CHAPTER 8

Highway Maintenance

INTRODUCTION

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

8.1 General Causes of Pavement Failures

Some of the general causes of pavement failures needing maintenance measures may be classified as given below:

(*i*) Defects in the quality of materials used, construction method and quality control during construction.

(*ii*) Inadequate surface or subsurface drainage.

(*iii*) Increase in the magnitude of wheel loads and the number of load repetitions due to increase in traffic volume.

(*iv*) Settlement of foundation of embankment.

8.2 Maintenance of Highway

Various maintenance operations are as follows:

(i) Routine Maintenance: It includes filling up of potholes and patch repairs, maintenance of shoulders and the cross slope and repairing of creeks.

(ii) Periodic Maintenance: This include renewals of wearing course of pavement surface.

(iii) Special Repairs: It includes major restriction of the pavement through reconstruction of overlaps to rectify structural deficiencies.

8.3 Basic Maintenance Objective

The basic objective of maintenance functions are to maintain and operate the highway system in a manner such that:

(*i*) Comfort, convenience and safety are afforded to the public.

(*ii*) The investment in roads, bridges and appurtenances is preserved.

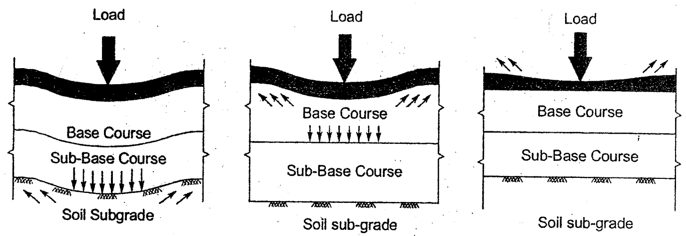
(*iii*) The aesthetics and compatibility of highway system with the environment is preserved.

(*iv*) The necessary expenditure of resources is accomplished with continuing emphasis on economy.

8.4 Failure in Flexible Pavement

One of the prime cause of flexible pavement failure is excessive deformation in subgrade soil. This can be noticed in the form of excessive undulations or waves and corrugations in the pavement surface.

The lateral shoving of pavement near the edge along the wheel path of vehicle is due to insufficient bearing capacity or a shear failure in subgrade soil. The failure of subgrade may be attributed due to inadequate stability and excessive stress application.



(a) Failure in Subgrade (b) Failure in base course (c) Failure in wearing course

***Figure*-8.1 :** *Failure in flexible pavement*

8.4.1 Failures in Base Course

Following are the major types of base course failures:

(*i*) Inadequate stability or strength

(*ii*) Loss of binding action

(*iii*) Loss of base course material

(*iv*) Inadequate wearing course

(*v*) Use of inferior materials and crushing of base course material

(*vi*) Lack of lateral confinement for the granular base course

8.4.2 Types of Defect in Flexible Pavement

The types of defect in flexible pavement are grouped under four categories:

(i) Surface Defect: These are associated with the surfacing layers and may be due to excessive or deficient quantity of bitumen in these layers. It includes fatty surfaces, smooth surfaces, streaking and hungry surfaces.

(ii) Crack: It contains hair line crack, alligator crack, longitudinal crack, edge crack, shrinkage crack and reflection crack.

(iii) Deformation: It includes slippage, rutting, corrugation, shoving, shallow, depression, settlement and upheaval.

(iv) Disintegration: It covers stripping, loss of aggregates, ravelling, potholes and edge cracking.

Table-8.1 : Symptoms, Causes and Treatment of defects in bituminous surfacings

Types of distress	Symptoms	Probable causes	Possible types of treatment
A. Surface defect			
1. Fatty surface	Collection binder on the surface	Excessive binder in premix, spray or tack coat; loss of cover aggregates, excessively heavy axle load.	Sand-blinding; open graded premix; liquid seal coat; burning of excess binder; removal of affected area.
2. Smooth surface	Slippery	Polishing of aggregates under traffic, or excessive binder.	Resurfacing with surface dressing or premix carpet.
3. Streaking	Presence of alternate lean and heavy lines of bitumen.	Non-uniform application of bitumen, or at a low temperature.	Application of a new surface.
4. Hungry surface	Loss of aggregates or presence of fine cracks.	Use of less bitumen of absorptive aggregates.	Slurry seal or fog seal.
B. Cracks			
1. Hair-line cracks	Short and fine cracks at close intervals on the surface.	Insufficient bitumen, excessive filler or improper compaction.	The treatment will depend on whether pavement is structurally sound or unsould.
2. Alligator cracks	Inter-connected cracks forming series of small blocks.	Weak pavement, unstable conditions of sub-grade or lower layers, excessive over-loads or brittleness of binder.	Where the pavement is structurally sound, the cracks should be filled with a low viscosity binder or a slurry seal or fox seal depending on the width of cracks. Unsound cracked pavements will need strengthening or rehabilitation treatment.
3. Longitudinal cracks	Cracks on a straight line along the road.	Poor drainage, shoulder settlement, weak joint between adjoining spreads of pavement layers or differential frost heave.	
4. Edge cracks	Cracks near and parallel to pavement edge.	Lack of support from shoulder, poor drainage, frost heave, or inadequate pavement width.	
5. Shrinkage cracks	Cracks in transverse direction or inter-connected cracks forming a series of large blocks	Shrinkage of bituminous layer with age.	
6. Reflection cracks	Sympathetic cracks over joints and cracks in the pavement underneath.	Due to joints and cracks in the pavement layer underneath.	
C. Deformation			
1. Slippage	Formation of crescent shaped cracks pointing in the direction of the thrust of wheels.	Unusual thrust of wheels in a direction, lack or failure of bond between surface and lower pavement courses.	Removal of the surface layer in the affected area and replacement with fresh material.
2. Rutting	Longitudinal depression in the wheel tracks.	Heavy channelised traffic, inadequate compaction of pavement layers, poor stability of pavement material or heavy bullockcart traffic.	Filling the depressions with premix material.
3. Corrugations	Formation of regular undulations	Lack of stability in the mix, oscillations set up by vehicle springs, or faulty laying of surface course.	Scarification and relaying of surfacing, or cutting of high spots and filling of low spots.
4. Shoving	Localised bulging of pavement surface alongwith crescent-shaped cracks.	Unstable mix, lack of bond between layers, or heavy start-stop type movements and those involving negotations of curves and gradients	Scarification and relaying of surfacing, or cutting of high spots and filling of low spots.
5. Shallow depression	Localised shallow depressions	Presence of indequately compacted pockets.	Filling with premix materials.
6. Settlement and upheaval	Large deformation of pavement.	Poor compaction of fills, poor drainage, inadequate pavement or frost heave.	Where fill is weak the defective fill should be excavated and redone. Where inadequate pavement is the cause, the pavement should be strengthened.

