

# Highway Maintenance, Repair, and Rehabilitation

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1

## Highway Maintenance, Repair, and Rehabilitation

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- Classification of Maintenance Activities for Road Pavements and Road facilities
- Inspection, Prioritization and Planning of Maintenance Operations
- Evaluation of Pavement Distress and Pavement Condition
- Types of Road Failure and its causes
- Types and Methods of Pavement Repairs
- Types of Overlays and Strengthening of Existing Pavements

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2

## Highway Maintenance

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- Preserving and keeping the serviceable conditions of each components of the highway such as roadway structure and other components in their original condition as normal as possible and as best as practicable.
- If the maintenance works are not done at all or done faulty, the pavement structure is inadequate for present day traffic and loading, the life may be drastically reduced.
- On poor designed roads, the cost of maintenance may be higher than the initial cost.

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3

## Necessity of Highway Maintenance

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- Continuity of traffic flow
- Safety of road users
- Protection of road and other structures
- Providing economical, comfort service to the road users
- Protection from negative environmental impacts

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4

## Classification of Highway Maintenance Works

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- Road Maintenance
- Road side Maintenance

5

## Road Maintenance

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- Concerns all maintenance works on the roadway and on all structures within and immediately adjacent to the roadway such as ditches, culverts, causeways, bridges, etc.

6

## Road side Maintenance

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- Concerns all the maintenance works on structures and surfaces above and below the road having direct active and/or passive influence of the road.
- This comprises protection works, retaining walls, cut slopes, unstable natural slopes, river protection works and vegetation.

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7

## Classification of Highway Maintenance Activities

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- Routine Maintenance and Repairs
- Recurrent Maintenance and Repairs
- Periodic Maintenance and Repairs
- Special Repairs

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8

## Classification of Highway Maintenance Activities

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- Routine Maintenance and Repairs
  - Carried out frequently as required during each year on all elements of the highway in order to ensure serviceability at all times in all weathers.
  - Maintenance of localized nature required continually on any road whatever its engineering characteristics or traffic volume may be.
    - Grass and bush cutting
    - Grading and reshaping of unpaved surfaces
    - Cleansing of carriageways, ditches, drains, signs and safety barriers
    - Repair of minor damage of carriageways, slopes, culverts, signals, lighting facilities
    - Replacement of furniture and equipment that has been damaged
    - Filling potholes

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9

## Classification of Highway Maintenance Activities

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- Recurrent Maintenance
  - Localized nature of limited extent carried out at more or less regular intervals of six months to year, depending upon traffic volume.
  - Activities within this category are: sealing cracks, local surface treatment, filling up of pot holes and patch repairs, edge repairs, etc.
  - The works are done by the use of minor equipment.

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10

## Classification of Highway Maintenance Activities

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- Periodic Maintenance
  - Maintenance operations of large extent only at intervals of several years.
  - Renewal of wearing course of pavement surface.
  - Resealing (surface treatment, slurry sealing), resurfacing (thin overlay), renewals of wearing course, restoration of road markings, culverts, repainting of metal bridges.

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11

## Classification of Highway Maintenance Activities

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- Special Maintenance/Emergency Maintenance
  - Urgent emergency maintenance
    - Works needed for reopening the road or construction of a temporary diversion to allow the traffic to pass around the constructions such as slides, road wash-outs.
    - Urgent maintenance activities are removal of debris and other obstacles, placement of warning signs and diversion works.
  - Reinstatement of the road
    - Reinstatement of the road after the critical period is over by reconstruction or repair of the pavement, the structures and the drainage as the case may be strengthening or reconstruction of pavement surface.

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12

## Highway Maintenance can be grouped as

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- Preventive Maintenance
  - Maintenance operation of road surface, geological and geotechnical nature to protect the roadway.
  - Sealing of longitudinal and transverse cracks, laying of net on the slopes trimming of loose materials including stones, installation of subsurface drains, construction of retaining walls, dams, gabion walls, river training structures, riverbank protection, slope protection with bioengineering.
- Corrective Maintenance
  - Known as remedial/curative maintenance.
  - Includes maintenance actions taken to correct deficiencies which are potentially hazardous.
  - Repairing of defects which seriously affect a pavement's operation so as to keep the highway within a tolerable level of serviceability.

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13

## Difference between Maintenance, Rehabilitation and Reconstruction

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- Maintenance: Works performed to upkeep a pavement in its original constructed condition.
- Rehabilitation: Measures improving the structural strength of the pavement.
- Reconstruction: Upgrading of a road elements as well as partial change in horizontal and vertical alignment for the betterment for the route strengthening of pavement structure.

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14

## Inspection, Prioritization and Planning of Maintenance Operations

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### 1. Assessment of Maintenance Needs

- Depends upon serviceability standard.
- Information required to identify maintenance needs
  - Road inventory including information of soils, terrain and climate
  - Nature and amount of traffic using the road

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15

## Inspection, Prioritization and Planning of Maintenance Operations

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### 2. Determining Priorities

- Maintenance priorities can be as follows
  - Urgent works like emergency repairs, removal of debris
  - Routine drainage works as cleaning ditches, bridges, etc.
  - Routine pavement works as grading of unpaved roads, patching and local sealing.
  - Other routine works as filling on unpaved roads, shoulders and slopes, grass cutting, cleaning, repainting, etc.
  - Periodic works like heavy grading, re-graveling, surface dressing
  - Special works like overlaying, reconstruction

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16

## Inspection, Prioritization and Planning of Maintenance Operations

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### 3. Maintenance Management System

- Minimum acceptable serviceability standard
- Field survey for evaluation of maintenance requirement
- Factors influencing maintenance needs (subgrade, drainage, climate, traffic)
- Estimation of rate of deterioration under prevailing conditions
- Type and extent of maintenance requirement
- Availability of funds
- Maintenance cost, availability of materials, manpower and equipment
- Need based allocation of inputs and fixing maintenance priorities

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17

## General causes of pavement failure

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- Defects in the quality of material used.
- Defects in the construction method and improper quality control during construction.
- Inadequate surface or subsurface drainage of the road resulting in the stagnation of water in the subgrade or in any of the pavement layers.
- Increase in the magnitude of wheel load and the number of load repetitions due to increase in traffic volume.
- Settlement of foundation of embankment of fill materials.
- Environmental factors like heavy rainfall, soil erosion, high water table, snowfall, frost actions, etc.

