A

PROJECT REPORT

ON

DESIGN AND ESTIMATION OF FLEXIBLE PAVEMENT

SUBMITTED IN PERTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF THE DEGREE OF

BACHELOR OF TECHNOLOGY

IN

CIVIL ENGINEERING

SUBMITTED BY:

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Under the Guidance of

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BBD UNIVERSITY

BABU BANARASI DAS UNIVERSITY, LUCKNOW

2020-2021

CERTIFICATE

This is to certify that the project Entitled **"Design and Estimation of Flexible pavement"** which is being submitted by **Hanu Singh (2180431004), Rishabh Kumar Tiwari (2180431010), Deelip Kumar (1170431019) Syed Shabaz Shamim (1160431065), MD Imran Khan (2180431006)** in partial fulfillment of the award of degree of bachelor of Technology (Civil Engineering), have been carried out by them under our supervision and guidance. They have shown keen interest in doing the project work, and we wish them the best in their future career.

Mr. KAMAL NABH TRIPATHI
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UNDERTAKING

Which is being submitted by Hanu Singh (2180431004), Rishabh Kumar Tiwari (2180431010), Deelip Kumar (1170431019) Syed Shabaz Shamim (1160431065), MD Imran Khan (2180431006)**,** student of ***Bachelor of Technology,*** hereby declare that the work detailed in this project entitled ***"Design and Estimation of Flexible pavement"*** submitted to the Department of Civil Engineering, Babu Banarasi Das University Lucknow, for the award of Degree of ***Bachelor of Technology*** in ***Civil Engineering***, is our original work. We have neither plagiarized nor submitted this work for the award of any other Degree. In case, this undertaking is found incorrect, we accept that our Degree may be unconditionally withdrawn.

Date:

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ACKNOWLEDGEMENT

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We must duly pay our acknowledgement to our teacher who taught us the various subject of Civil Engineering.

Words may fail us, when we think of all, that our parents have done for us. Throughout our life, they have always been a constant source of inspiration and whose admirations helps us in our academic pursuits. There sacrifice, prayers and good wishes made me to reach this stage. We are also thankful to my friends who gave me their valuable suggestion and discussions. They all deserve my sincere thanks.

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PREFACE

This work contains the project of final year B.Tech in Civil Engineering. The problem of considered project is "**Design and Estimation of flexible pavement**". A project like this contains a complete and through knowledge of design and estimation. It requires the good knowledge of the recent theory to help in making project more economical. My satisfaction becomes more relevant that I have completed the reports on time. I tried my best to deal with the project problem in the best possible way with the help of my knowledge. I have expressed all my ideas about my project which I have gained from my respected teachers. This project is concerned with planning, analysis, Estimation and Design of Flexible Pavement. I wish my sincere thanks to my teachers my friends who helped me in completing the project.

Contents

PROBLEM

A O.D.R. 3.00m widening & strengthening to **BHATNI to LALGANG VIA RAMPUR DHARUPUR PURUARA DISTRICT PRATAPGARH U.P.** under C.R.F. under **Superintending Engineer Pratapgarh Fathepur circle PWD Pratapgarh**. Bond No.: - 07/Sep./F circle/08-09 through the contractor M/S Abhyudaya housing & Const. P. Ltd. Shriram Tower Lucknow. 0-3.490 Km long connecting the village to a state highway is proposed to be metaled with bituminous concrete by wet mix macadam (W.M.M.) method, design the road pavement using following data.

Geometrical parameters of road.

The road consists of one turn of 30^0 as shown in the plan.

The radius of the horizontal curves of 30^0 are 100 m each 60 m each [$R=100m$, $R_1=60m$]

The value of camber for the road is 2.5%, side slope is 3.5% and Vertical Cut ½.

The width of pavement or carriage way is 5.50 m and land width is 8.50m

Traffic Data

Fast moving vehicle				Agricultural Tractor				Buses		Lorries Truck				Total Commercial Vehicle per day	Slow moving vehicle								
Motor cycle		Cars and vans		Loaded		Unloaded				Loaded		Unloaded			Cycle		Cycle Rickshaw		Bullock carts Front ground		Bullock carts	Bullock Carts	
Up	Down	Up	Down	Up	Down	Up	Down	Up	Down	Up	Down	Up	Down		Up	Down	Up	Down	Up	Down	Up	Down	
25	11	7	10	9	10	7	7	1	1	1	2	1	2	25	28	16	7	10	6	5	14	11	36

Classification test of the sub grade soil.

S. No.	Identification Of sample chainage	Grain size analysis % passing by weight			Atter berg's limits			Is classification
		4.75mm	0.75mm	0.002mm	LL%	PL%	P1%	ML-CL
1	0.500	100	69.8	0.00	27.00	23	5.00	CL
2	1.000	100	60.5	6.2	32.00	23	10.00	CL
3	1.500	100	65.2	6.8	32.5	23	9.50	CL
4	2.000	100	60.2	8.2	33.5	23	10.50	CL
5	2.500	100	60.5	6.2	32.00	23	10.00	CL
6	3.000	100	65.5	6.8	32.5	23	9.50	CL
7	3.500	100	60.2	8.2	33.5	23	10.50	CL
8	3.810	100	64.2	8.1	32.9	23	9.8	CL

CBR Test of the Sub grades soil

S. No.	Identification of Symbol chainage	optimum	Max moisture content	CBR
1	0.500	19.10	18.88	5.45
2	1.000	14.80	18.79	5.43
3	1.500	15.11	18.85	5.06
4	2.000	15.50	18.33	5.11
5	2.500	15.60	18.44	5.60
6	3.000	15.55	17.70	5.24
7	3.500	14.90	18.02	5.46
8	3.810	14.95	18.81	5.81

The extra widening and super elevation at curves should be provided as per IRC norms for design speed of 50 km/hr.

- **i.** Elevation of the state highway = 110.35m
- **ii.** The existing reduced level of the road are as follows

Km	0	1	2	3	4	5	6	7	8	9
Existing R.L. of G.L LHS	109.025	109.005	108.670	109.608	109.702	110.495	111.770	110.535	110.180	110.285

Existing R.L. of G.L. Center	109.250	109.250	108.950	109.950	110.0250	110.750	111.050	110.850	110.500	110.500
Existing R.L. of G.L. RHS	108.725	108.630	108.420	109.470	109.420	110.230	110.510	110.260	109.995	110.105

Chapter 1

Introduction

INTRODUCTION

GENERAL

Transportation is vital for the economic social & Cultural development of any country. The adequacy of transportation system of a country indicates its economic and social development. The inadequate transportation facilities retard the process of socio-economic development of the country.

Among four major modes of transportation; Roadways, Railways, Water ways and Airways the transportation by road is the only mode which could give maximum service to one and all. It is our accepted fact that of all modes of transportation, road transport is the nearest to the people. It is possible to provide door to door service only by road transport. The road network is therefore needed not only to serve as feeder system for other modes of transportation and to supplement them, but also to provide independent facility for road travel by a well-planned network of roads throughout the country.

With over 75 percent of the population of the country living in villages, the development in urban center alone does not indicate the overall development of the counter. Only with the improvement in transportation facilities in rural areas, there could be faster development of the rural center. The fertilizers and other inputs for agriculture and cottage industries could reach the rural population easily and similarly the products can be sold at the nearest marketing centre for more remunerative price resulting in faster economic growth.

For efficient functioning, it is essential to design the road to carry the traffic loads. Pavement is one of the road components which require technical attention from design point of view.

Pavement is the upper layer of a road/highway which is relatively stable and non-yielding constructed over soil is termed as pavement. The main function of pavement is to support and distribute the heavy wheel loads of vehicles over a wide area of the underlying subgrade soil and permitting the deformations in with elastic or allowable range and to provide an adequate surface.

OBJECTS AND REQUIREMENTS OF PAVEMENT

The surface of the roadway should be stable and no-yielding, to allow the heavy wheel loads of road traffic to move with least possible rolling resistance. The road surface should also be even along the longitudinal profile to enable the fast vehicles to move safely and comfortably at the design speed- The earth road may not be able to fullfil any of the above requirements, especially during the varying conditions of traffic loads and the weather. At high moisture contents, the soil becomes weaker and soft and starts yielding under heavy loads, thus increasing the tractive resistance. The unevenness and undulations of the surface along the longitudinal profile of the road causes vertical operation cost. Apart from this uneven pavement surface causes discomfort and fatigue to the passengers of fast-moving vehicles and cyclists. Therefore, in order to provide a stable and even surface for the traffic, the roadway is provided with a suitably designed and constructed pavement structure. Thus, a pavement consisting of a few layers of pavement material is constructed over a prepared soil subgrade to serve as a carriageway.

The pavement carries the wheel loads and transfer the load stresses through a wider are on the soil subgrade. Thus, the stresses transferred to the subgrade soil through the pavement layers are considerably lower than the contact pressure or compressive stresses under the wheel load on the pavement surface. The reduction in the wheel load stress due to the pavements depends both on its thickness and the characteristics of the pavement layers. A pavement layer is considered more effective or superior if it is able to distribute the wheel load stress through a larger area per unit depth of the layer. However, there will be a small amount of temporary deformation even on a good pavement surface when heavy wheel loads are applied. One of the objectives of highway designed and constructed pavement is therefore to keep this elastic deformation of the pavement within the permissible, so that the pavement can sustain a large number of repeated load applications during the design life.

Based on the vertical alignment and the environmental conditions of the site, the pavement may be constructed over an embankment cut or almost at the ground level itself. It is always desirable to construct the pavement well above the maximum level of the ground water to keep the subgrade relatively dry even during monsoons.

TYPE OF PAVEMENT

For the design purpose, the pavement may be divided into the following two categories depending upon their structural action.

1. Flexible pavement

2. Rigid pavement.

The main difference between these two types of pavements is the manner in which they distribute the load, over their subgrade.

Flexible pavement:

Flexible pavements are those, which on the whole have low or negligible flexure strength and are rather flexible in their structural action under the load The flexible pavements consist of relatively thin wearing surface, a base and sub-base course which rest on Compacted subgrade. This type of surface, reflects deformation of subgrade and subsequent layers on them. Thus if the lower layer of the pavement or soil subgrade is undulated the flexible pavement surface also gets undulated. A typical flexible pavement consists of four components:

- **i.** Soil Subgrade
- **ii.** Sub-base course
- **iii.** Base course
- **iv.** Surface course

The design of such pavements is based on the principle that a load of any magnitude is dissipated by carrying it deep through the successive layers of granular material. The intensity of the load diminishes in geometric progression as it is transmitted downward from the surface by spreading over increasingly larger areas. This results in reduction of strength with increased depth with the highest quality materials at or near the surface. Thus, the design thickness in a flexible pavement is influenced primarily by the subgrade. Flexible pavement are commonly designed using empirical design charts are equations taking into account some of the design factors. There are also semi empirical and theoretical! design methods. In this category following types of pavements may be included.

(a) Black top pavements

(b) Gravel pavements

(c) Water Bound Macadam pavements etc.

Rigid pavement:

Rigid pavement are those which passes note monthly flexural strength are flexural rigidity the stresses are not transferred from grain to grain the lower layer as in the ease of flexible pavement layer the rigid pavements are made of Portland cement concrete either plain, reinforce or pre stressed concrete. These pavements may not have a base course between the surface and subgrade. The Palin cement concrete slab are expected to take up about 30 kg per cm^2 The design of this class of pavements is based on ,the principle of providing sufficient strength in the structural cement concrete slab to resist the destructive action of the traffic. Due to their rigidity and high modulus of elasticity they distribute the load over a relatively wider area of soil. The rigid pavements can resist appreciable tensile stresses, therefore the minor variations in the strength of subgrade have no influence on the structural capacity[1] of the pavement. Thus they are capable of bridging small weak patches and depressions.