D. Disintegration			
1. Stripping	Separation of bitumen from aggregates in the presence of moisture.	Use of hydrophilic aggregate, inadequate mix composition, continuous contact with water, poor bond between aggregate and bitumen at the time of construction, etc.	Spreading and compacting heated sand over the affected area in the case of surface dressing; replacement with added anti-stripping agent in other cases.
2. Loss of aggregate	Rough surface with loss of aggregate in some portions	Ageing and hardening of binder, stripping, poor bond between binder and aggregate, insufficient binder, brittleness of binder etc.	Application of liquid seal, fog seal or slurry seal depending on the extent of damage.
3. Ravelling	Failure of binder to hold the aggregates shown up by pock marks of eroded areas on the surface.	Poor compaction, poor bond between binder and aggregate insufficient binder, brittleness of binder etc.	Application of cutback covered with coarse sand, or slurry seal, or a premix renewal coat.
4. Pothole	Appearance of bowl-shaped holes, usually after rain.	Ingress of water into the pavement, lack of bond between the surfacing and WBM base, insufficient bitumen content etc.	Filling pot-holes with premix material, or penetration patching.
5. Edge-breaking	Irregular breakage of pavement edges.	Water infiltration, poor lateral support from shoulders, inadquate strength of pavement edges, etc.	Cutting the affected area to regular sections and rebuilding with simultaneous attention paid to the proper construction of shoulder.