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18

## Types of road failure and its cause

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- Pavement Failure
  - Flexible pavement failure
  - Rigid pavement failure
- Road slope failure
- Road failure due to improper water management

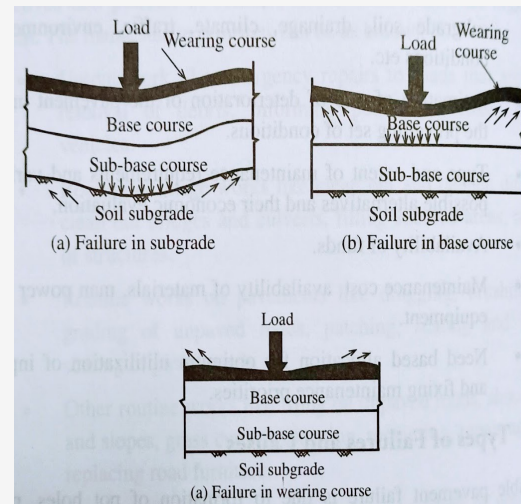
## Flexible Pavement Failure

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- Due to localized depression and settlements followed with the heaving in the vicinity.
- Failure of any layers of the pavement structure develops the wave and corrugation on the pavement surface or longitudinal ruts and shoving.
- Untimely surface deformation appears when failure due to excessive deformation either in sub-grade, sub-base, or base-course or on surface-course.

## Flexible Pavement Failure: Failure of sub-grade

- Due to excessive deformation in sub-grade soil due to insufficient bearing capacity.
- Major causes
  - Inadequate stability
    - Weakness of soil, excessive moisture, improper compaction
  - Excessive stress application
    - Insufficient thickness of pavement, excessive load than design value

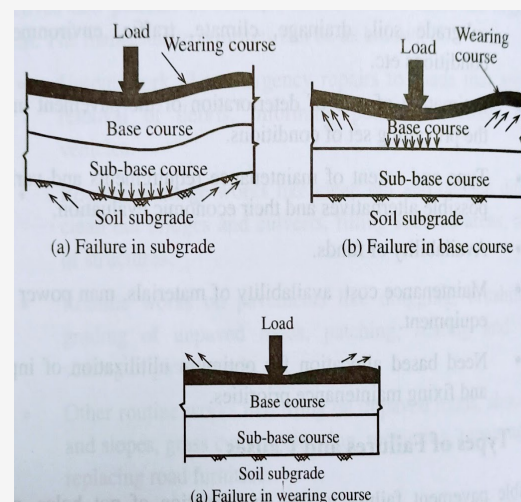


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21

## Flexible Pavement Failure: Failure of sub-base/base course

- Major causes
  - Inadequate stability or strength
    - Poor mix, inadequate thickness, poor quality control
  - Loss of binding action
    - Internal movement of aggregates due to loss of binding action
  - Loss of base course material
    - When it is not covered by wearing course or the wearing course has completely worn out
  - Absence of wearing course or inadequate thickness
  - Failure of wearing course
  - Use of inferior materials and lack of lateral confinement

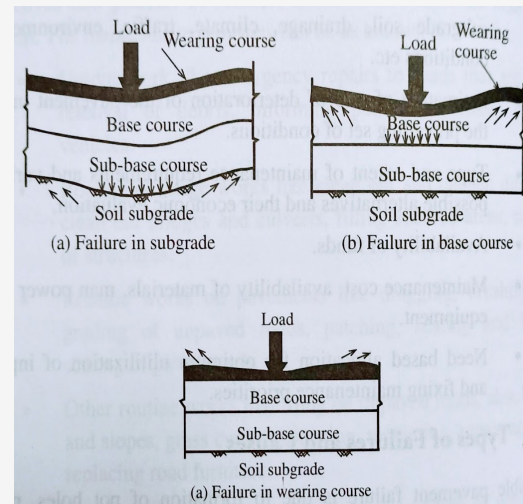


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22

## Flexible Pavement Failure: Failure of Wearing Course

- Major causes
  - Improper mix design
  - Poor quality control
  - Volatilization and oxidation of binder
  - Improper gradation of aggregates
  - Inadequate binder content or inferior type of binder, etc.



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23

## Pavement Distress: Typical failure in flexible pavements

- Alligator cracking
- Bleeding
- Block Cracking
- Corrugation and Shoving
- Joint Reflection Cracking
- Longitudinal Cracking
- Polished Aggregate
- Potholes
- Raveling
- Rutting
- Stripping
- Transverse (Thermal) Cracking

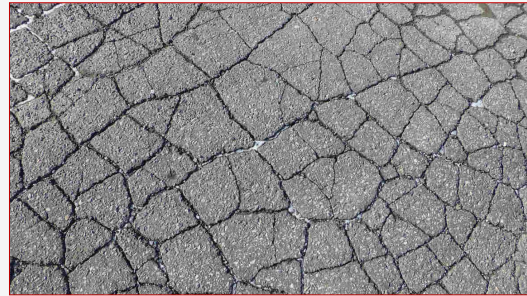
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24

## Pavement Distress: Typical failure in flexible pavements

### • Alligator cracking

- **Description:** A series of interconnected cracks caused by fatigue failure of the surface under repeated traffic loading.
- **Problem:** Roughness, indicator of structural failure, cracks allow moisture infiltration into the base and subgrade, eventually results in potholes and pavement disintegration if not treated.
- **Possible cause:** Decrease in pavement load supporting characteristics, Increase in loading, Inadequate structural design, Poor construction.