COMPONENTS OF A FLEXIBLE PAVEMENT

A Flexible pavement mainly consists of the following components:

1. Soil subgrade
2. Sub base Course
3. Base Course
4. Wearing Course

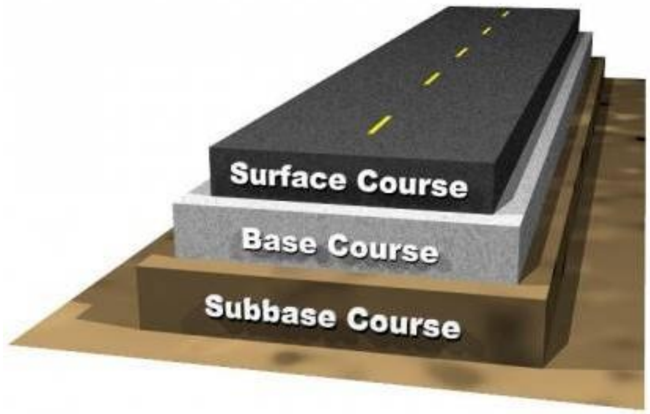


Fig: Sub Grade

Sub Grade:

The soil subgrade is a layer of natural soil prepared to receive the other layers of the pavement. The loads on the pavements are ultimately supported by the soil subgrade and dispersed to the earth mass below.

The subgrade should possess the following properties:

i. Strength
ii. Drainage
iii. Ease of compaction
iv. Permanency of compaction etc.

It is important to note that in no case the soil subgrade should be over stressed. The strength properties of the subgrade can be evaluated by any of the following tests:

1. California bearing ratio tests
2. California resistance value test
3. Plate bearing test
4. Triaxial shear test etc.

For this test reader is advised to consult some text on soil Mechanics.

Sub base course:

It is a layer of selected granular soil, stabilized soil or gravels, boulders, broken stones, bricks etc. The main purpose of providing sub base layer is to permit the building of relatively thick pavement at a low cost. In the design of sub base course economy is the essential requirement. As far as possible locally available material should be used. The sub base course usually is provided on fine grained soils for anyone or more purpose.

(a) To increase the structural support for the base and surface courses.

(b) To improve drainage.

(c) To eliminate frost heave and salt heave.

(d) To prevent the base and surface courses from the ill effect of poor qualities of the underlying soils.

Base Course:

It is the foundation layer designed for its structural stability. The main function of the base course in flexible pavements is to improve, the load supporting capacity by distributing the load through a finite thickness. The minimum thickness of base course should not be less than 7.5 cms. Base course should fulfill the following conditions.

(a) The base course should have sufficient thickness to distribute the heavy wheel load pressure adequately to the subgrade.

(b) They should possess sufficient structural stability to resist the vertical pressure and horizontal shear stresses developed due to moving or standing wheels loads.

(c) It should possess sufficient density.

(d) It should possess sufficient resistance to weathering.

For base courses suitable local materials such as soft aggregates, bricks, slag. Macadam, stabilized soil etc. may be used.

Base course under rigid pavements is provided for the following purposes:

(a) To prevent the pumping in fine grained soils.

(b) To protect soils susceptible to frost action**.**

(c) To check the volume changes of the sub grade on highly active soils**.**

(d) To form a working surface on silts and clays.

(e) To provide-Leveling course on rough shaped formations**.**

(f) To increase the structural stability.

The thickness in this case also may be kept as 7.5 cms. The choice of material depends on the purpose for which it is to be adopted. To prevent pumping, the base course should be well graded, should not have excessive tines, and should be capable to be compacted to a relatively high density.

To provide drainage, the material of the base course mayor may not be well graded, but it should contain no fines.

To prevent frost action, material should be non frost susceptible and free draining.

To provide adequate structural stability, tile base course may not be free draining, but it should be well graded, and should resist the deformation- due to leading.

Wearing Course

It is that component of pavement with which the wheels of vehicles are in actual contact. The main purpose of wearing course is to provide smooth and dense riding surface that resists the pressure exerted by tyres. It also resists the wear and tear due to traffic. It also offers resistance to the infiltration of surface water into the base or subgrade layer which might sufficiently lower the supporting power of the base and subgrade. It also prevents the pavement base from revelling and disintegrating effect of traffic.

The Wearing Course also adds appreciable strength to the entire pavement structure. In flexible pavements, usually bituminous surfacing is provided as a wearing course. In rigid pavements, Cement Concrete layer acts as a base as well as wearing course. The type of surface depends upon the availability of materials, plants, equipment's, and the magnitude of traffic, weight etc. The thickness of surface course depends largely on the applied load and stability of base course. Actually the selection of type of wearing surface and its thickness depends upon the cost and benefits derived from the pavement.

FACTORS AFFECTING STABILITY OF PAVEMENT

The thickness of pavement depends on a number of variables, but 'from experience, it has been found that the following five factors affect the performance of pavement to a great extent.

- **i.** Traffic factors. These include the character and volume of traffic which will use the pavement.
- **ii.** Moisture factors. These represent change of moisture content of the subgrade due to any of the conditions of precipitation, capillarity and irrigation in the area etc.
- **iii.** Climatic factors. These factors represent the effect of temperature changes such as frost penetration etc.
- **iv.** Soil factors. These factors represent the effect of the condition of natural foundation soil in cuts under shallow embankments or soil used in the embankment immediately underlying the subgrade surface. They measure the supporting power of the subgrade.
- **v.** Stress Distribution factors. These factors represent the function of pavement and base for transmitting the load of the subgrade.

Traffic Factors

The following wheel load factors are considered in the design of pavement.

1. Maximum wheel load
2. Dual or Multiple wheel loads and equivalent single wheel load.
3. Load Contact pressure
4. Repetition of loads.

Maximum wheel load in the design of a pavement the knowledge of maximum wheel load is more important than gross weight of the vehicle. In evaluating the magnitude of the wheel load to be selected as design criterion, the legal axle load specified in the area should be taken into account. In

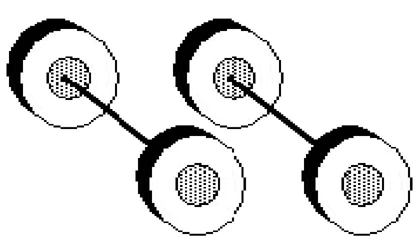


Fig: Tandem Axles with Single Tires

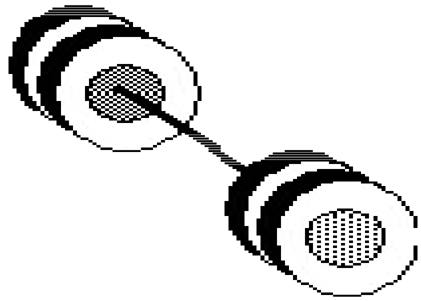
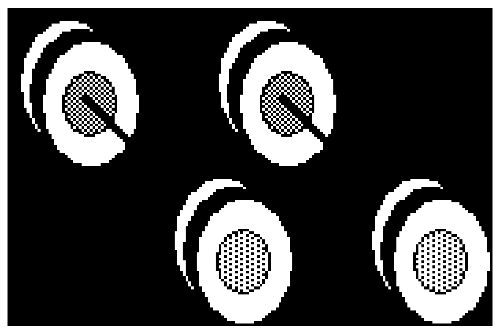


Fig: Single Axle with Dual Tires



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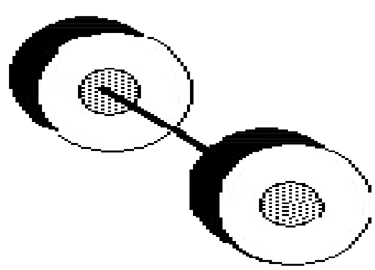


Fig: Single Axle with Single Tires

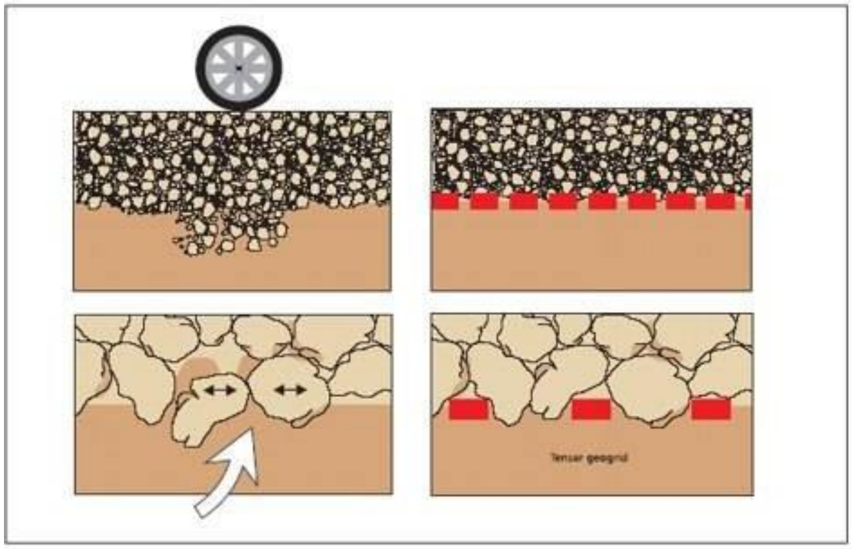


Fig: Road Subgrade

India, Indian Road Congress has specified the maximum legal load as 8170 kg. and maximum equivalent single wheel load as 4085 kg. It has been observed that unless the two wheels are spaced sufficiently closely, the area of sub-grade stressed by each wheel overlaps and as stated above in such cases the maximum wheel load is more important than gross weight of the vehicle. The configuration or space of wheel load gives an idea how the load of a vehicle acts on the surface of the pavement- Typical wheel load configuration of a tractor trailer unit of heavy duty vehicle has been shown in Fig.

The total load influences the thickness of the pavement while tyre pressure influences the quality of surface course. Actually the magnitude of vertical pressure at any depth of soil subgrade depends upon the surface pressure as well as on the total load.

The vertical stress at any depth can be computed by using Boussinesq equation represented

This equation is applied for uniformly distributed circular load. Using this equation the variation in vertical stress due to a load of 36 ton acting over a, area of 30 cms. radius has been plotted with depth in Fig.

Contact Pressure

The influence of tyre pressure is predominant in the upper layers. At greater depths the tyre pressure effect diminishes and the total load exhibits a considerable influence on the vertical stress magnitude. Thus to bear high magnitude of tyre pressure the upper layers of pavements should be of high quality materials. However the tyre pressure does not affect the total depth (thickness) of the pavement. With constant pressure, the total load governs the thickness requirements of the pavements so that stress in the upper layer on top of the subgrade is restricted within allowable limits.

Usually the distribution of wheel load is assumed on a circular area, but by actual measurement of the imprint of types with different- loads and inflation pressure, in many cases the contact area has been found as elliptical in shape. Thus contact pressure can be found by the following equation.

$$\textbf{Contact pressure} = \frac{\text{Load on wheel}}{\text{Contact area}}$$

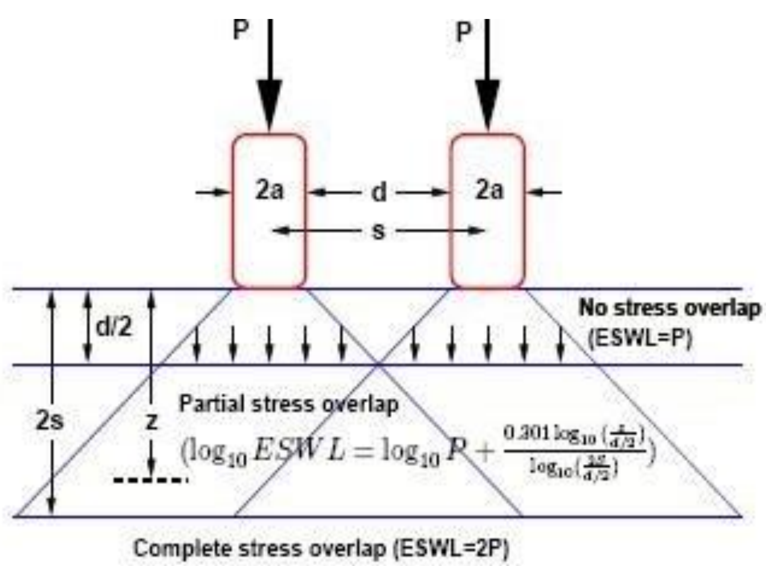
$$\textbf{Where contact area} = \frac{0.9 \times \text{wheel load}}{\text{Tyre pressure}}$$

The contact area can also be found by taking actual impression of the tyre imprint. Generally the tyre pressure and contact pressure are same when the tyre pressure is 6 kglcm2. The ratio of contact pressure to tyre pressure is known as Rigidity factor. The value of rigidity factor is 1.0 for an average tyre pressure of 7.0 kg/cm2. If the tyre pressure is lower than 7 kglcm2. this ratio is higher than unity and less than unity for higher pressure. Actually the rigidity factor depends upon the degree of tension developed in the walls of the tyres. The variation in contact pressure and measured contact pressure.