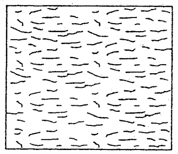


***Figure-8.2 :** Hair-line crack*

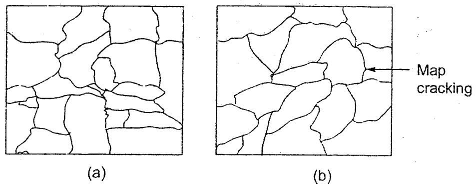


***Figure-8.3 :** Alligator Cracks*

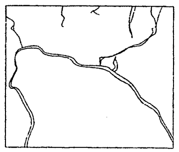


***Figure-8.4 :** Shrinkage Cracks*

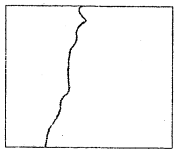


***Figure-8.5 :** Longitudinal Cracks*

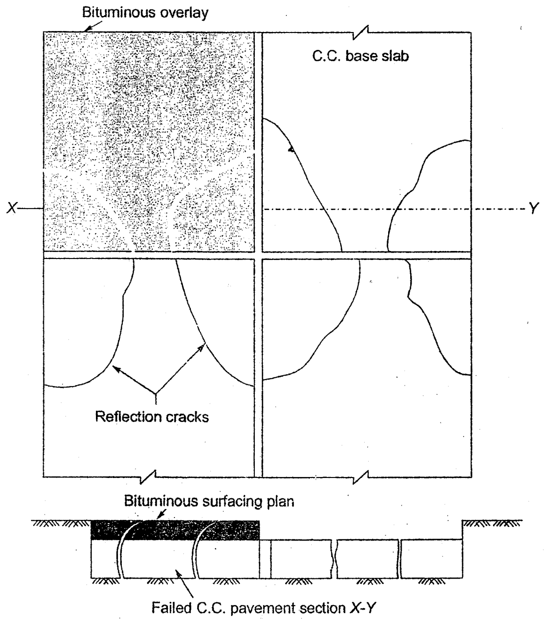


***Figure-8.6 :** Reflection Cracks*

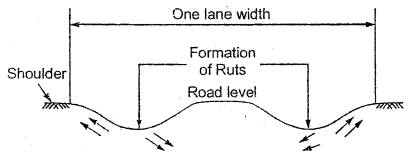


***Figure-8.7 :** Ruts*

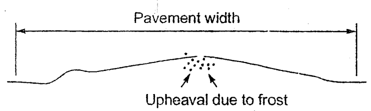


***Figure-8.8 :** Frost heave failure*

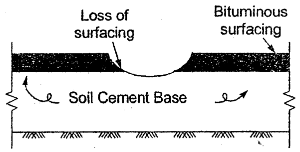


***Figure-8.9 :** Failure due to lack of binding*

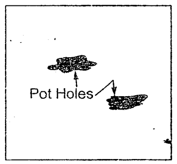


***Figure-8.10 :** Pot holes*

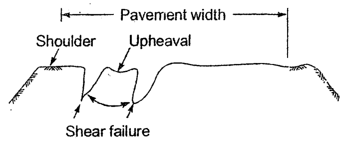


***Figure-8.11 :** Shear failure cracking in rigid pavement*

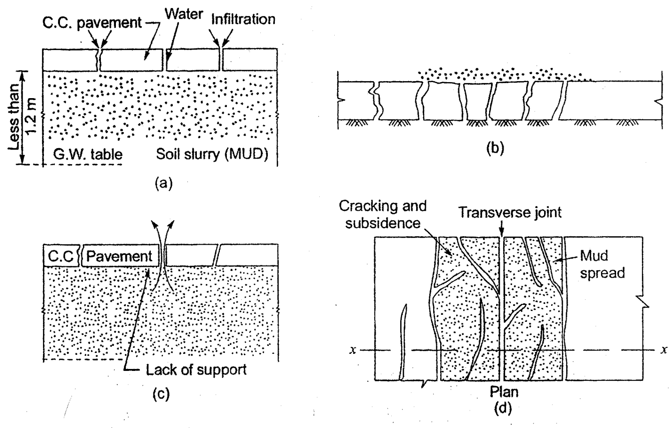


***Figure*-8.12 :** *Mud pumping*

8.4.3 Methods for Repairing the Defects

The repair methods are generally fall under two categories:

(i) Seal Coat: Seal coat is a single thin application of bitumen which may or may not be covered with aggregate.

Sealing can take the form of the following treatments:

(a) Liquid seal: It is an application of binder at 9.8 kg/10 m² followed up with a spread of cover aggregates (6.3 mm nominal size) at a rate of 0.09 cu-m/10 m² and rolling in position.

(b) Fog seal: It is a spray of slow-setting emulsion diluted with equal amount of water at a rate 0.5 - 1 litre/m². Traffic is allowed after the seal sets in. It is used to increase the binder content of bituminous surface. It can also be used as an emergency treatment measure for hungry surfaces.

(c) Slurry seal: It is an application of a slurry composed of slow-setting emulsion, water and aggregates to a thickness of 5 - 10 mm. The emulsion and water are 18 - 20% and 10 - 12% respectively of the weight of aggregate. The slurry is spread at the rate of 200 m² per tonne

Table-8.2 : Specification for sealing materials

Treatment	Binder	Aggregate	Specification in brief
Liquid seal	Penetration grade, or cut-back emulsion	6.3 mm size	Spray binder uniformly at 9.8 kg/ 10 sqm spread aggregate at 0.09 cu m/ 10 sq m and roll.
Fog seal	Slow setting emulsion RS diluted with equal amount of water.		Spray at 0.5 to 1 litre/sq m. Allow traffic after the seal sets.
Slurry seal	Slow setting emulsion	Well graded material between 4.75 mm and 75 micron (grading specified).	Apply tack coat with diluted emulsion at 2.5 to 3.5 kg/ 10 sq m. Apply slurry mix consisting of 18 to 20% water by weight of aggregate at the rate of 200 sq m per tonne.

(ii) Patching: Patching is the application of bituminous materials for filling potholes, shallow depressions, rutting and edge irregularities.

Table-8.3 : Specification for patching material

Treatment	Binder	Aggregate	Specification in brief
Sand premix	Penetration grade, or cut-back RC or MC	Fine grit 1.7 mm to 180 micron	Apply tack coat at 7.5 kg per 10 sq.m. Spread mix consisting of 0.06 cu m of grit and 6.8 kg of binder per 10 sq m and roll.
Open-graded premix	Paving grade, RC or MC cut-back, MS emulsion	12.5 mm and 10 mm size aggregate	Apply tack coat, prepare the mix as per IRC: 14-2004, spread and roll. Where cutback is the binder, the premix should be prepared at least 3 days in advance of use. The final surface should be provided with seal coat.
Dense graded premix	Paving grade	Well graded as per IRC: 16-2008	Apply tack coat and prepare, spread and compact mix as per IRC: 16 2008.
Penetration patching	Penetration grade RC or MC cut-back	Coarse and key aggregates as per IRC:20-1996	Apply tack coat, spread course aggregate and dry roll; apply binder and key aggregate and roll as per IRC:20. For patching 50-75 mm thickness, use built up spray grout as per IRC: 47-1972.

8.4.4 Special Repairs in Flexible Pavement

(i) Waves and Corrugations: Following are the factors which contribute to the formation of waves and corrugations:

(a) Defective rolling: If the rolling during construction stage in improper thus leaving the formation of waves then the process being progressive, the wave formation would continue indefinitely. However the subsequent traffic operations would also cause similar effects if the rolling is inadequate during the construction stage.