### • Repair:

- a) small localised fatigue = remove and replace
- b) large fatigued areas = overlay all over the surface

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25

## Pavement Distress: Typical failure in flexible pavements

### • Bleeding

- **Description:** A film of asphalt binder on the pavement surface. It usually creates a shiny, glass-like reflecting surface that can become sticky when dry and slippery when wet.
- **Problem:** Loss of skid resistance when wet.
- **Possible cause:** Excessive asphalt binder, Low HMA air void content, likely a mix design problem



### Repair:

- a) Minor bleeding can often be corrected by applying coarse sand to blot up the excess asphalt binder.
- b) Major bleeding can be corrected by cutting off excess asphalt with a motor grader.

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26

## Pavement Distress: Typical failure in flexible pavements

### • **Block Cracking**

- **Description:** Interconnected cracks that divide the pavement up into rectangular pieces.
- **Problem:** Allows moisture infiltration, roughness.
- **Possible cause:** Asphalt binder aging, Poor choice of asphalt binder in the mix design.



#### **Repair:**

- a) Low severity cracks (<2 inch)= crack seal
- b) High severity cracks= remove and replace

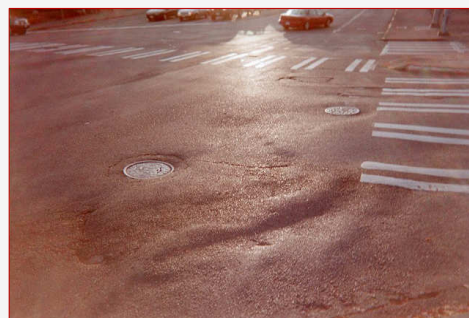
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27

## Pavement Distress: Typical failure in flexible pavements

### • **Corrugation and Shoving**

- **Description:** A form of plastic movement typified by ripples (corrugation) or an abrupt wave (shoving) across the pavement surface.
- **Problem:** Roughness.
- **Possible cause:** Usually caused by traffic action (starting and stopping) combined with an unstable asphalt layer.



#### **Repair:**

- a) Small localised corrugation = remove the distorted surface and patch.
- b) large corrugation= remove and overlay the damaged portion

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28

## Pavement Distress: Typical failure in flexible pavements

### • **Joint Reflection Cracking**

- **Description:** Cracks in a flexible overlay of a rigid pavement. The cracks occur directly over the underlying rigid pavement joints.
- **Problem:** Allows moisture infiltration, roughness.
- **Possible cause:** Movement of the rigid pavement slab beneath the HMA surface because of thermal and moisture changes.



#### **Repair:**

- a) Low severity cracks (<2 inch)= crack seal
- b) High severity cracks= remove and replace

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29

## Pavement Distress: Typical failure in flexible pavements

### • **Longitudinal Cracking**

- **Description:** Cracks parallel to the pavement's centreline or laydown direction. Usually a type of fatigue cracking.
- **Problem:** Allows moisture infiltration, roughness, indicates possible onset of fatigue cracking and structural failure.
- **Possible cause:** Poor joint construction or location, reflective crack from an underlying layer.



#### **Repair:**

- a) Low severity cracks (<2 inch)= crack seal
- b) High severity cracks= remove and replace

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30

## Pavement Distress: Typical failure in flexible pavements

- **Polished Aggregate**

- **Description:** Areas of pavement where the portion of aggregate extending above the asphalt binder is either very small or there are no rough or angular aggregate particles.
- **Problem:** Decreased skid resistance.
- **Possible cause:** Repeated traffic applications.



**Repair:**

Apply a skid-resistant slurry seal or a non-structural overlay.

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31

## Pavement Distress: Typical failure in flexible pavements

- **Potholes**

- **Description:** Small, bowl-shaped depressions in the pavement surface that penetrate all the way through the HMA layer down to the base course.
- **Problem:** Roughness, moisture infiltration.
- **Possible cause:** Generally, potholes are the end result of fatigue cracking.



**Repair:** Patching

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32

## Pavement Distress: Typical failure in flexible pavements

### • Raveling

- **Description:** The progressive disintegration of an pavement layer from the surface downward as a result of the dislodgement of aggregate particles.
- **Problem:** Loose debris on the pavement, roughness, water collecting in the raveled locations resulting in vehicle hydroplaning, loss of skid resistance.
- **Possible cause:** Loss of bond between aggregate particles and the asphalt binder .
- Mechanical dislodging by certain types of traffic (studded tires, snowplough blades or tracked vehicles).



#### **Repair:**

- a) small raveled areas= patching
- b) large ravelled areas= remove and overlay

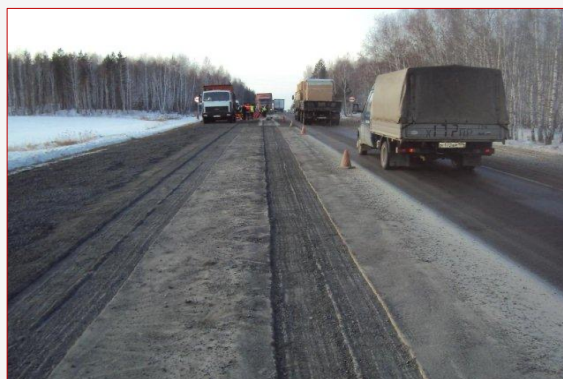
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33

## Pavement Distress: Typical failure in flexible pavements

### • Rutting

- **Description:** Surface depression in the wheel path.
- **Problem:** Ruts filled with water can cause vehicle hydroplaning, can be hazardous because ruts tend to pull a vehicle towards the rut path as it is steered across the rut.
- **Possible cause:** Consolidation or lateral movement of the materials due to traffic loading.