Effect of Multiple Wheels and Tandem Axles and Equivalent Single Load (E.S.W.L.)

In order to carry greater loads and at the same time to maintain the maximum wheel load within the legal prescribed limit, it is essential to provide dual wheel assembly to the rear axles of the highway vehicles. In doing so it is necessary to find out the effect of dual assembly on the pavement. It has been observed thin the depth of a flexible pavement, at which stresses in pavement due to dual wheel assembly are equal to those of a single wheel assembly depends upon the spacing of wheels. As shown in Fig. 16.3. near the surface, the wheels act independently and at a depth approximately equal to half the clear spacing 'd' between the wheels, they cease to act independently. Beyond this depth the stresses induced in the pavement result from each wheel load and overlap as shown in Fig. 1.3. As the depth increases the overlap of stresses also increases, but after a certain limit, the overlap is negligible. By experiments it has been observed that this lin 1it starts at a depth of about twice the centre to centre distance between the wheels and the equivalent single wheel load is equal to the load on the whole assembly.

Between these two critical limits, it has been assumed that the equivalent single wheel load varies as the logarithm of the pavement thickness. A straight line relationship has been assumed between the E.S.W.L. and depth of the pavement on log-log scale. The use of the procedure is explained below. On a log-log graph paper two points A and B with co-ordinates as (p, dl2) and (2p, 2s) are plotted.



where.

p - single wheel load

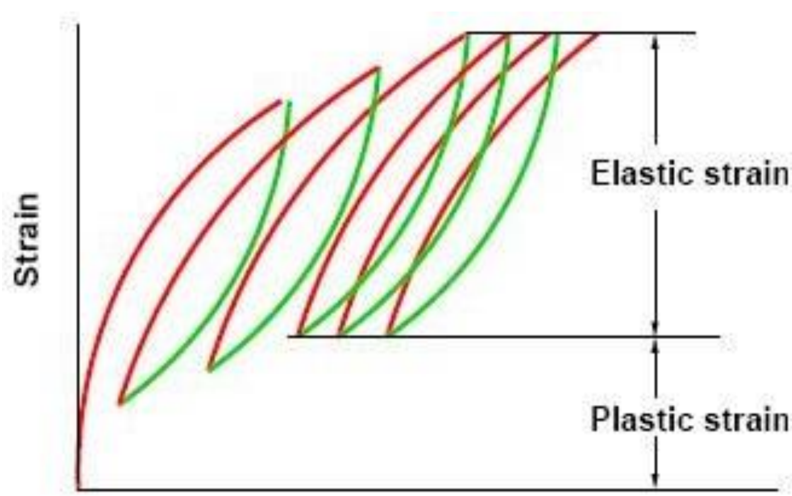
d = clear distance between the wheels

s = centre to centre distance between the wheels.

The points A and B are joined by a straight line. Thus line AB is the locus of points where any single wheel load is equivalent to a certain set of dual wheels. To find out the equivalent single wheel load for dual assembly configuration, it is essential to estimate the design thickness of the 'pavement first. In this way the E.S.W.L. is first calculated for the assumed design-depth from the graph and used for calculations in the design. If the thickness obtained from calculations is equal to the assumed thickness, the E.S.W.L. is correct, otherwise repeat the process till correct values are obtained.

Repetition of Load

The deformation of subgrade or pavement due to a single application of wheel load may he very small, but the repeated application of load on the pavement may result in increased magnitude of plastic and elastic deformations. The accumulated permanent deformation even may cause failure of the pavement. If the subgraae is poorly compacted or overstressed, the repeated loading



may produce a permanent and non uniform deformation of subgrade. This is more significant for rigid pavements as the reduced support is given by the subgrade may cause failure of the slab.

Laboratory as well as l1c1dplate loading tests have shown that the amount of deformation under repeated loads varies directly with the Logarithm of the load applications. This principle can be used to extend the load deformation data from few tests to a large number of repetitions. Thus it can be used to evaluate the supporting power of the subgrade for the anticipated load repetitions during the design life of the pavement, but the mixed traffic poses complications in the analysis. Thus to account for the effect of mixed traffic, traffic surveys are carried out to find out the repetition factor for wheel loads in the design of pavements. The data collected is converted to some constant equivalent wheel loads. Equivalent wheel loads are those loads which require same thickness and strength or quality of pavement taking into account the repetition of each load. In India the traffic composition is of mixed type. Thus it is essential to convert the various wheel loads into one single wheel load for design purposes. For example, if a pavement fails with N! Number of repetition of Pi kg load and similarly if N_2 number of repetition of P_2 kg load causes failure of this pavement then P_1 N_1 and P_2 N_2 are called equivalent. The above concept has been used for design purposes in many ways. Here only one concept put forth by Me Leod in 1956 has been described. He suggested the design criterion for flexible pavements which require 150% design, for 106 Repetitions. He assumed that the designed thickness will support 10^6 repetitions in 25 years for the design load. He further assumed that one repition of the design load will require only 25% thickness of the designed thickness required for 10^6 repetitions. For computing equivalent load, the load factors given in the following table are widely accepted and can be used as such. He assumed 2268 kg wheel load and the failure number of repetition for 25 cms thick pavement as standard. With these values as standard, the number of failure repetition for higher wheel loads may be obtained from Fig. 16.6. He plotted 25% of the design thicknesses for various wheel loads on vertical axis against one application and total thickness 100% were drawn on vertical axis at 106 repetition as shown in Fig. 1.5. The results obtained, are shown in Table 1.2. The equivalent factors are used for converting for daily traffic counts.

S. No.	Wheel load in kg	Repetition to failure No.	Equivalent to 2268 kg	Equivalent load factor	Remark
1.	2268	105,000	1.0	1	

2.	2722	50,000	2.0	2	
3.	3175	22,500	4.7	4	
4.	3629	13,000	8.2	8	
5.	4082	6 50000	16.3	16	
6.	4536	3;300	32.0	32	
7.	4993	1,700	62.0	64	
8.	5443	1,000	105	128	

Moisture Factors

Depending upon the type of soil, climatic conditions, ground water level and its variations, type of pavement and it's shoulders, drainage conditions, moisture variations in the subgrade may take place to a considerable extent. The reduction in moisture content may cause shrinkage and increase will cause change in strength of the subgrade and deterioration of the road surface. Generally all soils decrease their strength with the increase in moisture content, more especially clayey soils. On the other hand decrease in moisture content, increase the strength of subgrade soils, it has been observed that day long drying period dries out soil more near the edges than the central portion of the road. In clayey soils this may cause considerable differential shrinkage of the soil which results in longitudinal cracks in flexible pavements and differential movement in rigid slabs. These effects are likely to cause considerable damage to the pavements.

The increase in moisture may take place due to any of the following causes:

1. Percolation of surface water through cracks in the pavement surface.
2. Entry of water through edges of the pavement.
3. Seepage.
4. Capillary rise from high water table or due to rise of table in rainy reason, etc.
5. Thus in situations where it is anticipated that moisture under subgrade may reach 100% saturation during rainy season, the strength of subgrade should be calculated on soaked specimens. In most of the cases, the design of flexible pavements is made on me assumption

that the subgrade/base course will possess a high degree of saturation through out most of its life.

3. Climatic Factors

The performance of a pavement is adversely affected by the climatic conditions of a place. It includes the frost action. Frost action affects the pavements in two ways.

1. Frost heave
2. Loss of subgrade support during thaw period or alternate cycles of freezing and thawing.

Frost Heave.

The term frost heave refers to rising up of the pavement portion. When the temperature falls slowly below freezing temperature, the free water available in the larger pores of the soil freezes. As the temperature continues to fall down, the ice crystals formed in the large pores attract water in smaller capillary pores and freeze it also and the original crystals increase in size. The process of increasing ice crystals continues till the capillary go on supplying water and the soil above these crystals ultimately heave up. If due to frost heave, the rise of pavement portion is uniform, then the supporting power of the subgrade is not affected adversely. However, if the rise is no uniform, the supporting power of subgrade is affected adversely.

Further due to the change or rise in temperature, the ice crystals melt and soften the road bed. Due to the ice melting, the voids in the soil increase and the water collects in these voids in larger quantity below the pavement, which decreases the load carrying capacity of the pavement to a great extent. Under heavy loads the pavement would deflect excessively, causing progressive failure due to decreased load carrying capacity of the sub-grade. Thus the freezing and thawing or melting ice crystals which occur alternately due to variation in the weather cause much damage to the pavement. The over ail effect due to frost heave, frost melting, and alternate freezing and thawing cycle is called 'Frost Action'. The frost action is influenced by the following factors.

(a) Frost susceptible soil.

(b) Low temperature below freezing point,

(c) Supply of water.

(d) Cover.

Thus the soil type, grain size distribution, permeability and capillarity of soil influence frost action. The most effective and practical method to decrease the water and frost action is to provide surface and sub surface drainage system.

Soil Factors

Soil under the pavement foundation is seldom homogeneous. Large variations may occur in its properties. To predict the behavior of the soil under different conditions, it is essential to carry out certain tests. The soil strength varies with type of soil, bulk density, moisture content, permeability, internal structure of the soil etc. It also depends upon the method of application of load on the soil.

We know that the soil strength increases with increasing density and decreasing moisture content. As the elastic properties of soil are very low, in the design of flexible pavements the supporting power of subgrade is very important factor. To evaluate the supporting power of subgrade, compressive, and tensile strengths are not of much importance. To determine the supporting power of subgrade generally following properties of the soil are determined:

(a) Shear strength

(b) Bearing power

(c) Penetration resistance of the soil. Here we shall discuss penetration test only.

Elastic Modulii

Depending upon the design method, the modulii of elasticity of different materials are calculated mainly from plate bearing method. It may also be determined from triaxial compression test. For the design purpose the modulii of subgrade, base course and sub base course materials are determined by plate bearing test.

1. Subgrade modulus is calculated from the plate bearing test data. For flexible pavements the elastic modulus can be computed from Boussinsg's settlement equation. The maximum vertical deflection is given by the equation as

In this case the pressure distribution will not be uniform. If the plate bearing test is conducted with a mild steel plate, then it will be considered as rigid plate and equation will be used for deflection, instead of steel plate. The loads are applied through inflated rubber tyres. Then it is considered as flexible plate loading and equation no shall be used.

Chapter 2

Literature Survey

DESIGN STANDARDS

2.0 General

The principal criterion for determining the thickness of a flexible pavement with a thin bituminous surfacing is the vertical compressive stain on top of the subgrade imposed by standard axle load of magnitude 8.17 KN (8170kg.) Excessive vertical subgrade strain causes permanent deformation in the accepted in village roads ma be taken as 50as before rehabilitation work is needed. Analytical evaluation of performance of other district roads and village roads on the basis of the vertical subgrade strain criterion has indicated that the design curves as per IRC ; 37 are generally valid for the design traffic from 0.1 million standard axles (msa) to 2 msa. However, for design of rural roads, the design charts have to be simple and convenient for the grass-root level agencies. Road Note 29 of TRL, IRC;37 and experience in India suggests that the charts may be for the traffic in the range upto 450 CVPD. Since subgrade CBR may be as high as 20 per cent, design curves are also prepared for subgrade CBR up to 20 per cent. The minimum recommended pavement thickness is 150 mm even when design chart gives lower thickness. For rigid and semi-rigid pavements tensile stress is taken as the design criteria to prevent fracture of the concrete layer within the design period. In case of concrete block pavements, vertical subgrade stiain is the critical criterion to limit rut depth due to traffic loading.

2.1 <u>Traffic:</u>

For the purpose of structural design only the number of commercial vehicles of laden weight 3 tones or more should be considered. To obtain a realistic estimate of design traffic, due consideration should be given to the existing traffic and its rate of growth. In case of new construction, anticipated traffic, possible changes in the road network and land use of the area served as well as the probable growth of traffic over design life are to be carefully accounted for. If adequate data is not a available, an average value of 6 per cent may be adopted for traffic growth rate. The traffic study for the road may be earned out as per the IRC:9.