(b) Poor subgrade conditions: Subgrade consisting of poor soils including highly plastic or organic soils and high water table close to subgrade surface may cause non-uniform and inadequate subgrade stability. When boulders are used as soling course in such subgrades there is differential settlement or sinking of these stones. All these would contribute to formation of corrugated pavement surface.

(c) Poor gradation: Defective gradation or mix for the surface layer is another factor which gives rise to the wave formation pushing and pulling caused due to the vehicular movement enhance the defect further more.

(d) Compaction temperature: Viscous state of the bitumen binder greatly depends upon the temperature and thus very high temperature during mixing and compaction of bituminous mix would make the resulting pavement surface layers with low stability and wavy surface is formed during rolling.

(e) Unstable underlying layers: Weak underlying layers also cause the formation of waves due to repeated lying of vehicles on such road. Failure of any one of the pavement layers can cause surface deformations.

Remedial measures to be taken for the wave and corrugations are:

(a) There appears to be no way to improve the road surface once the waves and corrugations are already formed. Usually another layer of surface course is laid after laying a levelling course. But often the waves and corrugation again develop, unless the basic reason for this problem is investigated and proper measure is taken.

(b) If the instability of underlying layer is due to excessive moisture conditions suitable subsurface drainage system is warranted to remedy the defect permanently.

(c) If the failure is due to improper compaction of the lower layers this would need complete reconstruction.

(d) If the failure is due to subgrade soil which may be a highly plastic expansive clay the solution may be by subgrade treatment using a modifying agent for stabilization.

(ii) Skidding of Pavement Surfaces:

(a) Skid resistance property of pavement surface is essential requirement for highway safety. The skid resistance or the friction of the pavement surface may be measured using any one of the devices such as the pendulum type friction recorded or the skid testing device attached to test vehicle or the instrument mounted dynamic skid resistance tester towed by another vehicle.

(b) Water, clay, dust, dry sand, oil and grease on the pavements are few factors which cause skidding. These materials on the pavement surface cause a reduction in grid between tyre and the pavement surface.

(c) Skidding is of three types straight skidding, impending skidding and sideway skidding. The straight skidding occurs in the direction of travel when the sudden brakes are applied. Impending skidding is encountered when the braking is gradual and wheel continues to revolve. Sideway skidding occurs on curves where sufficient superelevation is not provided or when the coefficient of friction is inadequate.

(d) Highways can develop sufficient skid resistance if they are maintained clean and dry. But the presence of water film, debris and polishing characteristics of aggregate influence the skid resistance properly. Rough surfaces or textures like those of gravel road, WBM and cement concrete roads offer sufficient amount of skid resistance. Bituminous pavements are more prone to skidding.

8.5 Failure in Rigid Pavement

Failure of cement concrete pavements are perceived mainly by the formation of structural cracking. The failures are mainly due to two factors:

(*i*) Deficiency of pavement materials
(*ii*) Structural inadequacy of the pavement system

8.5.1 Deficiency of Pavement Materials

Following are the main causes which would give rise to the different defects or failures of cement concrete pavement:

(*i*) Soft aggregate
(*ii*) Poor joint filler and sealer material
(*iii*) Poor surface finish
(*iv*) Improper and insufficient curing
(*v*) Poor workmanship in joint construction

Various defects which arise due to deficiency of pavement materials are:

(*i*) Disintegration of cement concrete
(*ii*) Formation of cracking
(*iii*) Spalling of joint
(*iv*) Poor riding surface
(*v*) Slippery surface
(*vi*) Formation of shrinkage cracks
(*vii*) Ingress of surface water and further progressive failures

8.5.2 Structural Inadequacy of the Pavement System

Inadequate subgrade support or pavement thickness would be a major cause of developing structural cracking in pavements. Following are the causes and types of failure which develop:

(*i*) Inadequate pavement thickness
(*ii*) Inadequate subgrade support and poor subgrade soil
(*iii*) Incorrect spacings of joints

Above would give rise to the failures of the following types:

(*i*) Cracking of slab corners
(*ii*) Cracking of pavements longitudinally
(*iii*) Settlement of slabs
(*iv*) Widening of joints

8.5.3 Typical Rigid Pavement Failure

Following are some typical and basic types of failures in rigid pavements:

(i) Scaling of Cement Concrete: Scaling is observed in cement concrete pavement showing overall deterioration of the concrete. The scaling is mainly attributed due to the deficiency in the mix or presence of some chemical impurities which damage the mix.

Due to excessive vibration given to mix, the cement mortar comes to the top during construction and thus with use, the cement mortar gets abraded exposing the aggregate of the mix. This makes the pavement surface rough and shabby in appearance.

(ii) Shrinkage Cracks: Shrinkage cracks normally develop during the curing operation of cement concrete pavements immediately after the construction. The placement of cracks are both in longitudinal and transverse direction.

(iii) Spalling of Joints: Sometimes when preformed filler materials are placed during casting of pavement slabs, the placement is some how dislocated and filler is thus placed at an angle. The concreting is completed without noticing this faulty alignment. Thus this forms an overhang of a concrete layer on the top side and the joint later on shows excessive cracking and subsidence.

