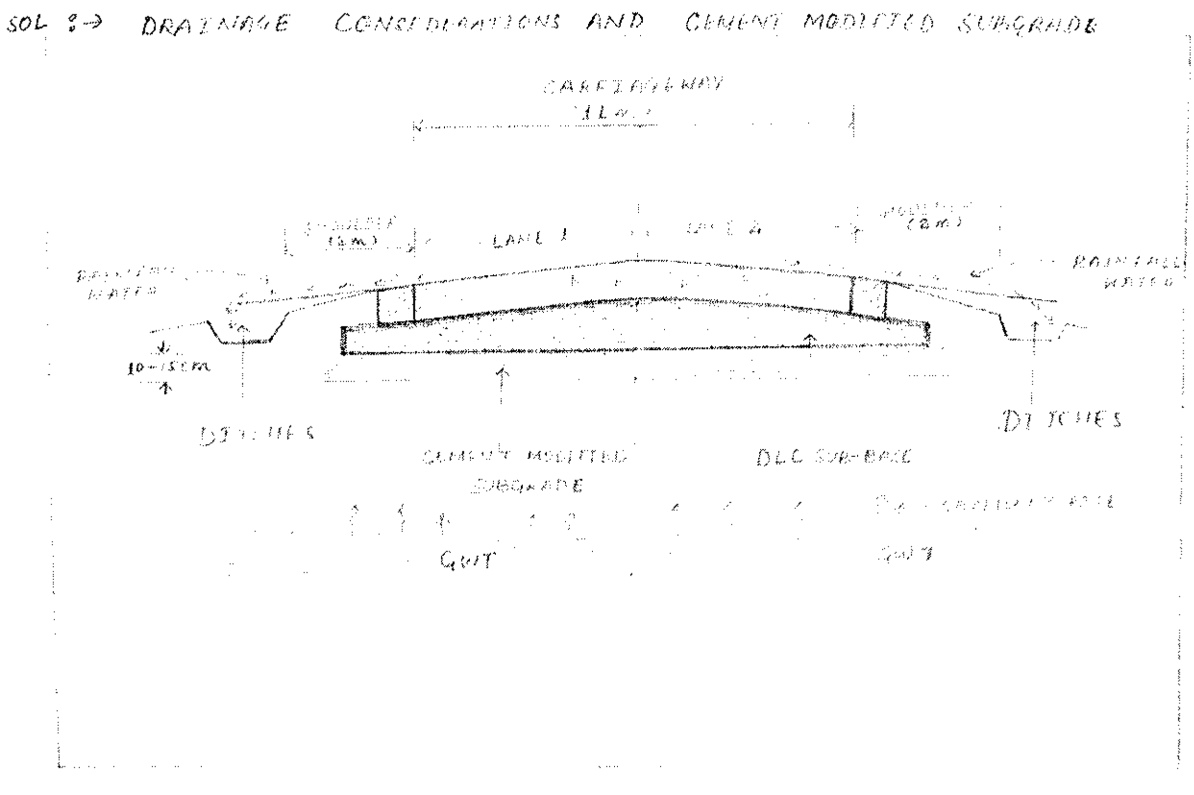


Figure 11.2

12

QUALITY CONTROL

12.1 INTRODUCTION

The process of quality control commences right from the preconstruction surveys of material, like selecting the coarse aggregate with the required Engineering properties. Even after construction quality control is practiced, as in some instances samples of hardened concrete are tested for their quality. If one is to expect a uniformly high quality of cement mix for a concrete pavement, it is necessary to ensure that the various ingredients like aggregate; cement and water are of equally high quality. Due to lack of proper quality control on water and cement, extensive damage has taken place. Prior to the construction stage all materials to be used in the project need to be checked and approved in advance, to ensure that they meet specified requirements and proper precautions are taken in regard to their storage and handling etc. These are described here under:

1.CEMENT

Initial setting time, soundness test, fineness test and compressive test as per standard procedures (IS 4031-partsI-13). The presence of coal ash as an adulterant can be detected by taking cement in a test tube, adding water, shaking the mixture and allowing settling for a few minute. It is desirable to have one limited storage of cement bags at the site, approximately one day's requirements. The stock of the bags should be covered by a tarpaulin and anchored well at the sides, so that the entire stock is always kept protected from humid atmosphere. It is always preferable to use cement from one source only. If however, there has some other sources, the cement bags from each source should be stored and tested separately.