<u>Design life:</u>

Design life is usually defined as the number of years until the first major reconstruction is anticipated, For unsurpassed roads, aggregated are displace on either side of the wheel path and frequent blading is necessary to maintain a good riding surface. For unsealed/unsurpassed roads aggregates roads aggregates are often lost due to traffic action as well as erosion by rains, and the pavements become thinner with time. Material lost must be replenished periodically to maintain the rideability. It is necessary that sufficient thickness is provided to prevent rutting failure during the design life due to high vertical subgrade pressure. It is considered appropriate that roads in rural areas should be designed for a design life of 10 years. The thin bituminous surfacing that is commonly provided on the low volume roads has a life of about 5 years.

2.3 Computation of design traffic:

The design traffic is considered in terms of the future traffic to be carried during the design life of the road. Its computation involves estimates of the initial volume of commercial vehicles per day, traffic growth rate and design life in years. In case of rural roads the commercial vehicles will be trucks (small and big), buses and tractor- trolley. The traffic for the design life is computed as :

Where

$$\mathbf{A = P\,(1+r)^{n+x}}$$

A = Number of commercial vehicles per day for design. **P** = Number of commercial vehicles per day at last count **r** = Annual growth rate of commercial traffic
n = Number of years between the last count and the year of completion of construction
x = design life in years

Since the width of rural roads will be single lane, design traffic should be based cb total number of commercial vehicles per day in both directions. Bullock carts with iron rims are still in use in different parts of the country and the total weight including the pay load of buliock cart may range from 1.0 tonne to 1.5 tonnes. Though the designed pavements as a whole will be safe from shear failure, the iron rims damage the top layer of the pavement because of high concentration of stress. Thus the wearing course must be made up of good quality aggregates with aggregate impact value not exceeding 30 per cent to reduce degradation of the aggregates by crushing.

2.4 METHODS OF DESIGN FOR FLEXBLE PAVEMENT

Though-large numbers of methods of flexible pavement design have been proposed by different agencies, but they can be grouped into the following three broad groups:

1. **Empirical Methods**
2. **Semi theoretical Methods**
3. **Theoretical methods**

2.4.1 Empirical Methods:

In this class of methods soil strength test may or may not be carried out. In this category, group index method, California Bearing Ratio method, North Dekota Cone method etc. can be grouped.

,

(a) Group Index Method:

In this method no soil strength tests are performed, but the soil classification and past experience of pavement performance is taken into account.

(b) California bearing Ratio Method and North Dekota Cone method:

In these methods soil strength tests and past performance of pavements have been used.

2.4.2 Semi-theoretical Methods

These methods are based partly on past experience -and partly on simplified theories of stress distribution as Boussinesq analysis and Westergaard analysis methods etc. Actually Westergaard method is used for rigid pavements.

2.4.3 Theoretical methods:

These methods, are wholly based on mathematical analysis of stress and strains developed in the pavements and subgrade. Burmister analysis method falls under this category. Out of the above noted methods we shall discuss the following methods only.

(a) Group Index Method

(b) California Bearing Ratio Method

(c) Me Leod Method

(d) Westergaard method for the design of rigid pavements,

(a) Group Index Method

It is a very simple method. It was suggested by the Highway Research Board, for estimating approximate thickness of the pavement. Group Index is an empirical quantity for finding out the strength of the subgrade. The value of the Group Index can be calculated from the following equation.

$$\textbf{G.I.} = \textbf{0.2a} + \textbf{0.005ac} + \textbf{0.0Ibd} \qquad \text{... (1.3)}$$

Where,

a = that portion of material passing 75 micron sieve (0.075 mm) greater than 35 and not exceeding 75% (Expressed as a whole number from 0 to 40).

b = that portion of material passing 75 micron sieve greater than 15 and not exceeding 55%. (Expressed as a whole number from 0 to 40).

c = that value of liquid limit in excess of 40 and less than 60 (Expressed as a whole number from 0 to 20).

d = that value of plasticity index exceeding 10 and not more than. 30 (Expressed as a whole number from 0 to 20).

The higher the value of group index, the weaker and poorer is the subgrade and greater thickness of the subgrade is required for a constant value of traffic volume.

At suggested by DJ. steel, the design chart of Group Index method for finding out the thickness of the pavements, is given in Fig. 2.1 In this method the traffic is divided into three groups.

Table 2.1-1

S. No.	No. of Vehicles per day	Tra Traffic Volume (Commercial vehicles)
1.	Less than 50	Light
2.	40 - 300	Medium
3.	Over 300	Heavy

Method. The thickness of the pavement can be obtained by this method as follows: Step1. First the value of Group Index is found out by equation

G.I.= 0.2a + 0.005ac+ 0.0Ibd

Step2. Anticipated traffic is estimate and classified as light, medium, and heavy as shown in

Step3. Appropriate curve is chosen and the total thickness of pavements is calculated.
Step 4. Curve A gives the required thickness of the sub base. Curve B gives the total thickness of sub base, Base and surfacing for light traffic. Curves C and D give total thickness of pavements for medium and heavy traffic respectively- Curve E gives the additional base thickness which may be substituted for sub base of curve A (The above curves are based on Dr. Aim Singh's work).

California Bearing Ratio Method

This method was originally developed in 1928-29 by California (U.S.A.) division of highways for pavement designs. Later the original curves were modified by U.S. Corps of Engineers. The original curves developed by 0.1. Porterare shown in Fig. 2.3. CRR tests were carried out by the California State Highways Department on existing layers including subgrade, sub base, and base course. From the data collected on the existing pavements which behaved satisfactorily and as well as which failed, empirical design curves were developed correlating CBR values and pavement thickness. The original curves as shown in Fig. 2.3 were developed for 3175 kg and 5443 kg total wheel loads representing light and heavy traffic.

Later design curves for 4082 kg. wheel load were designed by interpolation.

For medium traffic.

Probably it is the most widely used method for all designs of flexible pavements. In India too, Indian Road Congress has recently finalized CBR design curves for the design of flexible pavements. These curves are similar to original curves

Procedure.

For designing a pavement, first of all, the CBR value of the soaked

material of subgrade is determined and the corresponding total thickness of the pavement required is read from the curve. The total thickness obtained is further sub divide into sub base, base and surfacing by knowing their respective CBR values. The thickness of each layer to be constructed above the particular type of material can be from the curves. It requires that each layer must be of higher quality than the layer just below it.

Regarding the use of CBR design method Indian Road Congress has made certain recommendations. Some of the important points are reproduced below from (ICR-37-1970).

1. In the laboratory CBR tests should be performed on remolded soils. For design purpose in situ tests are not recommended. Preferably specimens should be prepared by static compaction; if it is not possible dynamic compaction may be employed. Standard test procedure should be strictly adhering to.
2. For the design of new pavements, if suitable equipment is available, the subgrade soil samples should be compacted at optimum moisture content to proctor density in the field. If it is not possible the said sample may be compacted to the dry density expected to be achieved in the field. In the case of existing roads the samples of soils should be compacted to field density of subgrade soil at O.M.C. or at the field moisture.
3. For the design of new pavement construction in area of heavy rainfall, the CBR test should be performed on samples soaked in water for four days before testing. In areas where rainfall is less than 50 cms and water table is too deep to affect the subgrade adversely and when thick and impermeable bituminous surfacing is often provided, to soak the soil samples before testing for CBR is not necessary. Whenever possible the most adverse moisture conditions of the subgrade be ascertained from field studies.
4. For each type of soil at the same moisture content and density at least three soil samples should be tested. If the maximum variation in CBR values of three specimens exceed the specified limit then the average of at least six samples should be taken for the design purposes. (For CBR values upto 10, the specified limit of maximum variation is 3.0, for values upto 10 to 30, limit is 5 and for values 30 to 60, limit is 10)
5. The 50 cms thick top layer of subgrade should be compacted at least upto 95 to 100% of proctor density.
6. he estimated traffic using the pavement at the end of its expected useful life should be estimated on the basis of existing traffic and probable future increase in the traffic. The maximum life of major pavements may be taken as 10 years. For the traffic prediction following formula may be used for such major pavements:

$$\mathbf{A = P\,[1 + r]^{n + 10}}$$

Where,

A = No. of heavy vehicles (weight more than 3000 kg) per day for design.

P = No. of heavy vehicles per day on the last count.

r = Annual rate of increase of heavy vehicles.

n = No. of years between the last count and the year of completion of construction.

Note:-

1. The value of P should be calculated on the basis of 7 days average of heavy vehicles found for 24 hours count.

2. If the reliable value of growth rate factor Y is not available it may be assumed as 7 5% for roads in rural areas.

3 For design purposes the traffic is counted in terms of heavy vehicles per day-in both directions divided into seven groups A to G as shown in Fig 6.10 under curves.

4 For design purposes single axle loads are taken upto 8200 kg and tandem axle loads upto 14500 kg.

5 If the sub base course material contains substantial proportion of aggregates of size more than 20 mm the CBR value of such materials would not be valid for design of subsequent layer above them.

6 Thin layers of wearing course such as surface dressing or open graded premixed carpet upto thickness of 2.5 cms should not be counted into total thickness of the pavement as they do not contribute to the structural capacity of the pavement.

On the basis of their studies, the U.S. Corps of Engineers have shown that pavement thickness, wheel load, tyre pressure and CBR have a definite relationship with in a limit of 10 to 20% error. Thus they have suggested the following equation to find out the pavement thickness.

Where,

t = Pavements thickness in cms

P = wheel load in kg.

p = tyre pressure in kg/ cm^2

A = Area of contact in cm^2

CBR = California Bearing ratio in percent

India being an agricultural country, the bullock carts with steel tyre wheels are very commonly used as a means of transportation. The thickness of the pavement can be calculated by the curve of fig. 2.4 proposed by Mr. N. Mohan Rao. Stresses due to carts being very high in the 10 cms. Thick layer so it should comprise of very strong material.

Me Leod Method

The Canadian Department of transport conducted extensive plate bearing tests to investigate the stability of air fields and pavements under the direction of Norman
W. Me. Leod. The tests are made on surface, base course, and subgrade etc. at large number of locations. On the basis of his test results he developed a definite design method which is known as Me. Leod after his name.

Test Procedure:

The test set up consists of a set of plates of diameter 75,60, 45 and 30 cms., a loading device consisting of a reaction frame such as a truss frame, providing ring and jack, The load on the plate is exerted by the jack against the reaction of the frame. The settlement of loaded plate is measured by dial gauges attached to a datum frame resting on the ground at a distance from the loaded area. The loading arrangement is shown in Fig. 2.6. From this test the modulus of subgrade reaction is determined. The modulus of subgrade reaction may be defined as the pressure sustained per unit deformation of subgrade at specified pressure or deformation using a specified plate. It is usually denoted by the letter 'K' Usually to find out the value of ‘K’ a 75 cms. diameter plate is used shows a relationship between the diameter of the plate and the base course constant K.

Procedure.

he test site is properly leveled and prepared. The plate is placed on this leveled ground. The plates in decreasing diameter are placed one over the other. Over these plates the jack and proving ring assembly is fitted to give reaction against the frame. For the measurement of settlement, three or four dial gauges are fixed on the periphery of the plate from the separate datum frames. Now a load of 0.07 kg/ cm^2 is applied on the plates for few seconds and released. This load is known as seating load. The rate of loading should be such that the maximum load increment should not exceed 10% of the maximum wheel load, or a weight or load sufficient to cause a settlement of about 0.025 mm is applied till the rate of settlement reaches 0.05 mm per minute. At this stage the settlement by all the dial gauges is noted and average of all gauges is calculated. The load is noted from the proving ring. The procedure is repeated till the settlement reaches 0.125 cms.

Or $$\mathbf{K} = \frac{p}{0.125} \ \mathbf{kg/cm^2} \quad \text{..} \ (1.7)$$

U.S. Crops of engineers has suggested revised loading procedure which gives quick results than conventional method.