(iv) Warping Cracks: If the joints are not well designed to accommodate the warping of slabs at edges, this results in development of excessive stresses due to warping and the slab develop cracking at the edges in an irregular pattern. Hinge joints are generally provided for relieving the slabs of warping of warping stresses.

(v) Mud Pumping: Mud Pumping is perceived when the soil slurry ejects out through the joints and cracks of cement concrete pavement caused during the downward movement of slab under the heavy wheel loads.

Following factors may cause mud pumping:

(a) Extent of slab deflection

(b) Type of subgrade soil

(c) Amount of free water

Pumping is noticed just after the rains in cement concrete pavements that are placed on clayey soil subgrade. Due to the applications of repetition loads, initial spaces are developed underneath the pavement slabs and water infiltrates into these spaces through joints, cracks and edges of the pavements. Since the soil is also of the fine grained type, it holds water and forms the soil slurry or soil suspension in water or the mud.

8.5.4 Special Repair of Rigid Pavement

Mud Jacking or Lifting of Slabs

Once pavement starts pumping the remedy for correcting it lies in providing the effective drainage. If the subsidence is localized then the same is repaired by patching the portions of slabs with bituminous mixes. Advanced countries adopt the procedures of mud jacking. The process consists of drilling number of holes 4 cm to 5 cm diameter 1.5 to 3 m apart in the cement concrete slab. Grouting in such slabs is done under pressure through these holes. The grout normally used is either $1:3\frac{1}{2}$ cement-sand mix or bitumen. The mix is thus injected through a pressure holes using the compressor. The slabs are thus raised from below by the pressure grout, upto the desired level.

8.6 Pavement Evaluation

Pavement evaluation involves a thorough study of various factors such as

(*i*) Subgrade support

(*ii*) Pavement composition and its thickness

(*iii*) Traffic loading

(*iv*) Environmental conditions

The various methods of pavement evaluations may be broadly classified into two groups:

(*i*) Structural evaluation of pavement

(*ii*) Evaluation of pavement surface condition

8.6.1 Structural Evaluation of Pavement

Structural evaluation of both flexible and rigid pavements may be carried out by plate bearing test. Benkelmen Beam measurements are preceded by a rating survey of the road so as to divide it into homogenous section of approximately similar serviceability. A few number of non-destructive testing techniques are used for assessing the load carrying capacity of the pavements.

8.6.2 Evaluation of Pavement Surface Condition

The pavement unevenness may be measured using unevenness indicator. The pavement serviceability concept was introduced at the AASHTO Road Test for comparing relative performance of various test sections during different periods.

The Present Serviceability Rating (PSR) is the mean opinion of the members of the rating panel and this is correlated with the physical measurements such as longitudinal and transverse profile of the pavement degree of cracking and patching etc. affecting pavement serviceability.

Table-8.4 : Riding quality of pavements

Unevenness index, cm/km	Riding quality
In old pavements < 95 95 to 119 120 to 144 145 to 240 > 240	Excellent Good Fair Poor (possible resurfacing) Very poor(resufacing required)
In new pavements < 120 120 to 145 >145	Good (acceptable) Fair (acceptable) Poor (not acceptable)

8.7 Strengthening of Existing Pavement

Strengthening may be done by providing additional thickness of the pavement of adequate thickness in one or more layers over the existing pavement, which is called overlay. If the existing pavements have completely deteriorated on overlay would not serve the purpose and hence we should remove the existing damaged pavements structure and rebuild it. In partially damaged pavement sections, patch repair works are carried out before constructing the overlay.

8.7.1 Types of Overlay

The overlay combinations are divided into four categories based on the type of existing pavement and the overlay:

(*i*) Flexible overlay over flexible pavement

(*ii*) Rigid overlay over flexible pavement

(*iii*) Flexible overlay over rigid pavement

(*iv*) Rigid overlay over rigid pavement

NOTE: The choice of the overlay type depends upon number of factors including total thickness of overlay required, local material, wheel load, cost etc.

8.7.2 Design of Overlay

The overlay thickness required over a flexible pavement may be determined either by one of the conventional pavement design methods or by a nondestructive testing method like the Benkelman beam deflection method.

8.8 Benkelman Beam Deflection Method

Benkelman Beam is a device which can be conveniently used to measure the rebound deflection of a pavement due to a dual wheel load assembly or the design wheel load. The design wheel load is a dual wheel load assembly of gross weight 4085 kg with an inflation pressure of 5.6 kg/cm^2. The beam is 3.66 m long and is pivoted at a distance of 2.44 m from the contact point. The other end of the beam activates a dial gauge.

8.8.1 Principle of Overlay Design

A well compacted pavement section or one which has been well conditioned by traffic deforms elastically under each wheel load application such that when the load moves away, there is an elastic recovery or rebound deflection of the deformed pavement surface.

The amount of deflection depends upon a number of factors such as:

(*i*) Wheel load
(*ii*) Pavement thickness
(*iii*) Soil strength
(*iv*) Surface temperature

Larger rebound deflection indicates weaker pavement structure which may require earlier strengthening or higher overlay thickness.

8.8.2 Procedure of Benkelman Beam Deflection Method

(*i*) A minimum of 10 points are selected along the outer wheel path for each lane.

(*ii*) A single rear axled truck is selected with the rear axle loaded of 81.7 kN, the tyre pressure being 5.6 kg/cm^2. The probe is inserted in between the two wheels, the wheel position representing the point where the deflection is desired. The contact point is also the same point. The dial gauge reading is noted i.e. D_0.