**Repair:** Slight ruts (< 1/3 inch deep) can generally be left untreated. Pavement with deeper ruts should be levelled and overlaid.

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34

## Pavement Distress: Typical failure in flexible pavements

### • **Transverse Cracking**

- **Description:** Cracks perpendicular to the pavement's centreline or laydown direction. Usually a type of thermal cracking.
- **Problem:** Allows moisture infiltration, roughness.
- **Possible cause:** Shrinkage of the HMA surface due to low temperatures or asphalt binder hardening.



#### **Repair:**

- a) Low severity cracks (<2 inch)= crack seal
- b) High severity cracks= remove and replace

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35

## Pavement Distress: Typical failure in flexible pavements

### • **Stripping**

- **Description:** The loss of bond between aggregates and asphalt binder that typically begins at the bottom of the HMA layer and progresses upward.
- **Problem:** rutting, shoving/corrugations, raveling, or cracking.
- **Possible cause:** Poor aggregate surface chemistry, Water in the HMA causing moisture damage.



**Repair:** The stripped pavement needs to be removed and replaced after correction of any subsurface drainage issues.

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36

## Pavement Distress: Typical failure in rigid pavements

- Joint Spalling
- Faulting
- Shrinkage Cracking
- Pumping
- Punch out
- Linear Cracking
- Durability Cracking
- Corner Break

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37

## Pavement Distress: Typical failure in rigid pavements

- **Joint Spalling**

- **Description:** Joint spalling is the breakdown of the slab edges within 2 feet (60 cm) of the side of the joint.
- **Possible cause:**
  - Joints subjected to excessive stress due to high traffic or by infiltration of any incompressible materials.
  - The joint that are constructed with weak concrete.
  - Joint that is accumulated with water that results in rapid freezing and thawing.



**Repair:**

Less than 75mm = partial depth patch  
 >= 75mm = full depth patch

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38

## Pavement Distress: Typical failure in rigid pavements

### • **Faulting**

- **Description:** Settlement or faulting is a difference in elevation at a joint or crack caused by upheaval or non-uniform consolidation of the subgrade or subbase material.
- **Possible cause:**
  - Settlement of the pavement that is caused due to soft foundation.
  - The pumping or the erosion of material under the pavement, resulting in voids under the pavement slab causing settlement.
  - The temperature changes and moisture changes that cause curling of the slab edges.



#### **Repair:**

- Faulting heights of less than 3 mm (0.125 inch) need not be repaired.
- Faulting in an undoweled between 3 mm (0.125 inch) and 12.5 mm (0.5 inch) is a candidate for a dowel bar retrofit.
- Faulting in excess of 12.5 mm (0.5 inches) generally warrants total reconstruction.

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39

## Pavement Distress: Typical failure in rigid pavements

### • **Shrinkage Cracking**

- **Description:** These are hairline cracks that are less than 2m in length. They do not cross the entire slab.
- **Possible cause:**
  - These are caused due to higher evaporation of water due to higher temperature cracks.
  - Improper curing can also create shrinkage cracks in rigid pavements.



#### **Repair:**

- In mild to moderate severity situations, the shrinkage cracks can be sealed and the slab should perform adequately.
- In severe situations, the entire slab may need replacement.

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40

## Pavement Distress: Typical failure in rigid pavements

### • Pumping

- **Description:** Movement of material underneath the slab or ejection of material from underneath the slab as a result of water pressure.
- **Possible cause:** High water table, poor drainage, and panel cracks or poor joint seals that allow water to infiltrate the underlying material.



### **Repair:**

- First, the pumping area should be repaired with a full depth patch.
- Dowel bars across any significant transverse joints created by the repair.
- The source of water or cause of poor drainage should be addressed.

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41

## Pavement Distress: Typical failure in rigid pavements

### • Punchout

- **Description:** A localized area of concrete slab that is broken into pieces will be named as punch out distress.
- **Possible cause:** Heavy repeated loads, the slab thickness inadequacy, the foundation support loss or the construction deficiency like honeycombing.



### **Repair:**

- Full-depth patch.

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42

## Pavement Distress: Typical failure in rigid pavements

### • **Linear Cracking**

- **Description:** Linear cracks not associated with corner breaks or blowups that extend across the entire slab.
- **Possible cause:** Usually a combination of traffic loading, thermal gradient curling, moisture stresses and loss of support.



#### **Repair:**

- Slabs with a single, narrow linear crack may be repaired by crack sealing.
- More than one linear crack generally warrants a full-depth patch.

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43

## Pavement Distress: Typical failure in rigid pavements

### • **Durability Cracking**

- **Description:** Series of closely spaced, crescent-shaped cracks near a joint, corner or crack.
- **Possible cause:** It is caused by freeze-thaw expansion of the large aggregate within the PCC slab.



#### **Repair:**

- A full-depth patch or partial-depth patch can repair the affected area.
- It does not address the root problem and will not, of course, prevent "D" cracking elsewhere.

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44

## Pavement Distress: Typical failure in rigid pavements

- **Corner Break**

- **Description:** A crack that intersects the PCC slab joints near the corner.
- **Possible cause:** Severe corner stresses caused by load repetitions combined with a loss of support.
- Poor load transfer across the joint.
- Curling stresses and warping stresses.