In this procedure after seating the plates, a load sufficient to pressure of 0.7 kg/cm^2 is applied on the plates in 10 seconds and held in position till the rate of settlement reaches less than 0.05mm. per minute (in case of clayey soils). At this stage the settlement reading of all dial gauges is taken and a mean settlement in cms. Is calculated, then K is given by the relation.

$$K = \frac{0.7}{\square} \quad kg/cm^2/cm \qquad ...(1.7)$$

where,

□ = average settlement in cm. corresponding to a pressure of 0.7kg/ cm^2

From the plate load test results, he derived the following relation for thickness of flexible pavement.

$$T= K \log_{10} P/S \qquad (1.8)$$

Where,

T = Required thickness of the base course in cms.

P = Gross wheel load in kg.

S = Total subgrade support in kg (for the same contact area and deflection as for load P)

Thus if the subgrade support is known from the plate test, the base course thickness can be obtained from above equation 16.8. It can be calculated for 30 cm diameter plate at 0.5 cm deflection and ten repetitions. Fig. 16.15 can be used for finding the ratio of unit subgrade support for the design wheel load diameter to that on 30 cms. diameter plate at 0.5 cms deflection.

California Resistance Value Method

F.M Hveem and R.M Carmany in 1948 provided design method based on stabilometer R-value and cohesiometer C-value. The working of the stabilometer and cohesiometer are explained in article 6.4 based on performance data, it was established by Hveem and Carmany that pavement thickness varies directly with R value and logarithm of load repetitions. It vary inversely with fifth root of C value the expression for pavement thickness is given by the empirical equation.

$$\mathbf{T = K(TI)\ (90\text{-}R)}$$

Here

T = Total thickness of pavement, cm

K = numerical constant = 0.166

CBR Method of Pavement Design by Cumulative Standard Axle Load

T = traffic index = 1.35 (EWL) $^{0.11}$ **R** = stabilometer resistance value **C** = cohesiometer value

The annual value of equivalent wheel load (EWL) here is the accumulated sum of the products of the constants and the number of axle loads. The various constants for the different number of axles in a group are given below:

Number of axles	EWL constants (yearly basis)
2	330
3	1070
4	2460
5	4620
6	3040

These contents were obtained based on the State wide load meter survey carried out in California during 1955-56. Hence if the annual average daily traffic volumes (AADT) data are available for different groups of axles, the yearly EWL is obtained by multiplying by the appropriate constant given above and taking the sum.

In the design of flexible pavements based on California Resistance value method, the following data are needed :

- **(i)** R-value of soil subgrade
- **(ii)** TI value
- **(iii)** Equivalent C-value of pavement materials

R value of soil subgrade is obtained from the test using stabilometer as explained the computation of TI value has been explained above.

The cohesiometer value C, is obtained for each layer of pavement material separately from tests. It is not possible to have a composite C-valve for the total pavement section experimentally. However the composite or equivalent C-valve of the pavement may be estimated if the thickness of each component layer and the C- value of the material of the layer is known. The method of calculating the equivalent C-value of a multilayered pavement is illustrated.

While designing a pavement as the thickness of the pavement is not known, it is easier if the pavement is first assumed to consists of any one material like gravel base course with known C-value. Subsequently the individual thickness of each layer is converted in terms of gravel equivalent by using relationship :

Where, t_1 and t_2 are the thickness values of any two pavement layers and C_1 and C_2 are their corresponding cohesiometer values.

Typical C-values for some pavement materials are given below (in metric equivalents) :

Materials	**C-value**
Soil -cement base course	120-230
Bituminous concrete	60-62
Open graded bituminous mix	22-30
Gravel base course	15

Design Procedure as per California Parameter Value

In this design method it is required to provide a pavement section which satisfies :

(i) Resistance value of sub-grade (R-value)

(ii) Expansion pressure

(iii) Exudation pressure

Laboratory tests are carried out on subgrade soil sample compacted at different moisture contents to find Hveem stabilometer R-values expansion pressure and exudation pressures. The pressure required (applied at rate of about 900 kg per minute) to force out water from a compacted subgrade soil sample is known as exudation pressure and this depends on soil type and the moisture content. As the compacting moisture content of the soil is increased, the R value, exudation and expansion pressure decreases.

In pavement design problems, first the pavement thickness required may be calculated assuming it to consist of a single layer material of known C-value such as gravel or water bound macadam (WBM) base course. Subsequently the thickness of the other component layers are chosen as per the traffic and climatic requirements and the equivalent base course layer thickness to be replaced by these pavement layers are calculated based on their C-values using Equation 7.9

Design steps

1) The pavement thickness values required as per the R-values of subgrade soil at different moisture contents are calculated (say, T_{r1} T_{r2} ....) using Equation 7.8. Here the pavement may first be assumed to consist of single base course layer of known C-value, Cg.

2) The pavement thickness values required to counteract the subgrade expansions pressure are found by diving the expansion pressure by the average density of the pavement which may be assumed as about 2.1 g/cm^2. The pavement thickness value (say Te_1, Te_2 ...) as per expansion pressures at different moisture contents are calculated.

3) The pavement thickness fulfilling both R-value and expansion pressure is found by plotting Tr values against the corresponding Te values from (i) and (ii) above, to the same scale and by drawing a 45° line so that Te=Te.

4) The exudation pressure of subgrade soil found at various compacting moisture contents are plotted against the pavement thickness found from above based on the corresponding R values. The pavement thickness corresponding to an exudation pressure of 28 kg/cm^2 is obtained from this graph, say Td.

5) The pavement thickness as per California design method is the higher of the values determined in (iii) and (iv) above.

6) The thickness of other pavement layers are decided and the equivalent values of base course thickness replaced are calculated using Eq. 7.9 with the known Cohesiometer values of the materials.

The California R-values method of pavement design is a purely empirical method and therefore the test procedure and the specifications should be strictly followed. Nomograms are also available to simplify the design calculations.

(d) Triaxial Method

L. A. Palmer and E.S. Barber in 1910 proposed the design method based on Boussinesq's displacement equation homogeneous elastic single layer :

Assuming that the pavement is incompressible, z becomes T, the thickness pavement

In the above analysis the pavement and the subgrade are assumed to have the same E-value.

Use of Triaxial Test

The triaxial compression test as explained in use of determining the values of elastic modulii for various materials. A lateral pressure of 1.4 kgicm2 is applied in the test to find the E value of the material. This lateral pressure is arbitrarily assumed as the lateral confinement in pavement layers by the Kansas State Highway Department of USA. This department employs this design equation along with empirical modifications for: (i) traffic coefficient, X and (ii) saturation coefficient, Y. These coefficients are used as multiplying factors to the total pavement thickness value which is thus modified. The pavement thickness Ts consisting of material with modulus Es is given by the

equation:

$$T_S \square \sqrt{\left(\frac{3PXY}{2\square E_s\Delta}\right)^2 - a^2}$$

Traffic coefficient (X)	ADT (number)
1/2	40-400
2/3	401-800
5/6	801-1200
1	1201-1800

7/6	1801-2700
8/6	2701-4000
9/6	4004-6000
10/6	6001-9000
11/6	9001-13,500
12/6	13501-20,000

Rainfall coefficient (Y)	**Average annual rainfall cm.**
0.5	38-50
0.6	51-64
0.7	65-76
0.8	77-90
0.9	91-100
1.0	101-127

The recommended values of coefficients X and Y based on ADT of design traffic and rainfall are given below :

If pavement and subgrade are considered as a two layer system, a Stiffness factor has to be introduced to take into account the different values of modules of elasticity of the two layers. The pavement thickness is then modified using the stiffness factor equal to $(E_s/ E_p)^{1/3}$ where E_s and E_p are values of modulus of elasticity of the subgrade and pavement, respectively. Thus the thickness of pavement, Tp is calculated from the relation :

The thickness design above equation is based on elastic theory. However the modified equations taking into account the traffic and rainfall coefficients and stiffness factor (Above Equations) are empirical modifications. The relation between pavement layers of thickness t_1 and t_2 of elastic modulus E_1 and E_2 is given by :

Thus the Kanas Highway Department design method may be categorized as semi theoretical method, using triaxial test results.

(e) <u>Burmister's (Layered System) Method</u>

Donald M. Burmister developed the layered system analysis. As known the flexible pavement sections are composed of layers and the elastic modulus of the top layer is the highest. The total mass of pavement and subgrade does not possess a constant E value as assumed by Boussinesq in his analysis. However, Boussineq's analysis can be considered as aspeciai case of Burmister's layered system analysis. if layers of soil subgrade, sub-base course are assigned elastic modulii of E_S E_{sb}, E_b then as per Boussineq's analysis, it is considered $E_s = E_{sb} - E_b$ whereas in layered analysis, it is taken that $E_b > E_{sb} > E_s$ The effectiveness of the reinforcing action of the pavement layers is logically utilized in Burmister's approach. Following are the assumptions made in this approach :

the materials, in the pavement layers are isotropic, homogeneous and elastic. The pavement forms a stoiffer reinforcing layer having modulus of elasticity higher than that of the underlying subgrade in the two layer system.

he surface layer is infinite in horizontal direction and finite in vertical direction ; the underlying layer in two layered system is considered infinite in both directions. The layers are in continuous contact ; the top layer is free of shearing and normal stresses outside the loaded area. Provides the comparison of vertical stress distribution between Bousstneq's single layer system and Burmister's two layer system, assuming the pavement to consist of a single layer having elastic modulus E_p lying over subgrade with elastic modulus E_s

It is observed from this figure that the verticai stress on the subgrade is reduced from 70 to 30 percent by introducing a pavement layer of thickness equal to the radius of the load or h = a, having elastic modulus 10 times higher than the elastic modulus of subgrade soil i.e, for $E_p / E_s = 10$.

The Burmister's approach therefore utilizes the reinforcing action of the pavement layer.

The deflection factor F_2 is introduced in two layered system which is dependent on E_s / E_p and h/a.

The relationship between two layer deflection factor f_2 and pavement thickness in terms of radius a of loaded area and ratios E_s / E_p is given-

The displacement equations given by Burmister Equations are written here: For flexible plate,

For single layer, h = 0, and $E_s / E_p = 1$ therefore F_2 «i and these reduce to Boussinesq's settlement equations. See Figure 2.9. In the derivations of displacement equations the Poisson's ratio u is taken as 0.5 both for subgrade and pavement material,

The above analysis is adopted by U.S Navy Department for design of air field pavements. It is considered that the layered system analysis can also be applied for design of highway pavements. Following assumptions can be suitable made. The plate diameter for load tests may be taken as 30 cm and design deflection may be taken as 0.5 or 0.25 cm.

Chapter 3

QUALITY CONTROL AND ASSURANCE

QUALITY ASSURANCE

A three-tier quality management mechanism has been operationalized under PMGSY for ensuring that the quality of assets created conform to the prescribed standards. The first tier of quality management mechanism is in- house quality control at the level of the executing agencies whereas the second tier provides for quality monitoring through independent State Quality Monitors (SQM). Monitoring by independent National Quality Monitors (NQM) constitutes the third tier of this arrangement. Under this arrangement, it is the responsibility of the State Government to operationalize the first and the second tiers of the quality management structure.

It is proposed to widen the scope of quality control by including the principles of Quality Assurance laid down by the Indian Roads Congress in their guidelines on quality systems for roads (IRC:SP:57-2000) and for bridges (IRC:SP:47-1998). A Total Quality Management approach is envisaged. The concept of Total Quality Management (TQM) as defined by ISO reads as "TQM is a management approach of an Organisation, centered on Quality, based on participation of all its members and aiming at long term

success through customer satisfaction, and benefits to all the members of the Organisation and the Society". In fact the TQM is a management strategy aimed at embedding awareness of Quality in all organisational processes. The TQM concept in the context of Rural Roads suggests that quality has to be seen as the basic policy starting from conception till the operation and management of Rural Road assets. The objective of the PMGSY is to provide "Good All Weather Roads" and the implementation

strategies of the programme are therefore, centered on the word 'Quality'.