(*iii*) The truck is moved forward slowly and the dial gauge readings are taken when the truck is 2.7 m and 9.0 m away from the initial position to given the intermediate (D_i) and final readings (D_f).

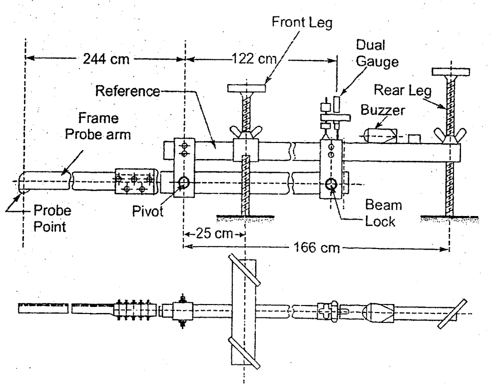


Figure-8.13 : *Benkelman beam*

(*iv*) Pavement temperature is recorded.

(*v*) The intermediate and final readings are subtracted from the initial reading. If the deflections so obtained compare within 0.025 mm, the actual deflection is twice the difference between the initial reading and the final reading.

(*vi*) If the deflection obtained from the two positions do not compare within 0.025 mm, twice the difference between the final and initial readings gives the apparent deflection, this is known as leg correction.

(*vii*) The three dial gauge readings D_o, D_i and D_f from a set of readings at one deflection point under consideration. The deflection observations are continued at all the desired points.

(*viii*) The mean and standard deviation of the measurements are determined. The characteristics deflection is taken as summation of mean and twice of standard deviation.

NOTE: Generally deflections are recorded after the rainy season. If they are taken in dry seasons, they should be multiplied by 2 for clayey soils, 1.2 to 1.3 for sandy soils and interpolated for soils in between.

(*ix*) The allowable deflections are given in Table 8.5.

Table-8.5 : Allowable deflections

Design Traffic Intensity (commercial vehicles/day)	Allowable Deflection (mm)
150 - 450	1.50
450 - 1500	1.25
1500 - 4500	1.00

8.9 Flexible Overlay over Flexible Pavement

Overlay thickness over flexible pavements are generally determined by means of deflection measurements. Measurements are made using Benkleman Beam. The analysis of data for overlay design and the determination of overlay thickness as given in IRC: 81 - 1997 (First Revision)

8.9.1 Analysis of Data for Overlay Design

The rebound deflection values D_1, D_2, D_3 are determined in mm after applying corrections, if necessary, to the observed values of D_o, D_f and D_i in each case.

The mean value of the deflections at n points is given by, $D = \frac{\Sigma D}{n}$

The standard deviation of the deflection values is given by, $\sigma = \sqrt{\frac{\Sigma(\bar{D}-D)^2}{(n-1)}}$

Characteristic deflection D_c is given by, $D_c = \bar{D} + t \times \sigma$

where, $t = 1.0$, $D_c = \bar{D} + \sigma$ covers about 84% of the cases

$t = 2.0$, $D_c = \bar{D} + 2\sigma$ covers about 97.7% of the cases of deflection values on the pavement section, assuming normal distribution of rebound deflection values

NOTE: IRC recommends the former case, $D_c = \bar{D} + \sigma$

Temperature Correction: IRC suggests measurements of deflection at a standard temperature of 35°C. If the temperature is different than 35°C, then the correction is applied to deflection value.

$$D_t = D_c - (t°C - 35°C) \times 0.0065$$

Subgrade Moisture Correction: Generally deflection are recorded after rainy season but if they are taken in dry seasons, they should by multiplied by 2 for clayey soils and 1.2 to 1.3 for sandy soils.

NOTE: For higher altitudes, measurements are recommended at 20° C with no corrections.

8.9.2 Overlay Thickness Design

The overlay thickness required h_0 may be determined after deciding the allowable deflection D_a in the pavement under the design load. According to Ruiz's equation, overlay thickness h_0 in cm is given by:

$$h_0 = \frac{R}{0.434}\log_{10}\frac{D_c}{D_a}$$

where, h_0 = Thickness of bituminous overlay in cm

R = Deflection reduction factor depending on the overlay material

= 10 to 15 (for bituminous overlay)

D_a = Allowable deflection which depends upon the pavement type and the desired design life

The formula suggested by Indian Road Congress for the design of overlay thickness equivalent to granular material of WBM layer,

$$h_0 = 550\log_{10}\frac{D_c}{D_a}$$

where, h_0 = Thickness of granular or *WBM* overlay in mm

$D_c = \bar{D} + \sigma$, after applying the corrections for pavement temperature and subgrade moisture

When bituminous concrete or Bituminous Macadam with bituminous surface course is provided as the overlay, an equivalency factor of 2.0 is suggested by the IRC to decide the actual overlay thickness required. Thus the thickness of bituminous concrete overlay in mm will be $h_0/2$ when the value of h_0 is determined from above equation.