**Repair:**

- Full-depth patch.

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45

## Types and Methods of Pavement Repair

- Type and extent of maintenance depends on:
  - Serviceability standard
  - Funds available
  - Priorities for maintenance operation

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46

## Types and Methods of Pavement Repair

### A. Maintenance of earthen roads

- Usual damages on the earthen roads
  - Formation of dust in dry weather
  - Formation of longitudinal ruts along wheel paths
  - Formation of cross ruts after monsoon due to surface water

#### **Repair:**

- Frequent sprinkling of water
- Use of dust palliatives
- Spreading of moist soil
- Reshaping of roadway during and after monsoon
- A surface treatment or stabilized layer may be provided on the top

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47

## Types and Methods of Pavement Repair

### B. Maintenance of WBM roads

- Usual damages of the surface are due to fast moving and heavy vehicles
  - Formation of dust in dry weather
  - Formation of mud during rainy season
  - Ruts and potholes formation on the road surface

#### **Repair:**

- Spreading of a thin layer of moist soil binder periodically, usually offer rainy season
- Use of dust palliatives
- Providing a bituminous surface dressing over WBM
- Patch repair woks on rut and potholes
- Resurfacing after the period of useful life

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48

## Types and Methods of Pavement Repair

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### C. Maintenance of Bituminous Surfaces

- Patch Repair
  - For damaged portion, removing pot holes, removing surface inequalities, removing waviness of surface
  - Done in localized areas using cold mix
  - Cut to rectangular shape and excavate till sound material is encountered
  - Clean the hole of loose materials, dust and water before patch is applied
  - Apply prime coat on bottom and sides of cut portion
  - Apply patching mixture just after applying prime coat
  - Material in pot hole should be placed in height of 6 cm
  - Finished surface should be slightly higher than normal surface

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49

## Types and Methods of Pavement Repair

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### C. Maintenance of Bituminous Surfaces

- Resurfacing
  - For totally worn out pavement surface
  - For inadequate thickness of pavement, overlay is provided
  - For damaged surface, new surface course is provided
- Maintenance of waves and corrugations
  - Another layer of surface course may be laid after laying a levelling course
  - If sub surface moisture is problem, drainage should be provided
  - If it is due to improper compaction of gradation of underlying layer, complete reconstruction is required
  - If failure is due to highly expansive subgrade clay, suitable modifying agent should be used

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50

## Types and Methods of Pavement Repair

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### D. Maintenance of Cement Concrete Roads

Only few maintenance works are required for well designed cement concrete roads.

Formation of cracks is main defect in C/C pavement.

Maintenance works in C.C. pavement

- Treatment of cracks
- Maintenance of joints

There are two types of cracks

- Temperature cracks: Initially fine cracks or hair cracks formed across the slab due to temperature stresses.
- Structural cracks: Near the edge and corner region of the slab, due to combined effect of wheel load and warping stress.

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51

## Maintenance of drainage structure

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Drainage system consists of

- Surface drainage system
- Ditches
- Sub-surface drainage system, cross drainage structures
- Good surface drainage should be maintained in pavement surface
- Shoulders should be maintained flush with pavement and smooth enough to provide free flow of water
- Side drains should be kept 30-40 cm below the top of subgrade and sufficiently large to carry runoff
- All components should be cleaned and inspected for proper functioning

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52

## Maintenance of shoulders

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- Most common defect is depression in shoulder along the edge of pavement
- Maintained to remain in full contact with pavement edge
- Development of turf
- Holes and ruts repaired by filling and grass re-establishments
- Periodic reshaping and re-tamping

## Maintenance of retaining wall

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- Regular inspection to detect any defects
- Drain holes should be kept clean
- Erosion at base of wall should be prevented

## Maintenance of miscellaneous items

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- Maintenance of cut and fill slopes by stabilizing vegetable growth
- Rock slope should be watched for loose rocks and scaled if necessary

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55

## Pavement Condition Evaluation

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- To assess the existing conditions and make decision to what extent the pavement fulfils the intended requirements so that the maintenance and strengthening job can be planned in appropriate time.
- Covers a thorough study of various factors as:
  - Sub-grade support
  - Pavement composition history, pavement materials, quality of construction, pavement type, pavement design and specification
  - Traffic loading (Present)
  - Environmental condition

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56

## Methods of pavement evaluation

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- Structural evaluation of pavements
  - To evaluate load carrying capacity of the pavement
  - Carried out by plate bearing test
  - Structural capacity of the pavement may be assessed by load carried out at a specified deflection or by the amount of deflection at a specified load
  - Benkelman beam is the most commonly used equipment for the assessment of flexible pavement overlay thickness requirement

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57

## Methods of pavement evaluation

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- Evaluation of pavement surface condition
  - To evaluate the surface distress index (SDI), pavement roughness index (RI) and skid resistance.
  - Surface Distress Index: Visual assess on the distress levels of the pavement, i.e. minor and major
 

SDI Value	Condition
0 – 1.7	Good
1.8 – 3.0	Fair
3.1 – 5.0	Poor
  - Roughness Index (m/km): Measured by Merlin cycle or with bump integrator mounted in the vehicle
  - Skid resistance: By skid resistance tester
  - Surface distress: Indication of poor or unfavorable pavement performance of signs of impending failure, any unsatisfactory performance of a sort of failure as: Fracture a) Cracking b) Spalling, Distortion: Deformation like rutting, corrugation, shoving and Disintegration: Stripping, raveling.