Class of Quality Assurance (QA) for Rural Roads:

Four classes of Quality Assurance are prescribed as under: For rural roads, Class Q 2 may be adopted. However, for a particular project or even for particular activities, decision regarding up gradation of QA class could be taken by the Project Implementation Unit keeping in view the level of quality and the level of control expected beyond Class Q 2. The quality assurance requirements in respect of materials and workmanship to be achieved during execution are described against each item of road and bridge work in relevant Sections

3 For day-to-day reference of the Engineers in the field and the Contractors engaged in construction of rural roads, this Handbook on Quality Assurance has been prepared drawing heavily on the following sources:

(i) Specifications for Rural Roads, MoRD (2004).
(ii) Rural Roads Manual IRC:SP:20-2002.
(iii) Handbook on Quality Control: Road Works NRRDA (2002).
(iv) Hill Road Manual: IRC:SP:48-1998.

The frequency of tests has been further rationalized and NRRDA will bring out the necessary modifications in MoRD Specifications for Rural Roads. The quality control requirements prescribed in the Book will be mandatory for all PMGSY works. This book would also serve as a useful reference to the State Technical Agencies, State-level Quality Control Units, and National Quality Monitors.

3. QUALITY CONTROL

The Quality Control on Rural Roads and Cross-Drainage Works shall be exercised as follows:

Quality Control Tests on Materials before incorporation in the Works: Quality Assurance Class

1. Nominal QA Q 1
2. Normal QA Q 2
3. High QA Q 3
4. Extra High QA Q 4

All materials before incorporation in the work shall be tested by the Contractor for the tests indicated under 'Tests to be carried out Prior to Construction'. The tests shall be carried out from each source identified by the Contractor. The test samples shall be representative of the material available from the source. Any change/variation in the quality of material with depth of strata shall be reported. Important tests like the Moisture-Density relationship (Proctor Compaction), Aggregate
Impact Value, Plasticity Index, CBR and any other tests specified by the Engineer shall invariably be carried out in the presence of a representative of the Engineer, who will not be below the rank of Junior Engineer. The test results shall form the basis for approval of the source and the material for incorporation in the work and shall be approved by the Engineer. For manufactured items, however, such as concrete pipes, elastomeric bearings etc, a test certificate obtained by the Manufacturer from an approved Test House shall be accepted.

(i) <u>Quality Control Tests During Construction:</u>

During execution of the work, quality control for workmanship and ensuring conformance to specifications shall be exercised on the basis of the tests indicated under 'Field Quality Control Tests During Construction'. The tests shall be carried out by the Contractor independently or in the presence of Employer's representative, normally a Junior Engineer, when available at site or
where association of the Employer's representative in test is prescribed. The Junior Engineer shall record the results in his own handwriting. The Contractor shall be fully responsible for all the tests carried out for the work. The Assistant Engineer/Executive Engineer during their site visits shall have a few tests carried out in their presence and sign the Quality Control Register.

(ii) Stage Passing:

Supervisory officers of the level of AE and EE shall exercise quality control checks and certify the work of various stages on the basis of tests and their frequencies indicated under 'Quality Control Checks'. The officer certifying the work at various stages as prescribed shall be responsible for the quality and quantity of the work certified by him.

(iii) Procedure to form part of the Contract:

The prescribed tests, frequencies and the procedure for stage passing by Supervisory Officers shall be mandatory and shall form part of the Contract.

Random Checks

Where random checking has been recommended, the procedure to be adopted for random checking shall be as follows:

(i) The complete section to be checked shall be divided into ten sub sections of equal length viz. 0-100m, 100-200 m, 200-300 m. Of these, only two sub-sections shall be selected for carrying out tests by draw of lots.

(ii) Longitudinal profile shall be tested by a 3 m straight edge in a stretch of atleast 9 m length.

(iii) Transverse profile viz. camber/crossfall/ super elevation shall be tested using camber templates at two or three locations for each 100 m length.

(iv) Temperature measurement shall be done by metallic contact thermometer with digital display.

Simple/Hand-Feel Tests

For monitoring the quality of work, generally it may not be possible to carry out the detailed quality control tests and therefore, for the purpose of quality monitoring simple/handfeel tests can be performed.

Normally various simple tests have been used by the experienced practicing engineers in the field to make a quick assessment of the quality of the product. However, these procedures have not been standardized and involve human judgement. Therefore, these tests which provide useful guidance for supervisory officers during inspections, should by no means be used as a replacement of the specified quality control tests.

COVERAGE :

The Topic is divided into two volumes:

I: Quality Management System and Quality Control Requirements II: Equipment and Test Procedures

The Volume I covers quality management system and describes in detail quality control of works by Field Units and supervisory staff and quality monitoring by National/State Quality monitors for various activities of construction and maintenance of rural roads. The Sections in this Volume correspond to the Sections of the Specifications for Rural Roads of the Ministry of Rural Development, Government of India.

The Volume II covers laboratory set up, equipment and test procedures for various quality control tests.

Flow Chart:

A typical flow chart for quality assurance checks during the construction of rural roads is given as an ON THE FLOW NET SHOWN BELOW.

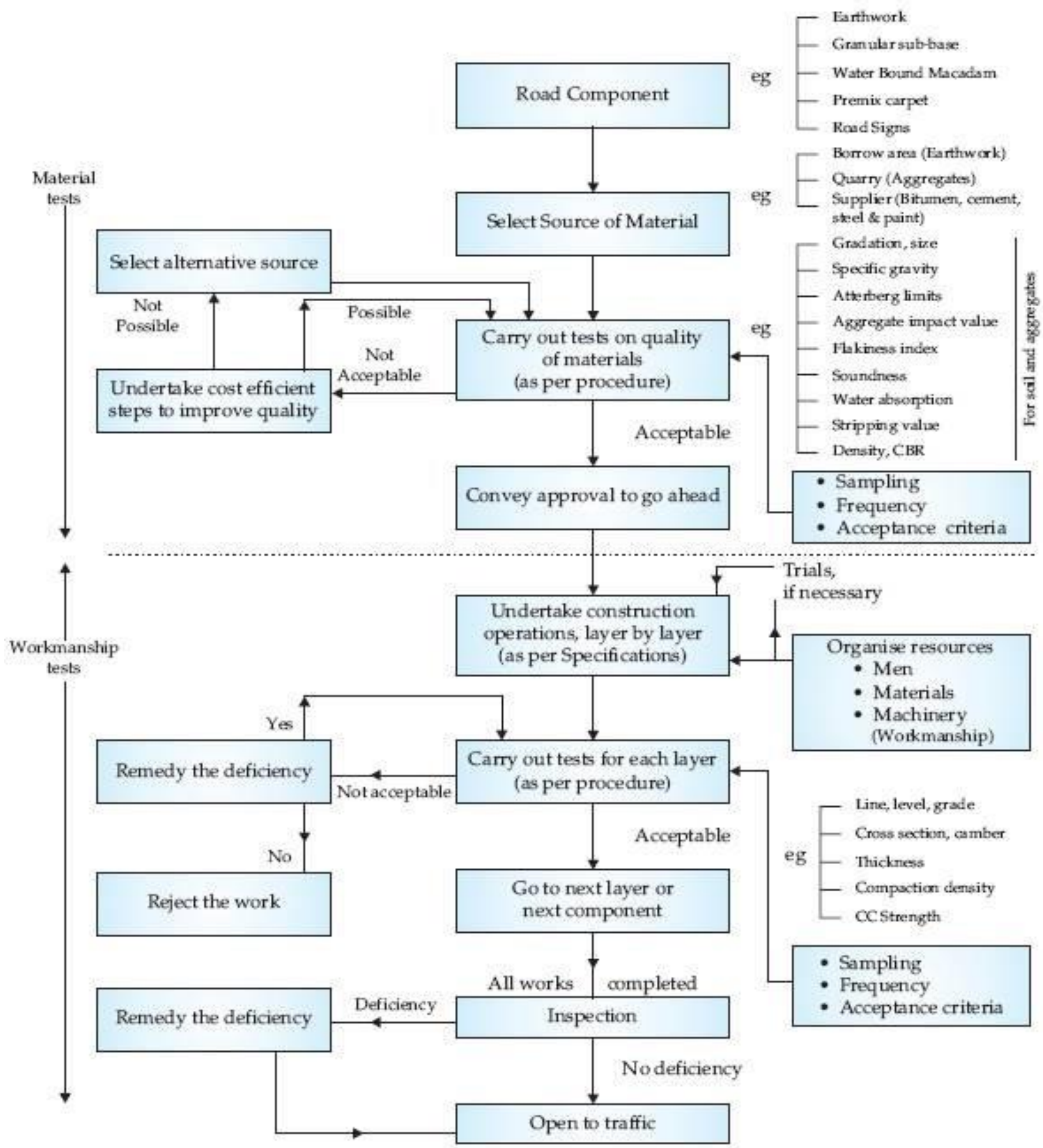


Figure 1.1: Typical Flow Chart for Quality in Road Works

QUALITY MANAGEMENT SYSTEM

Rural Road Projects are often very small in size and widely scattered in remote areas with very limited basic facilities like ready availability of electric supply, drinking water and road access to heavy plant/ equipment etc. The material specifications generally incorporate the use of a wide variety of low cost locally available materials. The speed of construction is relatively slow and the available resources as well as skills with small contractors are at a relatively lower level.

It is, therefore, necessary that while developing a suitable Quality Management System for both construction and maintenance work, such constraints are kept in view. The types of quality control tests and their frequency have also to be judiciously selected so as to be achievable under the prevailing conditions.

Keeping the above factors in mind, a three tier quality management system together with a simplified practical approach to Quality Assurance in Rural Road works is prescribed as detailed in subsequent paragraphs.

THREE TIER SET UP FOR QUALITY MANAGEMENT SYSTEM

The three tier quality management mechanism comprises:

(a) **First Tier:** In-house quality control by the executing agency

(b) **Second Tier:** Independent quality control set up of the State Rural Roads Development Agency.

(c) **Third Tier:** National Quality Monitoring system as operationalised by NRRDA for PMGSY. Thesecond and third tier will not be connected with the Project Implementation Unit (PIU).

FIRST TIER

1. The PIU is envisaged as a first tier of quality management with the primary function of construction supervision and quality control. The quality management functions of the PIU shall include the following:

(i) Preparation of realistic detailed project report (DPR) with adequate attention to investigations and pre-construction activities which are essential for proper design and estimation of the project following MoRD Specifications for Rural Roads, Rural Roads Manual and other relevant IRC specifications.

(ii) Preparation of bid documents and effective selection process for procurement of works, based on proven capacity and ability of the contractors.

(iii) Ensuring that:

(a) Contractors have brought the necessary machinery and equipment to site.

(b) Field laboratory has been established.

(c) Key engineering personnel have been deployed by the Contractor and

(d) The work programme has been approved.

(iv) Supervising Site Quality Control arrangements including materials and workmanship,

primarily through testing as per provisions of the Quality Assurance Handbook.

(v) The following frequency of inspection visits to site by PIU staff is recommended while the work is in progress:

(a) Junior Engineer – Daily

(b) Assistant Engineer – Twice a week

(c) Executive Engineer – Once a week

(vi) Taking timely action to ensure replacement of defective material and rectification of defective workmanship.

1 To ensure effective Quality Control on materials and workmanship,

2 A monthly return of the tests shall be submitted in the prescribed proforma by the AE to the EE in the first week of every month. The EE will review this return regularly to see that the Quality Control tests are being performed at the desired frequency and with the desired accuracy. The EE will also verify that the Non Conformance Reports (NCR) are being issued by the AE whenever nonconformance

occurs and the Contractor is taking action promptly on the NCR. Payment to the Contractor shall be regulated by the EE as per the returns of the Quality Control tests. Any deviation will be the personal responsibility of the EE.

3 The SE in charge of the circle and the Chief Engineer having jurisdiction are responsible for the proper functioning of the PIU as part of their normal administrative duties. Their inspection and quality testing supervision will therefore be counted as part of effective supervision of the first tier of quality management (and not as a second tier of quality management). The SE/CE shall:

(i) During his visits to the work, oversee the operations of the quality control testing procedure and record his observations in the Quality Control Register. The SE/CE will also verify that the Non-Conformance Reports are issued in time and action is being taken by Contractor promptly.

(ii) Prepare Inspection Reports which shall be sent to the PIU for taking remedial action.

The State Govt. /State Rural Roads Development Agency shall prescribe frequency of inspections by various officers and formats for furnishing inspection reports by SE/CE.