Some of the common tests conducted on site are:

1.Finess test

2. Initial and final setting time

2.AGGREGATES

Both the coarse aggregate and sand should be thoroughly checked at least once initially to see that the results of various tests are within the range of specified requirements (IS: 383-1970). These tests are shape and size test, texture, specific gravity test, water absorption test crushing strength test and durability test. Proper storing of aggregate is also a important factor to prevent seggregation and maintain uniformity of grading and surface water condition. The coarse aggregates should be stored in aggregate size ranges 40-20mm, 20-10mm and 10-4.75mm.

Some of the common tests conducted on site are:

1. Penetrometer Test
2. Light Compaction Test
3. Mechanical Properties of Aggregates
   (i) Crushing strength Test
   (ii) Abrasion Test
4. Particle size and Shape Test
   (i) Sieve Analysis
   (ii) Flakiness and Elongation Index
5. Soundness Test for Aggregate

3.WATER

It is essential that the chemical analysis should be carried out on representative samples of sources of supply, to see that the specified requirements of the quality of water. Water should be stored in adequate quantity for continuity.

4.CONCRETE

The laboratory mix design unclosed the desired aggregate proportion and absorption values, the water cement ratio and the mix proportion of cement, aggregate and water. Based on these laboratory designs, the field trial mixes are made to fix the cement aggregate, fine aggregate coarse aggregate ratios, cement quantity and air content, for the required strength and workability.

Some of the common tests conducted on site are:

1.Slump test

Checking for workability

The freshly mixes concrete should be checked fro better workability, either by conducting slump tests for compaction factor tests of concrete.

Check for strength

During the construction phase, samples of freshly mixed concrete are cast for testing strength at 7 days and 28 days of curing as per IS: 516.

A proper inspection is carried out by the investigators of particular site of an expressway which is thoroughly examined by the quality controls at the site. Quality controls plays a vital role in checking of all materials which are being used at the construction site. While construction all materials are checked by the quality controls engineers and after proper checking, they allow the materials to be used at the site. Some of the materials are pre-checked by the engineers from where it comes to the site. So quality control take care or we can say that it visualize and checks all the construction works as well as their testing of materials with in quick time regularly.

13

EXPRESSWAY AND ENVIRONMENT

13.1 EFFECT OF HIGHWAY ON ENVIRONMENT

Highway and traffic have earned the dubious distinction of being the worst defilers of the environment .They have a direct impact on social and community values, the environment and the ecology.

Before any scheme is prepared by the highway engineer, he should prepare an Environmental Impact Statement (EIS), in which he should discuss the effects of the scheme on various components of the environment.

The effect of the highways and traffic on the environment will be of the following types:

1. Noise pollution
2. Air pollution
3. Community pollution

13.1.1 NOISE POLLUTION

Noise is the unwanted sound. The growth of traffic on highways and streets has increased the noise levels, intruding upon the quiet life and privacy of the dwellers nearby. Also it causes discomfort and annoyance.

Acceptable noise levels recommended by IRC

SITUATION	NOISE LEVELS Db(A)	
	Day	Night
Country areas	40	30
Suburban areas	45	35
Busy urban areas	50	35

Table 13.1

Noise can be abated in the following ways:

1. Providing smooth surface for roads
2. Providing noise screens such as trees and shrubs
3. Providing bypasses and ring roads to siphon off the through traffic entering the towns
4. Noise barriers made up of concrete , wood or metal should be provide in noise –sensitive areas

13.1.2 AIR POLLUTION

Air pollution takes the form of poisonous fumes and smell caused by the emissions from the engine exhaust .The major pollutants are carbon monoxide, oxides of nitrogen , lead particles and smoke. The major thrust area of reducing pollution is vehicle itself.

13.1.3 COMMUNITY IMPACT

The construction of a highway has adverse impacts on the social conditions of a community .A particular route location may cause severance of land and uproot a settled community. It may entail land consumption, including precious agricultural land. Such impacts should be evaluated carefully before a scheme is implemented.