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58

## Strengthening of Existing Pavement

- Overlay
  - Providing additional thickness of the pavement in one or more layers over existing pavement
- Types of overlay
  - Flexible overlay over flexible pavement
  - Rigid overlay over flexible pavement
  - Flexible overlay over rigid pavement
  - Rigid overlay over rigid pavement
- Design of overlay
  - Conventional design method
  - Non destructive testing method like Benkelman beam deflection method

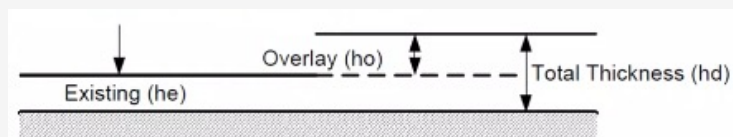
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59

## Flexible Overlay over Flexible Pavement (Conventional Design Method)

- Total pavement thickness required is worked out based on subgrade CBR and design traffic volume
- Existing pavement thickness is found from test pit dug along wheel path
- Overlay thickness required is

$$h_o = h_d - h_e$$



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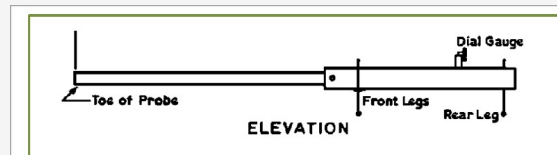
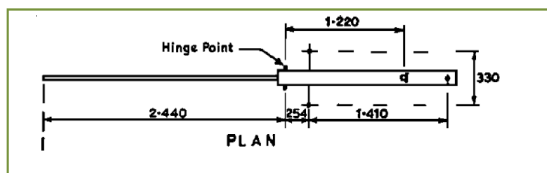
60

## Overlay design by Benkelman Beam Method

- Equipment

- Benkelman Beam

- Consist of slender beam of length 3.66 m
    - Pivoted at 2.44 m from probe
    - Distance from pivot to dial gauge 1.22 m
    - Distance from pivot to front leg 25 cm
    - Distance from pivot to rear leg 1.66 m



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61

## Overlay design by Benkelman Beam Method

- Equipment

- Loaded truck

- Rear axle load 8170 kg (dual tyre)
    - Spacing between tyres (30-40 mm)
    - Inflation pressure 5.6 kg / sq.cm.

- Accessories

- Tyre pressure measuring gauge
    - Thermometer (0-100°C) with 1° division
    - Measuring tape, etc.



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62

## Overlay design by Benkelman Beam Method

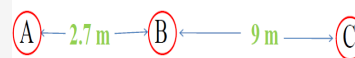
- IRC have formulated guidelines for design of overlays on flexible pavements.
- The method is based on measurement of pavement deflection by the Benkelman beam.
  - The stretch of road length to be evaluated is first surveyed to assess the general condition of the pavement with respect to the ruts, cracks and undulations.
  - The pavement stretches are classified and grouped into different classes (of length not less than 500m) such as good, fair and poor for the Benkelman Beam studies.
  - The loading points on the pavement for deflection measurements are located along the wheel paths, on a line 0.9m from the pavement edge in the case of pavements of total width more than 3.5m, the distance from the edge is reduced to 0.6m on narrow pavements.
  - A minimum of 10 deflection observations may be taken on each of the selected stretch of pavement.

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63

## Overlay design by Benkelman Beam Method

- The truck is driven slowly parallel to the edge and stopped such that the left side rear dual wheel is centrally placed over the first point for deflection measurement.
- The probe end of the Benkelman beam is inserted between the gap of the dual wheel and is placed exactly over the deflection observation point..
- The initial dial gauge reading  $D_o$  is noted.
- The truck is moved slowly through a distance of 2.7 m from the point and stopped. The intermediate dial gauge reading  $D_i$  is noted.
- The truck is then driven forward through a further distance of 9.0 m and the final dial gauge reading  $D_f$  is recorded.
- The three-dial gauge reading  $D_o$ ,  $D_i$ , and  $D_f$  form a set of readings at one deflection point under consideration. The deflection observations are continued at all the desired points.
- The difference between the final and the initial dial readings and also the difference between the intermediate and initial readings are both calculated.



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64

## Overlay design by Benkelman Beam Method

- If the difference of values lies within 0.025 mm, then the actual pavement deflection is twice the final differential reading.
- If not, apparent pavement deflection is defined as twice the final differential reading.
- True pavement deflection = Apparent pavement deflection + 2.91\*twice the difference between the final and intermediate dial readings.
- The deflection value D with leg correction at any point is given by one of the following two conditions

$$D = 0.02(D_o - D_f) \text{ mm} \quad \text{If } D_i - D_f \leq 0.025 \text{ mm}$$

$$D = 0.02(D_o - D_i) + 0.02K(D_i - D_f) \text{ mm} \quad \text{If } D_i - D_f > 0.025 \text{ mm}$$

$$K = \frac{3d - 2e}{f}$$

where, d = distance between the bearing of the beam and the rear adjusting leg

e = distance between the dial gauge and rear adjusting leg

f = distance between the front and rear legs

The value of K is to be determined for every make of the beam and generally this value in India is found to be 2.91.