Example-8.1 **Benkelman Beam deflection analysis was carried out on 10 selected points of a flexible pavement using a dual wheel load of 4085 kg and 5.6 kg/cm² pressure.**

Selected Points	1	2	3	4	5	6	7	8	9	10
Deflection (mm)	1.32	1.35	1.60	1.45	1.40	1.52	1.55	1.65	1.61	1.43

Determine the thickness of bituminous overlay using the following data:

1. **Present Traffic = 1500 cvpd**
2. **Pavement temperature = 30°C**
3. **Correction factor for moisture = 1.3**
4. **Annual rate growth of traffic = 7.5%**

Solution:

$$\text{Mean deflection } (\bar{D}) = \frac{\Sigma D}{n} = \frac{14.88}{10} = 1.488$$

$$\text{Standard deviation } (\sigma) = \sqrt{\frac{\Sigma(\bar{D}-D)^2}{n-1}} = \sqrt{\frac{0.11836}{9}} = 0.115$$

Characteristics deflection, $D_c = \bar{D} + \sigma = 1.488 + 0.115 = 1.603$ mm

Deflection after temperature correction = 1.603 – (30 – 35) × 0.0065 = 1.6355 mm

Corrected deflection for subgrade moisture = 1.6355 × 1.3 = 2.126 mm

Assuming the number of years after the last traffic count before the construction of overlay as $n = 3$, design traffic A is given by:

$$A = P(1+r)^{(n+10)} = 1500\,(1 + 0.075)^{13} = 3841 \text{ cvpd}$$

Therefore, as per IRC recommendations adopt allowable deflection,

$$D_a = 1 \text{ mm}$$

∴ Overlay thickness of granular material,

$$h_0 = 550\log_{10}\frac{D_c}{D_a} = 550\log_{10}\frac{2.126}{1.00} = 180.16 \text{ mm or } 18.016 \text{ cm}$$

Assuming an equivalency factor of 2.0 for bituminous concrete overlay, the design thickness of bituminous

$$\text{concrete overlay} = \frac{18.016}{2} = 9.008 \text{ cm}$$

8.10 Flexible Overlay over Rigid Pavement

The required thickness of flexible overlays on rigid pavements can be determined from the following equation:

$$t_0 = 2.5\,(F h_n - h_e)$$

where, t_0 = Required thickness of flexible overlay

h_n = Required thickness of equivalent single slab placed directly on subgrade or sub-base.

h_e = Thickness of existing slab

F = Factor which is function of the subgrade or sub-base (Figure 8.14)

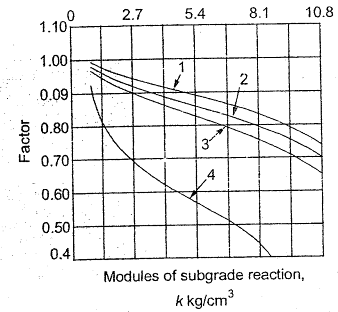


***Figure-8.14 :** Non-rigid overlay design*

8.11 Rigid Overlay over Rigid Pavement

The required thickness of rigid overlays over existing rigid pavement can be determined from the following equation:

$$h_0 = (h_n^x - C h_e^y)^z$$

where, h_0 = Thickness of concrete overlay in slab in cm

h_e = Thickness of existing slab in cm

h_n = Thickness of equivalent single slab placed directly on the subgrade with a working stress equal to that of the overlay slab

C = Coefficient depending upon condition of existing pavement.

= 1 when existing pavement in good condition

= 0.75 when existing pavement with initial corner cracks due to loading but no progressible crack

= 0.35 when existing pavement badly cracked or crushed

Recommended value of x, y and z are given in Table 8.6.

Table-8.6 : Values of x, y and z

Agency	Condition	x	y	z
U.S. corps of engineers	Overlay placed directly on existing pavement	1.4	1.4	1/1.4
	Levelling course used	2.0	2.0	0.5
PCA, FAA	Overlay placed directly on existing pavement	1.87	2.0	0.5
	Levelling course used	2.0	2.0	0.5

8.12 Rigid Overlay Over Existing Flexible Pavement

In this case, the original flexible pavements is considered as sub-base course and the rigid overlay thickness can be determined by using design criteria for rigid pavements. The value of subgrade reaction k of existing flexible pavement can be determined and this value can be used for the design of overlay.

The normal deflection to be expected of a flexible pavement is about 6.25 mm, whereas the deflection of a rigid pavement sufficient to cause the pavement to break is about 2.5 mm. Unless this deflection is limited, the rigid pavement will crack and lose its effectiveness.

Illustrative Examples

Example-8.2 Design the overlay with the help of following data:

(*i*) Mean = 1.0 mm, standard deviation = 0.25 mm
(*ii*) Temperature at the time of measurement = 38°C
(*iii*) Soil type = Clay
(*iv*) Design traffic at the end of 10 years is 1000 cvpd
(*v*) Coverage of the deflection values on pavement = 98%

Solution:

Allowable deflection, $D_a = \bar{D} + 2\sigma$

Characteristic deflection, $D_c = 1.00 + 2 \times 0.25 = 1.50$ mm

Deflection after temperature correction = 1.50 – (38 – 35) × 0.0065 = 1.48

Deflection after moisture correction = 1.48 × 2 = 2.96 mm

Overlay thickness, $h_0 = 550 \log_{10} \frac{D_c}{D_a} = 550 \log_{10} \frac{2.96}{1.25} = 206$ mm or 20.6 cm

Example-8.3 Determine the thickness of rigid overlay for a 10 cm thick slab in good condition. The design thickness required, due to increased loading, is 20 cm.