SECOND TIER

1. The first tier of quality management has the primary function of quality control through enforcement of technical standards and quality control requirements through regular testing, close

supervision and inspection. Function of the second tier of independent quality management is to ensure that the Quality Management System at the site is functioning satisfactorily and suggest possible improvements where required. For this, they may be required to carry out and report:

(a) Independent quality tests to verify that the quality management system achieving its intended objectives.

(b) Systemic flaws in the quality control process and action to improve the process.

2. The role of second tier in monitoring the quality of the work is of crucial importance during construction stage and therefore the State Quality Monitors are required to carry out inspections at appropriate stages of work under progress.

3. The independent Quality Management Division of the executing agency may function as the second tier. The State Rural Roads Development Agency will frame suitable guidelines for proper functioning of second tier.

THIRD TIER

The National Rural Roads Development Agency shall prescribe the guidelines for the third tier from time to time. The objective of this third tier of quality mechanism is to monitor the quality of road works executed by the States with a view to ensuring that the road works under the programme conform to standards and to see whether the quality management mechanism in the State is effective. The role of this tier is to provide guidance to State implementation machinery and the field engineers rather than 'fault finding'. As such, the shortcomings are identified by the third tier and a feedback is provided to the States for improvement.

QUALITY CONTROL

The requirement of a quality control organization will vary for different projects depending on departmental set-up and also size of the project. The minimum suggested organization of quality control laboratory set-up at Field, District and Central level shall be as follows:

Field Laboratory

The Contractor shall be responsible to set up and maintain an adequately equipped Field Laboratory for routine tests for quality control required to be conducted on a day to day basis. The Field Laboratory will have normally those test equipment that do not require electric power supply and are relevant to the project specifications. Field Laboratory will be manned by suitably trained personnel in material testing and quality control works.

District Laboratory

The tests which are required to be done during the project preparation stage such as those pertaining to suitability of construction materials, selection of quarries etc. to be carried out before incorporation in the work as part of quality control or the tests which cannot be carried out in the Field Laboratory shall be conducted in the District Laboratory. The District Laboratory will cover the testing requirements for the entire District. Such a Laboratory shall be equipped with facilities for most of the tests, including those required for DPR preparation.

A typical set up of a District Laboratory is given in fig. 2.1.

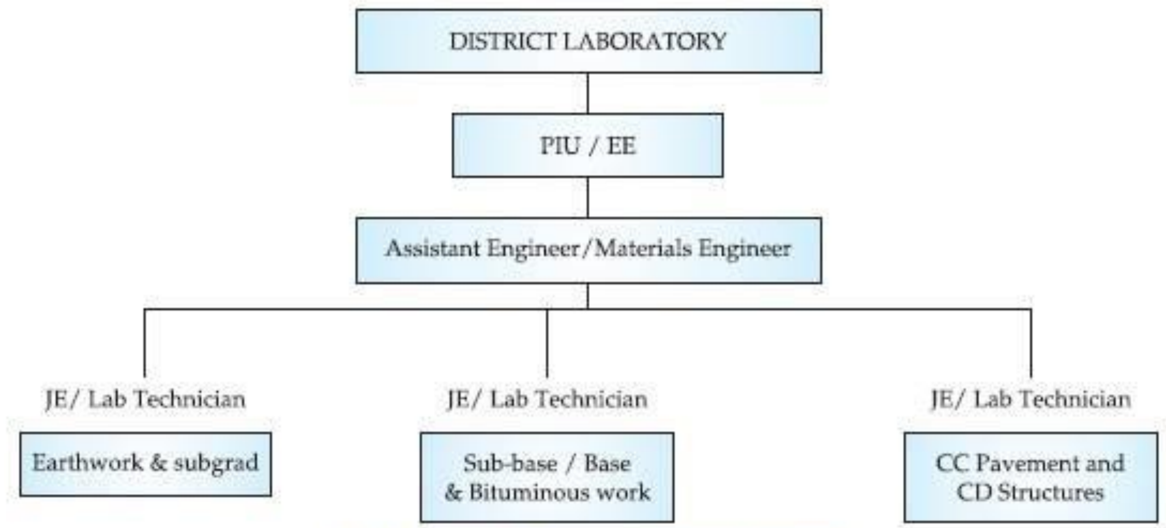


Fig. 2.1 Typical set up of a District Laboratory

Central Laboratory

Tests requiring high level of skills and sophisticated equipment as also for the other quality tests will be carried out at the Central Laboratory under the control of the Chief Engineer or In-charge Quality Control, State Rural Roads Development Agency preferably at the State Headquarters. Any special or sophisticated tests, for which the necessary equipment and expertise are not available in the Central Laboratory, shall be outsourced, to approved National Accreditation Board for Laboratories (NABL) accredited Test houses or Higher Technical (academic) Institutes or Research Laboratories.

SPECIFICATIONS AND CODES OF PRACTICE

The specifications and codes of practice laid down by Ministry of Rural Development, Indian Roads Congress and Bureau of Indian Standards are required to be followed in construction of rural roads.

LABORATORY AND EQUIPMENT

The equipment requirement for quality control tests for Field, District and Central Laboratories are given in Section100 of Volume II

Quality Assurance :

CONSTRUCTION EQUIPMENT

1. For ensuring quality of work, an appropriate technology must be adopted. In the context of rural roads, an appropriate technology implies an optimum blend of manual methods and mechanical equipment of adequate capacity which may also involve use of agricultural implements towed by tractor. Guidelines for choosing appropriate equipment and technologyfor rural roads
2. Ensure that the equipment deployed is appropriate to the work and is properly operated and maintained.
3. Arrange a trial run of the equipment before commencement of the work.
4. Ensure that no equipment is deployed at or removed from the site of work without prior approval of the employer.

SETTING OUT

Methodology

1. Establish working bench marks at 250 m intervals and also at or near all drainage structures and bridges on the road. All the bench marks should be tied with the Reference Bench Mark in the area.

2. In hilly areas, reference pillars handed over by the Engineer to the Contractor shall work as bench marks.

3. Establish centre line of the carriageway and have it referenced by marker pegs and chainage boards set near the road land boundary at 50 m intervals for roads in plain and rolling terrains. For roads in hilly areas and on curves in plains, the interval of reference pegs should be 20 m. For sharp curves, the interval should be 10 m and for hair pin bends the interval should be 5 m.

4. For hill roads, the valley side top edge of reference pillar shall be at ground level. The top levels of reference pillars should be tied with the level of Bench Mark adopted in the DPR.

5. For hill roads, back cutting line shall be demarcated on the hill face by digging, taking into account the designed slope of hill cutting. Back pillars showing the requisite information should be located at about 1.5 m away (towards hill side) from the back cutting line. Alternatively, back pillars can also be fixed on any permanent existing structures in difficult terrain. Check distance of back cutting line from reference pegs.

6. Prepare a schedule of reference dimensions and maintain the markers/ reference pillars until the works reach finished formation level and are accepted by the Engineer.

7. Verify the dimensions and levels, shown on the drawings or mentioned in contract documents, on the site and inform the Engineer of any apparent errors or discrepancies.

8. The lines and levels of formation, side slopes, drainage works, carriageway and shoulders should be carefully set out and frequently checked, care being taken to ensure that correct gradients and cross-sections are obtained everywhere.

9. The plan dimensions of the foundations for culverts shall be set out at the bottom of foundation trench and checked with reference to original line of reference and axis.

Quality Control Requirements

1. **Horizontal Alignment**

Horizontal alignment shall be reckoned with respect to the centre line of the carriageway

2. The permitted tolerances are Taken.

Alignment Plain and Rolling Terrain Hilly Terrain

Edges of carriageway ± 20 mm ± 30 mm

Edges of roadway and / lower layers of pavement ± 30 mm ± 50 mm

PUBLIC UTILITIES AND ENVIRONMENT

Methodology

1. Verify at site, public utilities like water pipes, sewers, electric lines, telephone cables etc.

included in contract documents.

2. Arrange for regular meetings with various agencies owning utilities at the commencement and throughout the duration of the works.

3. Temporarily support the utilities affected by the works.

4. Assist agencies owning the utilities in carrying out the works with approval of the Engineer.

5. Abide by all laws, rules and regulations in force governing pollution and environment and wild life protection, applicable in the area.

6. Obtain approval of concerned authorities for obtaining materials from quarries and for locating plant and equipment.

Do's

1. Check whether Reference benchmark is indicated on the drawings.
2. Regularly check the working bench marks as work proceeds.
3. Arrange safety of survey bench marks, monuments, beacons etc. and reference pillars in hilly areas
4. Check layout of Curves.
5. Supply a copy of survey file containing the necessary data to the Engineer for his record.

Don'ts

1. Don't commence work until the initial center line isestablished by marker pegs and cross sections atspecified intervals have been approved by the Engineer.
2. Do not remove reference pegs, pillars or markers without approval of the Engineer.

Quality Assurance

Do's

1. Protect utility services during construction period.
2. Control soil erosion, sedimentation and reduce levels of noise, vibration, dust and emissions from construction plant and equipment.
3. Keep the roadside and surroundings clean and free from dust, mud or other extraneous material.

4. Cut material should be disposed of at predetermined dumping places.

Don’ts

1. Do not carry out any clearance or alterations to any utility unless especially ordered by the Engineer.

2. Do not cause any damage to public utilities.
3. Do not pollute natural water-courses, pools, tanks and reservoirs.
4. Do not use hazardous materials without providing protective clothing, masks, shoes etc. to the workers.

METHODOLOGY AND SEQUENCE OF WORK

Methodology

Ensure that a detailed construction methodology is submitted by the Contractor prior to start of the construction activities in accordance with the Contract Agreement. The construction methodology will include:-

(i) Mechanical Equipment proposed to be used.

(ii) Sequence of various activities and schedule from start to end of the project. Programme relating to pavement and shoulder construction shall be an integrated activity to be done simultaneously in a coordinated manner. The methodology and sequence shall be so planned as to provide proper safety, drainage and smooth movement of traffic.

Chapter 4

Design of Pavement & Analysis of Rates

Design of Pavement & Analysis of Rates

3.0 Design of Flexible Pavement

Pavement thickness: The thickness of pavement is designed on the basis of projected number of commercial vehicles for the design life using the current commercial vehicles per day and its growth rate. Further it requires the subgrade strength value in terms of CBR. it is expected that rural road will not have more than 450 CVPD in any case. The design chart given in Fig. 3.1 may be referred to obtain the total pavement crust thickness (granular crust thickness) required over the subgrade for the design life of the pavement. Based on the strength of granular materials that are used, the total design thickness is divided into base and sub-base thicknesses. However, any other higher type of bituminous layer can be part of the designed thickness. With the exception of thin bituminous surfacing (PMC, MSS, etc) In case of rural roads, with low volume of traffic, structural layer of bituminous mix need not be provided, generally except in very special cases where the traffic volume is so high that the design suggests it.

For the convenience of engineers the whole range of traffic and CBR that exist for rural roads in various States of the country have been considered and flexible pavement thickness catalogues are given in Fig. 3.2.

Surfacing: A gravel road or WBM layer can serve adequately as surfacing depending on traffic volume. However, it is to be clearly understood that granular materials (like, soil gravel mixture) will be lost gradually be traffic action and thickness will be reduced. There fore, for gravel roads extra thickness should be provided. Further, for similar reasons, only WBM Grade-Ill should be used as a surfacing course for an unsealed WBM road. Other granular surfacing, like moorum, Kankar, etc. will have to be bladed as and when required to provide smooth riding surface.

CBR Method of Pavement Design by Cumulative Standard Axle Load

The Indian Roads Congress vide IRC: 37-1984 has revised the guidelines for the design of Flexible Pavements, based on the concept of Cumulative Standard Axle Loads father than the total number of all commercial vehicles as done earlier. In the case of roads with design traffic more than 1500 commercial vehicle per day, the design traffic is defined in terms of the cumulative number of standard axle loads of 8160kg carried during the design life of the road. The mixed commercial vehicles with different axle loads are to be converted in terms of the cumulative number of standard axle load, N_s to cater for the design, using the equation:

$$N_s = \frac{365A\left[(1+r)^n - 1\right]}{r} \times F$$

Where

A = Number of commercial vehicles per day when construction is completed, considering the number of lanes.