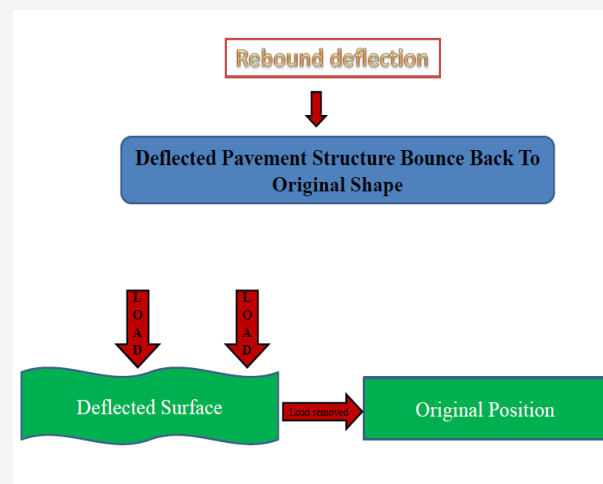
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65

## Overlay design by Benkelman Beam

### Determination of Rebound Deflection Values

- If  $D_i - D_f \leq 2.5$  divisions or 0.025 mm
  - $D = 2 (D_o - D_f)$  divisions of 0.01 mm units,  
i.e.  $0.02 (D_o - D_f)$  mm
- If  $D_i - D_f > 2.5$  divisions, leg correction is required
  - $D = 2 (D_o - D_f) + 2K (D_i - D_f)$
- For Benkelman beams made in India,  $K = 2.91$ 
  - $D = 0.02 (D_o - D_f) + 0.0582 (D_i - D_f)$  mm



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66

## Overlay design by Benkelman Beam Method

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- The mean value of the deflections at n points is given by

$$\bar{x} = \frac{\sum x}{n}$$

- The standard deviation of the deflection value is given by

$$\sigma = \sqrt{\frac{\sum(x - \bar{x})^2}{n-1}}$$

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67

## Correction for pavement temperature and subgrade moisture variation

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- The IRC suggested a standard pavement temperature of 35°C and a correction factor of 0.0065 mm per 1°C to be applied for the variation from this standard pavement temperature.
  - The correction will be negative when the pavement temperature is above 35°C and positive when it is lower.
  - However, it is suggested that deflection studies should be carried out when the pavement temperature is above 30°C, if this correction factor is to be applied.
  - No correction for thin bituminous surfacing, severe cracking in pavement, stripped bituminous layer.
- The seasonal variations cause variation in subgrade moisture.
  - As it is always not possible to conduct deflection studies during monsoon season when subgrade moisture content is the highest.
  - IRC has suggested that tentative correction factor of 2.0 for clayey soil and 1.2 to 1.3 for sandy subgrade soils may be adopted if the deflection observations are made during dry seasons.

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68

## Numerical

S.N.	Initial dial gauge reading	Intermediate dial gauge reading	Final dial gauge reading	Final – Intermediate ( $D_f - D_i$ )	Actual Deflection
1	0.00	0.54	0.56	0.02	$2*(0.56-0.00) = 1.12$
2	0.00	0.54	0.54	0.00	$2*0.54 = 1.08$
3	0.00	0.53	0.53	0.00	$2*0.53 = 1.06$
4	0.00	0.50	0.51	0.01	$2*0.51 = 1.02$
5	0.00	0.48	0.49	0.01	$2*0.49 = 0.98$
6	0.00	0.46	0.49	0.03	1.15*
7	0.00	0.50	0.51	0.01	$2*0.51 = 1.02$
8	0.00	0.57	0.57	0.00	$2*0.57 = 1.14$
9	0.00	0.54	0.56	0.02	$2*0.56 = 1.12$
10	0.00	0.53	0.54	0.01	$2*0.54 = 1.08$

$$* 2*0.49 + 2*2.91(0.49-0.46) = 1.15$$

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69

## Allowable deflection as per IRC guidelines

Design traffic (com.veh/day)	Allowable deflection, mm
150-450	1.50
450-1500	1.25
1500-4500	1.00

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70

## Allowable deflection as per MOST research

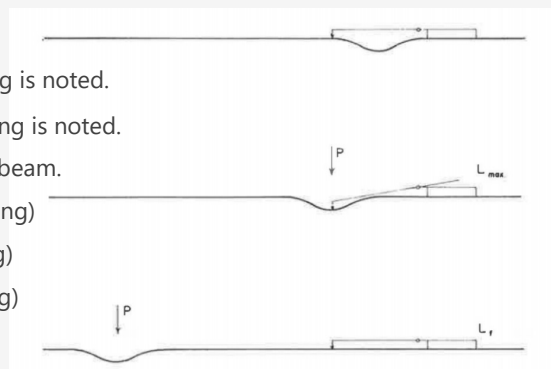
Design traffic million standard axle	Allowable deflection, mm
Upto 2	1.00
2-10	0.80
10-30	0.75
>30	0.70

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71

## WASHO Method

- Truck is initially 1.2m behind selected point.
- Probe end is at the selected point and initial reading is noted.
- Truck is moved forward to selected point and reading is noted.
- Truck is moved forward at least 3 m past the tip of beam.
- Maximum deflection =  $2(\text{max reading} - \text{initial reading})$
- Rebound deflection =  $2(\text{max reading} - \text{final reading})$
- Residual deflection =  $2(\text{final reading} - \text{initial reading})$



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72

## Numerical

Wheel position	Dial reading (mm)
1.2m behind the selected point	0.06
At selected point	0.46
3m in front of the selected point	0.08

- Maximum deflection = 2(max reading – initial reading) = 2(0.46-0.06) = 0.8mm
- Rebound deflection = 2(max reading – final reading) = 2(0.46-0.08) = 0.76mm
- Residual deflection = 2(final reading – initial reading) = 2(0.08-0.06) = 0.04mm

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73

## Design of Overlay/Overlay Thickness Design – Ruiz's equation

- After deciding the allowable deflection  $D_a$  in the pavement under the design load, the overlay thickness required may be calculated using Ruiz's equation as

$$h_o = \frac{R}{0.434} \log \frac{D_c}{D_a}$$

where,  $h_o$  = thickness of bituminous overlay in cm

$R$  = deflection reduction factor depending upon the overlay material (usually 10-15, average 12)

$D_a$  = allowable deflection which depends upon the pavement type and the desired design life, value ranging from 0.75-1.25 mm

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74

## Design of Overlay

- If the characteristics deflection is greater than the allowable deflection, the thickness of the overlay is then determined by the following formula.

$$h = R \log \frac{\Delta_0}{\Delta}$$

where,  $h$  = thickness of granular overlay (WBM) in mm

$\Delta_0$  = characteristics deflection

$\Delta$  = allowable deflection

The latest IRC guidelines (1997) gives a set of curves for determining the overlay thickness. The thickness is in terms of bituminous macadam construction. In case other materials are used, the following conversion factors are adopted.