13.2 ROAD ALIGNMENT AND THE ENVIRONMENT

All roads should be so aligned and located that the disturbance of the ecological balance is minimum, ie., removal of vegetative cover, upsetting of natural drainage pattern and instability of slopes etc. are minimized. It must be recognized that removal of vegetation not only leads to excessive surface erosion but also increases the tendency of water to seep through and render the slopes unstable, esp. in hilly areas. As a result of road development, if any change is brought about in the natural drainage system, appropriate remedial measures should be taken by suitably designing the surface ,subsurface and cross-drainage works.

13.3 EFFECT OF ROAD CONSTRUCTION AND MAINTAINANCE OPERATIONS ON THE ENVIRONMENT

All works of road construction and maintenance should be carried in conformity with the statutory and regulatory environment requirements .Where construction operations involve removal of vegetation, suitable compensatory measures need to be taken. Any spoil, debris, waste or any deleterious substance from the site, deposited on any adjacent land should be immediately removed and the affected area restored to its original state. All water courses, waterways, canals, lakes etc. should be protected from pollution arising out of the construction operations .During construction operations, any dust, gaseous or other air-borne emissions must be minimized so that air quality is not adversely affected. Mixing plant at the site should be equipped with a dust collector. Where gravel or earth roads have been made for haulage to and from the site of construction works, spraying over the gravel or earth road with water should be carried out at regular intervals. Any waste products like surplus aggregates, gravels, cement, bitumen, fuel and engine oil etc. should be disposed of conforming to local regulations.

14

CASE STUDY OF AHMEDABAD-VADODARA EXPRESSWAY

14.1 INTRODUCTION

The Ahmedabad- Vadodara Expressway is the first Expressway to have been taken up in the country. The Expressway was designed by CES Ltd. during 1984-85. For various reasons, the road works came to a standstill in the year 1991.This detailed project report relates to phase-II of the Expressway from 43-93km (Nadiad-Dakor state Highway to Vadodra end junction). The terrain traversed is generally flat, and the average annual rainfall in the area is of order of 800mm.

14.2 SURVEY AND INVESTIGATIONS

Field survey and investigations included a detailed site reconnaissance, traffic surveys, topographic surveys, soil and material investigations, and investigations for repair of drainage and other crossing structures, study for proper traffic dispersal at Nadiad, Anand interchanges and Vadodara end junction of Expressway.

14.3 DESIGN FOR RESTORATION AND BALANCE WORKS

The Expressway was originally designed based on the geometric design standards approved by MOST in the year. But designed standards were reviewed in detail. Based on this, the Expressway, 0.7m wide median side edge strip, 0.3m wide outer side edge, 2.5m wide paved shoulder and 1.5m edge shoulder. This gives a total crest width of 31m as against the earlier design of 28m. The alignment with large radius horizontal curves and flat gradient in most of the stretches.

Results of the soil investigations indicated that the pavement could be designed for a CBR of 5% for the entire section of the Expressway. The pavement composition designed and finalized accordingly worked out to 300mm thick granular sub-base, 150mmthick cement treated aggregate base, 2 layers of 150mmthick WMM, 150mmthick DBM binder course and 50mm thick BC wearing course for the entire stretch.

Necessary provisions have been made for surface, intra pavement and sub-surface drainage. For intra pavement drainage, the lower sub base to a depth of 150mm will be extended over the full width of the embankment. In stretches where the height of embankment is more than 3m, it is proposed to safely dispose off the surface water over the roadway through a system of kerbing .

14.4 PAVEMENT DESIGN

The recommended pavement composition for the Expressway was as follows:

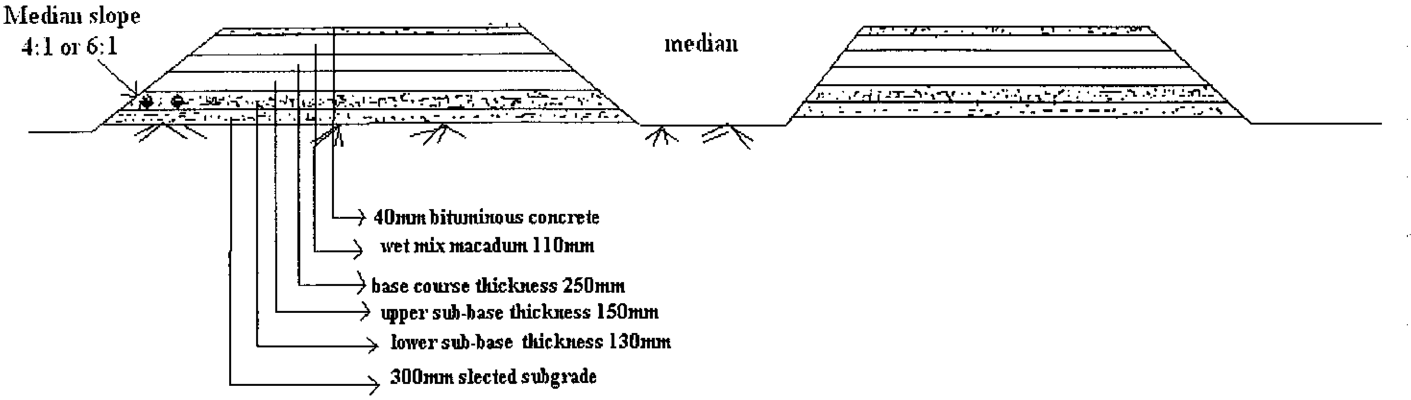
- 40mm Asphalt concrete wearing course
- 110mm DBM binder course
- 275mm WBM base course
- 195-220mm upper sub base having minimum CBR of 30%
- 150mm lower base having minimum CBR of 10%

The consultants opinioned that because of increase in traffic over the years, an additional 125m DBM layer would be required.

14.5 CONCLUSION

Ahmedabad-Vadodara expressway is a fast developing Expressway of the country. Once the Expressway becomes functional ,it could solve the highway conjusted traffic problem between Ahmedabad and Vadodara end of NH-8. It would also cater to the speedy haulage of materials in this region of economic development.

This, further could set example for the rest of the country to embark on the expressway projects , where traffic conjestion has been one of the trailing factors in regional development lately



Cross-section of Ahmedabad-Vadodara Expressway

<u>Figure 14.1</u>

#C++ PROGRAM ON "DESIGN OF A RIGID PAVEMENT"#

```
#include<iostream.h>
#include<math.h>
#include<conio.h>
void main()
{
float E,h,a,b,l,l1,x,y,P,K,n,Si,Sc,Se;
int i;i=6;
while(i!=0)
{
cout<<"\n******MAIN MENU******\n";
cout<<"press 0 for exit \n";
cout<<"press 1 for calculation of radius of relative stiffness \n";
cout<<"press 2 for calculation of radius of equivalent distribution of pressure\n";
cout<<"press 3 for calculation of stress at the interior \n";
cout<<"press 4 for calculation of stress at the edge \n";
cout<<"press 5 for calculation of stress at the corner \n";
cout<<"enter your choice";
cin>>i;
switch(i)
{
case 1:
cout<<"***calculation of radius of relative stiffness***\n";
cout<<"enter the value of E \n";
cin>>E;
cout<<"enter the value of h \n";
cin>>h;
cout<<"enter the value of K \n";
cin>>K;
cout<<"enter the value of n \n";
```

```
cin>>n;
l1 = ((E*pow(h,3))/(12*K*(1-(n*n))));
l=pow(l1,0.25);
cout<<"\nthe value of l = ";
cout<<l;
break;
case 2:
cout<<"***calculation of radius of equivalent distribution of pressure***\n";
cout<<"enter the value of h \n";
cin>>h;
cout<<"enter the value of a \n";
cin>>a;
b = pow(((1.6*a*a)+ (h*h)),0.5) - (0.675*h);
cout<<"\nthe value of b = ";
cout<<b;
break;
case 3:
cout<<"***calculation of stress at the corner***\n";
cout<<"enter the value of l \n";
cin>>l;
cout<<"enter the value of a \n";
cin>>a;
cout<<"enter the value of h \n";
cin>>h;
cout<<"enter the value of P \n";
cin>>P;
x = 1-pow((a*1.4144/l),0.6);
Sc = (3*P*x)/(h*h);
cout<<"\nthe value of Sc = ";
cout<<Sc;
break;
```

```
case 4:
cout<<"***calculation of stress at the interior***\n";
cout<<"enter the value of P \n";
cin>>P;
cout<<"enter the value of h \n";
cin>>h;
cout<<"enter the value of b \n";
cin>>b;
cout<<"enter the value of l \n";
cin>>l;
y = (4*log(l/b))+1.069;
Si = (0.316*P*y)/(h*h);
cout<<"\nthe value of Si = ";
cout<<Si;
break;
case 5:
cout<<"***calculation of stress at the edge***\n";
cout<<"enter the value of l \n";
cin>>l;
cout<<"enter the value of b \n";
cin>>b;
cout<<"enter the value of h \n";
cin>>h;
cout<<"enter the value of P \n";
cin>>P;
y = (4*log(l/b))+1.069;
Se = (0.572*P*y)/(h*h);
cout<<"\nthe value of Se is = ";
cout<<Se;
break;
default:
```

```
cout<<"exit\n";
}
}
}
```