Solution:

The required thickness of rigid overlay over existing rigid pavement is given by equation

$$h_0 = \left(h_n^x - Ch_e^y\right)^z$$

Here, $h_n = 20$ cm

$C = 1$, since the existing pavement is in good condition

$h_e = 10$ cm

Overlay can be placed directly over the existing pavement as it is in good condition. Therefore, from Table 8.6,

$x = 1.4$

$y = 1.4$

$z = \frac{1}{1.4} = 0.714$

$h_0 = (20^{1.4} - 1 \times 10^{1.4})^{0.714} = (66.29 - 25.12)^{0.714}$

$= (41.17)^{0.714} = 14.22$ cm say 15 cm

Important Expressions

1. Characteristic deflection, $D_c = \bar{D} + t \times \sigma$
2. Flexible overlay thickness over flexible pavement, $h_0 = 550 \log_{10} \frac{D_c}{D_a}$
3. Flexible overlay thickness over rigid pavement, $t_0 = 2.5\,(F h_n - h_e)$
4. Rigid overlay thickness over rigid pavement, $h_n = \left(h_0^x - Ch_e^y\right)^z$

Summary

- Various maintenance operations are routine maintenance, periodic maintenance and special repairs.
- Major cause of flexible pavement failure is excessive deformation in subgrade soil.
- Seal coat is a single thin application of bitumen which may or may not be covered with aggregate.
- Patching is the application of bituminous materials for filling potholes, shallow depressions and reacting.
- Scaling of cement concrete, shrinkage cracks, spalling of joints, warping cracks and mud pumping are types of rigid pavement failure.
- Pavement evaluation involves study of subgrade support, pavement composition, traffic loading and environmental conditions.
- Strengthening of pavement is done by providing additional thickness of the pavement of adequate thickness over existing pavement.
- Benkelman Beam is a device which is used to measure the rebound deflection of a pavement due to design wheel load.
- Benkelman Beam deflection method is generally used to design flexible overlay over flexible pavement.

Objective Brain Teasers

Q.1 The equivalent granular overlay thickness on a pavement is 180 mm. What will be the measured deflection in mm value in mm if the allowable deflection is 1.25 mm and measurement taken in rainy season at the temperature of 26° C.

(a) 2.65 (b) 2.60
(c) 1.325 (d) 1.27

Q.2 Match List-I (Pavement Deficiency) with List-II (Explanation) and select the correct answer using the codes given below the lists:

List-I
A. Bird Baths
B. Subsidence
C. Pot holes
D. Ravelling

List-II
1. Removal of larger surface aggregates leaving craters.
2. Deformation which may be caused by localized or variable subgrade failure
3. Abrupt lowering of the road surface due to poor drainage.
4. A step-sided, bowl shaped cavity caused by loss of surfacing as well as base course erosion.

Codes:

	A	B	C	D
(a)	1	4	3	2
(b)	2	3	4	1
(c)	2	3	1	4
(d)	4	1	3	2

Q.3 On a pavement section mean value of Benkelman beam deflection was obtained as 1.50 mm with standard deviation of 0.110 mm. Pavement temperature measured was 35°C and moisture correction was obtained as 1.6. What is the value of characteristic deflection considering the value of *s*?

(a) 2.316 mm (b) 2.576 mm
(c) 1.94 mm (d) 2.794 mm

Q.4 Read the following statements about a 'seal coat'

(*i*) It is a very thin surface treatment.
(*ii*) It develop skid resistance texture.
(*iii*) It seals the surface against ingress of water

Which of these, the correct statement are

(a) (*i*) and (*ii*) (b) (*ii*) and (*iii*)
(c) (*i*) and (*iii*) (d) (*i*), (*ii*) and (*iii*)

Q.5 Reflection cracking is observed in

(a) Flexibie pavement
(b) Rigid pavement
(c) Bituminous overlay over rigid pavement
(d) Rigid overlay over rigid pavement

Q.6 Match **List-I (Distress)** with **List-II (Meaning)** and select the correct answer using the codes given below the lists:

List-I

A. Settlement
B. Subsidence
C. Depression
D. Distortion

List-II

1. A localized, rather abrupt lowering of the road surface.
2. A general lowering of the road surface
3. Irregular deformation of the road
4. Dished localized deformations

Codes:

	A	B	C	D
(a)	2	1	4	3
(b)	1	2	4	3
(c)	2	1	3	4
(d)	1	2	3	4

Answers

1. (b) **2.** (a) **3.** (b) **4.** (d) **5.** (c)
6. (a)

Conventional Practice Question

Q.1 Existing black top pavement was tested using Benkelman Beam with a test vehicle of 8170 kg rear axle load. Observations recorded at a pavement temperature of 43°C are given below:

Length of test stretch = 300 m

Serial number subsection	Rebound deflection (mm)	Serial number subsection	Rebound deflection (mm)
1	1.46	7	1.68
2	1.52	8	1.74
3	1.56	9	1.96
4	1.76	10	1.42
5	1.96	11	1.56
6	1.74	12	1.62

Compute the thickness of overlay of bituminous concrete, taking allowable deflection as 1.25 mm, if the factor for subgrade moisture correction is 2.0.

[Ans : 25 cm]

■■■■