1 cm of bituminous macadam = 1.5 cm of WBM  
= 0.7 cm of DBM/BC/SDBC

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75

## Analysis of Data

Over lay design for a given section is based not on individual deflection value but on statistical analysis of all measurements in the section

Mean deflection (M) ( $\bar{x} = \frac{\sum x}{n}$ )

Standard deviation (S) ( $\sigma = \sqrt{\frac{\sum(x - \bar{x})^2}{n-1}}$ )

Characteristics deflection

$D_c = M + 2S$  For NH and SH

$D_c = M + S$  For other roads

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76

## IRC Formula

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- Design of overlay thickness equivalent to granular material of WBM layer is given by

$$h_o = 550 \log_{10} \frac{D_c}{D_a} \text{ mm}$$

where,  $h_o$  = thickness of granular or WBM overlay in mm

$D_c = (D + \sigma)$  after applying the corrections for pavement temperatures and subgrade moisture

$D_a = 1.00, 1.25, 1.50$  mm if projected traffic is 1500-4500, 450-1500 and 150-450 respectively.

$$A = P (1+r)^{n+10} \text{ design traffic}$$

Note: When superior materials are used in the overlay layer, the thickness value has to be suitably decreased taking equivalency factor of the material. When bituminous concrete or bituminous macadam with bituminous surface course is provided, an equivalency factor of 2.0 is used as suggested by IRC to decide the actual overlay thickness required. Thus, the overlay thickness would be  $h_o/2$ .

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77

## Numerical

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- Benkelman Beam deflection studies were carried out on 15 selected points on a stretch of flexible pavement during summer season. The deflection values obtained in mm are given below. If the present traffic consists of 750 commercial vehicles per day, determine the thickness of bituminous concrete overlay required, if the pavement temperature during the test was 39°C and the correction factor for subsequent increase in subgrade moisture content is 1.3. Assume annual growth rate of traffic as 7.5%. Adopt IRC guidelines.

1.4, 1.32, 1.25, 1.35, 1.48, 1.6, 1.65, 1.55, 1.45, 1.40, 1.36, 1.46, 1.50, 1.52, 1.45 mm

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78

## Numerical

- Mean Deflection  $D = \frac{\sum D}{n} = \frac{21.74}{15} = 1.45 \text{ mm}$
- Standard deviation  $\sigma = \sqrt{\frac{\sum(x-x)^2}{n-1}} = 0.107 \text{ mm}$
- Characteristics deflection  $D_c = D + \sigma = 1.45 + 0.107 = 1.557 \text{ mm}$
- Deflection after temperature correction =  $1.557 - (39-35)*0.0065 = 1.531 \text{ mm}$
- Corrected deflection for subgrade moisture =  $1.531*1.3 = 1.99 \text{ mm}$
- Assuming the number of years after the last traffic count before the construction of overlay as  $n = 2$ , design traffic A is given by:  $A = P(1+r)^{n+10} = 750(1+0.075)^{12} = 1768 \text{ commercial vehicles/day}$
- $D_a = 1.0 \text{ mm}$
- $h_o = 550 \log_{10} \frac{D_c}{D_a} \text{ mm} = 550 \log_{10} \frac{1.990}{1.00} = 164.4 \text{ mm}$
- Assuming an equivalency factor of 2 for bituminous concrete, design thickness =  $\frac{h_o}{2} = 8.25 \text{ cm}$

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79

## Rigid Overlay Over Rigid Pavement

- Since perfect bond cannot be developed, two types of interface are possible
  - By making old surface rough
  - Separating two slabs at interface by thin bituminous layer

- Overlay thickness is given by

$$h_o = (h_d^a - X h_e^b)^n$$

$h_o$  = rigid overlay thickness

$h_d$  = design thickness

$h_e$  = existing pavement thickness

Agency	Existing Pavement Condition	X		
Crops of Engineers and PCA	(i) Good condition	1		
	(ii) Initial cracking	0.75		
	(iii) Badly cracked	0.35		
Agency	Construction Method	a	b	N
Crops of Engineers	(i) Poured directly on old pavement	1.4	1.4	1/1.4
	(ii) Levelling course	2.2	2	1/3
PCA	(i) as (i) above	1.87	2	1/2
	(ii) as (ii) above	2	2	1/2

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80

## Flexible Overlay Over Rigid Pavement

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Wheel load is distributed through larger area hence reducing wheel load stress

Reduction of temperature differential → decreased warping stresses

Useful life can be increased

$$h_f = 2.5(Fh_d - h_e)$$

$h_f$  = rigid overlay thickness

$h_d$  = design thickness

$h_e$  = existing pavement thickness

F = factor depending upon modulus of existing pavement

For calculating the thickness of bituminous overlay, the following relationship is used

$$h_b = \frac{h_i}{1.50}$$

$$h_b = 1.66 (Fh_d - h_e)$$

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81

## Rigid Overlay Over Flexible Pavement

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- Plate bearing test is conducted on existing flexible pavement and modulus of subgrade reaction K is calculated
- Design is made using this value of K

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82

Thank You!

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