#C++ PROGRAM ON "DESIGN ELEMENTS FOR EXPRESSWAY DESIGN"#

```
#include<iostream.h>
#include<math.h>
#include<conio.h>
void main()
{
float V,S,C,f,L,n,e,R,Ls,Rc,Ac,d,t,m,sec;
int i;i=6;
while(i!=0)
{
cout<<"\n******MAIN MENU******\n";
cout<<"press 0 for exit \n";
cout<<"press 1 for calculation of SPACING BETWEEN VEHICLES\n";
cout<<"press 2 for calculation of CAPACITY OF VEHICLES PER HOUR PER LANE \n";
cout<<"press 3 for calculation of RADIUS OF HORIZONTAL CURVE \n";
cout<<"press 4 for calculation of LENGTH OF TRANSITION \n";
cout<<"press 5 for calculation of SAFE STOPPING DISTANCE \n";
cout<<"enter your choice";
cin>>i;
switch(i)
{
case 1:
cout<<"***calculation of SPACING BETWEEN VEHICLES***\n";
cout<<"enter the value of V(K.P.H) \n";
cin>>V;
cout<<"enter the value of L(m) \n";
cin>>L;
cout<<"enter the value of f \n";
cin>>f;
cout<<"enter the value of t(sec) \n";
cin>>t;
S = L + (0.278*V*t) + (V*V /254*f);
cout<<"\nthe value of S(m) = ";
cout<<S ;
break;
case 2:
cout<<"***calculation of CAPACITY OF VEHICLES PER HOUR PER LANE***\n";
cout<<"enter the value of V(K.P.H)\n";
cin>>V;
cout<<"enter the value of S(m) \n";
cin>>S;
C = (1000 * V)/ S;
cout<<"\nthe value of C(vehicles/hr/lane) = ";
cout<<C;
break;
case 3:

cout<<"***calculation of RADIUS OF HORIZONTAL CURVE***\n";
```

```
cout<<"enter the value of V(K.P.H)\n";
cin>>V;
cout<<"enter the value of e \n";
cin>>e;
cout<<"enter the value of μ \n";
cin>> n;
R = (V*V)/(127 * (e+n));
cout<<"\nthe value of R(m) = ";
cout<<R;
break;
case 4:
cout<<"***calculation of LENGTH OF TRANSITION***\n";
cout<<"enter the value of V(K.P.H) \n";
cin>>V;
cout<<"enter the value of Rc(m) \n";
cin>>Rc;
Ac = 80 / (75+V);
cout<<"\nthe value of Ac = ";
cout<<Ac;
Ls = ((0.0215*V*V*V) / (Ac*Rc));
cout<<"\nthe value of Ls(m) = ";
cout<<Ls;
break;
case 5:
cout<<"***calculation of SAFE STOPPING DISTANCE***\n";
cout<<"enter the value of d(m) \n";
cin>>d;
cout<<"enter the value of f \n";
cin>>f;
cout<<"enter the value of V(K.P.H) \n";
cin>>V;
cout<<"enter the value of t(sc) \n";
cin>>t;
d = ((V*V)/(254*f)) + (0.695*V*t);
cout<<"\nthe value of d(m) is = ";
cout<<d;
break;
default:
cout<<"exit\n";
}
}
}
```

CONCLUSION

Expressways act as a catalyst in the fast development of the area and the entire economy of the region. Hence, the design and safety aspects must be quickly evolved by taking advantage of International experience and expertise and valuable time must not be lost in conducting feasibility studies alone. Since design of various expressway elements are time consuming requiring undivided attention and involve simultaneous consideration of several parameters, computer applications have come as a boon and full advantage should be taken of this.

The study of various features of an expressway and their design has presented us with an opportunity to use the theoretical and technical know-how imparted to us to a real life project.

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