R = Annual growth rate of commercial vehicles

N = Design life of pavement, taken as 10 to 15 years

F = Vehicle damage factor, equivalent to number of standard axles per commercial vehicle on the road stretch. This is a factor converting the number of commercial vehicles of different axle loads to the number of standard axle load repetitions.

The total pavement thickness required is determined using the design chart given in Fig. 7.15, with the value of N_s in million standard axles (msa) determined as mentioned above and the CBR value of subgrade soil determined in the laboratory. The IRC has also suggested the minimum thickness of the pavement component layers of sub-base course and surfacing and the combinations for various ranges of cumulative standard axles. For example for the range of 20 to 30 msa, the sub-base course material should have CBR value of at least 30% and the minimum compacted thickness of this component should be 390 to 405 mm, the base course should have a minimum compacted thickness of 250 mm and surfacing should consist of 100 to 15 mm dense bituminous macadam and 40 mm asphaltic concrete.

The method revised by LR.C. in the C.B.R. method is briefly explained below.

S. No.	Layer	Thickness in (mm.)
1-	G1	100
2-	G2	75+75 = 150
3-	G3	75
4-	P1	-
5-	P2	-

(3.2) Computation of Design Traffic-As per IRC 37-2001

$$N = \frac{365 \times \left[(i+r)^n - 1\right]}{r} \times A \times D \times F$$

Where

N = Cumulative numbers of standard order to be catered for in the design in terms of msa.

A = In initial traffic in the-year of completion of construction in terms of the number of commercial vehicle per day = 1148

D = Lane Distribution Factor = 0.75 for two lane. F = Vehicle damage Factor - 4.5 for rolling plane n = Design life in year = 10 year

r =Annual growth rate of commercial vehicle i.e. r = 0.075 Where A =P (i + r)^x

P =Number of Commercial Vehicles as per last cont = 25

X= Number of years between last count and the year of completion

Hence

A = **25 (1 + 0.075)^1**

= **27**

$$N = \frac{365 \times \left[(1+0.75)^{10} - 1\right] \times 27 \times 0.75 \times .45}{0.075}$$

N = 0.47 X msa

As per IRC-37-2OO1 Total Crust required is 325mm. Hence providing 3 coats of 320 mm thick of W.B.M. surface, Ist & IInd Coat bituminous surface will be providing over W.B.M. surface as per design.

GEOMETRIC DESIGN STANDARDS

Following Salient Features have been adopted during design of Various geometric features as per IRC-SP-20-2002

SI.No.	Description		Adopted Standards
1	Terrain	Plain	0-10% Cross Slope
2	Design Speed	Ruling Minimum	50 Km./Hrs. 40 Km./Hrs.
3	Land Width	Open Area Built up Area	10.00 m / 12.00 m 6.00 m
4	Minimum Roadway Width at CWD Drainage structure for culverts upto 6.00 Mtr. Span	-	7.50 M for new culverts
5	Carriage Way Width	-	3.75 m/3.00 m
6	Pavement Camber	Thin Bitumen Surfacing Earthern Shoulder s	3.50% 4.00%

7	Design Traffic & Capacity	Single lane road having 3.75, 3.00 m wide carriage way with normal earthern shoulders	150 commercial verhicle per day
8	Design Life		10 Years
9	Traffic Growth	-	6.00%
10	Minimum Radius for Horizontal Curve	Ruling Minimum Absolute Minimum Adopted Minimum	90 m 60 m As per Actual Site

ITEMWISE MEASUREMENT OF SHEDULED WORK

Widening and strengthening of Bhatni to lalganj Via Rampur, Dharupur, Purwara (ODR in District Pratapgarh, UttarPradesh under C.R.F.

S.NO	Item Of Work	Unit	Quantity

1	Eartwork in trenches for widening of existing road in ordinary soil including lift upto 1.50 mtr & lead upto 30 mtr & also including remaining dressing the surface to required level	CUM	2,634
2	Earthwork in embankment in ordinary soil mechanically compacted to 95% proctor – density including hire & fuel charges of roller, tractor tanker & sprinklers etc. with their drivers/ Operators.	CUM	6,875
3	Providing laying and spreading of granular Sub- base by providing coarse graded material from approved quarry mixing in a mechanical Mix plant at OMC, carriage of mixed material to work site, spreading in uniform layers with motor grader on prepared surface and compacting with vibratory power roller to achieve the desire density	CUM	2,258
4	Scraping old painted surface including disposal of all scraped material to distance of 30 mtrs.	SQM	6,300
5	Providing, laying spreading and compacting graded stone aggregate from data quarry to wet macadam specification including premixing the material with water material by tipper to site, laying in uniform layers with paver.	CU M	551 3
6	Providing & applying primer coat with bitumen emulsion on prepared surface of granular base including cleaning of road surface and spraying primer at the rate of 0.75 KG/ Sqm using mechanical means	SQ M	245 00

7 .	Providing and applying tack coat with bitumen emission using emulsion pressure distributor at the rate of 0.25 KG per SQM on the prepared bitumen surface cleaned with mechanical broom	SQ M	243 75

S.NO	Item Of Work	Unit	Quantity
8	Providing and laying 50mm bituminous macadam with 100-120 TPH Hot mix plant producing an average output of 75 tones per hour using crushed aggregates of specified grading premised with 60/70 grade bitumen use binder @ 3.30% of the mix transported to site, laid over a previously prepared surface with paver finisher to the required grade level and alignment rolled.	CUM	1225
9	Providing and laying semi-dense bituminous concrete 25 mm thick with 100-120 TPH batch type H.M.P. producing and average output of 75 tone per hour using crushed aggregates of specified grading premix with bituminous binder grade CRMB_55@5.00 percent of mix and filler transporting the hot hot mix to work site laying with a hydrostatic paver finisher with sensor control to the required grade, level and alignment, rolling with smooth wheeled vibratory and tandem rollers to achieve the desired compaction including All material labour T & P, taxes to com plate the work as	CUM	613
	per M.O.R.T & H Specification clause 508 complete in all respects including cost of bitumen		
1 0	Brick edging on both sides of the road (in missing portions) of class 150 bricks laid on edge with with mud mortar including labour and supply of brocks, finished to the required template and in proper alignment and also including dressing and ramming the excavated earth as directed by the Engineer charge. (S.I. 765)	R M	1 6

11	Brick on edge pavement on parties with bricks laid dry joint filled with local sand including preparation of base to proper slope and its ramming the subgrade and including supply of all materials, labour and t & P etc. required for proper completion of the work. S.I. 763 in abadi portion	SQM	1050.00
12	Earth work in raising patri on both side of road in ordinary soil to be in 20 CM layer including 1.5 m lift and 30 lead dressing, ramming etc	CUM	5630.00
	Part- (B) Widening of NP3 Hume Pipe Culvert		
13	Earth work in excavation in trenches for foundations pipe, cable etc. in ordinary soil (loan clay or sand) including lift upto 1.5m lead upto 50m and dressing of sides and remaining of bottom and disposal of surplus excavated earth as directed by E/I	CUM,	70
14	Providing and laying cement concrete (1 cement :5 fine sand : 10 graded stone aggregate 40 mm. nominal size) and curing .	CUM	43
15	Providing, Laying & Joining Of Hume Pipe Np3 And Coller With 1:2 Cement And Sand Mortar.,		
	600 mm dia NP3 Hume pipe	RM	25
	1000 mm dia NP3 Pipe	RM	19
16	Class 150 B.W with 1:4 cement & tine sand mortor in foundation and plinth including supply all materials, labour and T & P and taxes etc. required for proper completion of the work. SI 309+310	CUM	169
17	Struck pointing on brick work in 2:1 cement portar (1cement & 2 fine sand) including supply all materials, labour and t & P and taxes etc. required for	SQM	313

	proper completion of the work. S.I. 17.116		
1 8	15mm cement plaster on brick work for making coping plate in 1:4 cement sand mortar	S Q M	1 3
	Construction of U-Shaped Drain work		
1 9	Earth in excavation in trenches for foundation in ordinary soil including lift upto 1:5m lead upto 50 m. and dressing of sides and reaming of bottom and disposal of surplus excavated earth as directed by the engineer-in-charge within a distance of 50m. SI 251	C U M	6 4 5
2 0	Providing and laying in cement concrete 1:4:8 (1 cement:4 fine sand:8 graded stone ballast 40 mm nominal size) and curing complete including supply ass materials, labour and T & P and taxes etc Required for proper completion of the work .	C U M	1 3 0
2 1	Class 150 B.W. with 1:4 cement & coarse sand mortor in foundation and plinth	C U M	4 2 8
2 2	15 mm cement plaster on brick work for making coping plate in 1:4 cement sand mortar	S Q M	3 9 0

Chapter 5

Result And Dissicussions

A O.D.R. 3.00m widening & strengthening to **BHATNI to LALGANG VIA RAMPUR DHARUPUR PURUARA DISTRICT PRATAPGARH U.P.** under C.R.F. under **Superintending Engineer Pratapgarh Fathepur circle PWD Pratapgarh**. Bond No.: - 07/Sep./F circle/08-09 through the contractor M/S Abhyudaya housing & Const. P. Ltd. Shriram Tower Lucknow. 0-3.490 Km long connecting the village to a state highway is proposed to be metaled with bituminous concrete by wet mix macadam (W.M.M.) method, design the road pavement using following data.

Geometrical parameters of road.

The road consists of one turn of 30^0 as shown in the plan.

The radius of the horizontal curves of 30^0 are 100 m each 60 m each [R=100m, R_1=60m]

The value of camber for the road is 2.5%, side slope is 3.5% and Vertical Cut ½.

The width of pavement or carriage way is 5.50 m and land width is 8.50m

Traffic Data

Fast moving vehicle				Agricultural Tractor				Buses		Lorries Truck				Total Commercial Vehicle per day	Slow moving vehicle								
Motor cycle		Cars and vans		Loaded		Unloaded				Loaded		Unloaded			Cycle		Cycle Rickshaw		Bullock carts Front ground		Bullock carts	Bullock Carts	
Up	Down	Up	Down	Up	Down	Up	Down	Up	Down	Up	Down	Up	Down		Up	Down	Up	Down	Up	Down	Up	Down	
25	11	7	10	9	10	7	7	1	1	1	2	1	2	25	28	16	7	10	6	5	14	11	36

Classification test of the sub grade soil.

S. No.	Identification Of sample	Grain size analysis % passing by weight	Atter berg's limits	Is classification

	chainage	4.75mm	0.75mm	0.002mm	LL%	PL%	P1%	ML-CL
1	0.500	100	69.8	0.00	27.00	23	5.00	CL
2	1.000	100	60.5	6.2	32.00	23	10.00	CL
3	1.500	100	65.2	6.8	32.5	23	9.50	CL
4	2.000	100	60.2	8.2	33.5	23	10.50	CL
5	2.500	100	60.5	6.2	32.00	23	10.00	CL
6	3.000	100	65.5	6.8	32.5	23	9.50	CL
7	3.500	100	60.2	8.2	33.5	23	10.50	CL
8	3.810	100	64.2	8.1	32.9	23	9.8	CL

CBR Test of the Sub grades soil

S. No.	Identification of Symbol chainage	optimum	Max moisture content	CBR
1	0.500	19.10	18.88	5.45
2	1.000	14.80	18.79	5.43
3	1.500	15.11	18.85	5.06
4	2.000	15.50	18.33	5.11
5	2.500	15.60	18.44	5.60
6	3.000	15.55	17.70	5.24
7	3.500	14.90	18.02	5.46
8	3.810	14.95	18.81	5.81

The extra widening and super elevation at curves should be provided as per IRC norms for design speed of 50 km/hr.

- **i.** Elevation of the state highway = 110.35m
- **ii.** The existing reduced level of the road are as follows

Km	0	1	2	3	4	5	6	7	8	9
Existing R.L. of G.L LHS	109.025	109.005	108.670	109.608	109.702	110.495	111.770	110.535	110.180	110.285
Existing R.L. of G.L. Center	109.250	109.250	108.950	109.950	110.0250	110.750	111.050	110.850	110.500	110.500
Existing R.L. of G.L. RHS	108.725	108.630	108.420	109.470	109.420	110.230	110.510	110.260	109.995	110.105

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