UPPSC-AE 2020

Uttar Pradesh Public Service Commission

Combined State Engineering Services Examination

Assistant Engineer

Civil Engineering

Transportation Engineering

Well Illustrated **Theory** *with*
Solved Examples and **Practice Questions**

MADE EASY Publications

Transportation Engineering

Contents

❍❍❍❍

CHAPTER 6

Highway Maintenance

6.1 Need for Highway Maintenance

Road maintenance is one of the important components of the entire road system. The maintenance operations involve the assessment of road condition, diagnosis of the problem and adopting the most appropriate maintenance steps.

6.2 General Causes of Pavement Failures

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

(a) Defects in the quality of materials used.

(b) Defects in construction method and quality control during construction.

(c) Inadequate surface or subsurface drainage in the locality resulting in the stagnation of water in the subgrade or in any of the pavement layers.

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

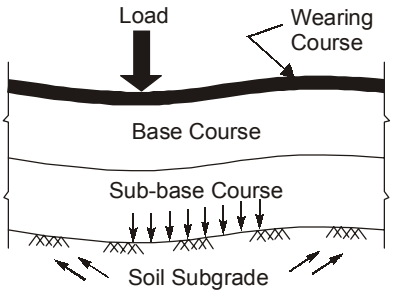
(e) Settlement of foundation of embankment of the material itself.

(f) Environment factors including heavy rainfall, soil erosion, high water table, snow fall, frost action, etc.

6.3 Failures in Flexible Pavements

6.3.1 Failure in Subgrades

- 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 vehicles is due to insufficient bearing capacity or a shear failure in subgrade soil.



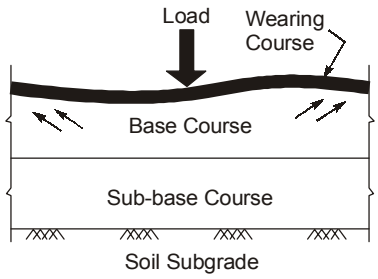
Failure in Subgrade

- The failure of subgrade may be attributed due to inadequate stability and excessive stress application.

6.3.2 Failures in Sub-base or Base Courses

Following are the chief types of sub-base or base course failures:

1. Inadequate stability or strength
2. Loss of binding action
3. Loss of base course materials
4. Inadequate wearing course
5. Use of inferior materials and crushing of base course materials.
6. Lack of lateral confinement for the granular base course.

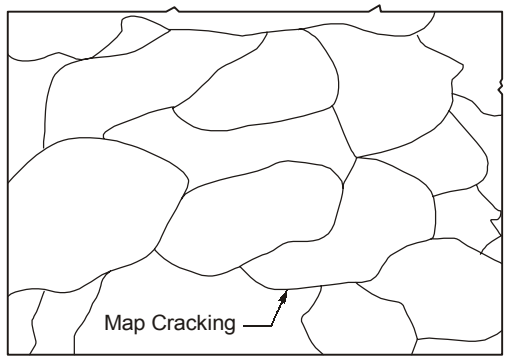


Failure in Base Course

6.3.3 Type of Flexible Pavement Failures

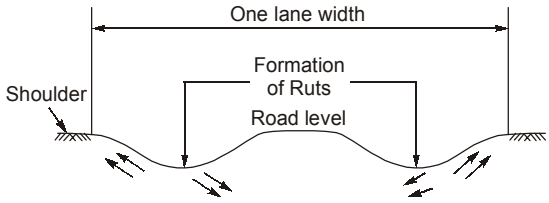
Alligator (Map) Cracking

- This is the most common type of failure and occurs due to relative movement of pavement layer materials.
- This may be caused by the repeated application of heavy wheel loads resulting in fatigue failure or due to the moisture variations resulting in swelling and shrinkage of subgrade and other pavement materials.
- Localized weakness in the underlying base course would also cause cracking of the surface course in this pattern.



Consolidation of Pavement Layers

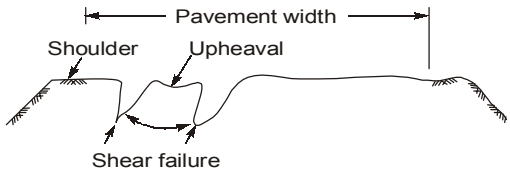
- Formation of ruts are mainly attributed to the consolidation of one or more layers of pavement.
- The repeated application of loads along the same wheel path cause cumulative deformation resulting in consolidation deformation longitudinal ruts.



Ruts

Shear Failure and Cracking

Shear failures are associated with the inherent weakness of the pavement mixtures, the shearing resistance being low due to inadequate stability or excessively heavy loading.



Shear failure cracking in rigid pavement

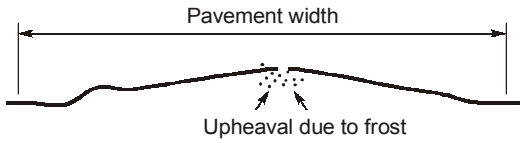
Do you know? *The shear failure causes upheaval of pavement materials by forming a fracture or cracking.*

Longitudinal Cracking

- Due to frost action and differential volume changes in subgrade longitudinal cracking is caused in pavement traversing through the full pavement thickness.
- Settlement of fill and sliding of side slopes also would cause this type of failure.

Frost Heaving

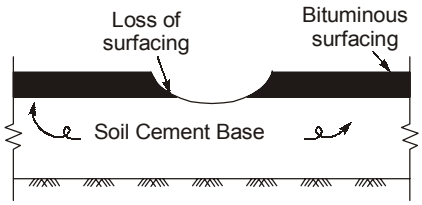
- In shear failure, the upheaval of portion of pavement is followed with a depression.
- In the case of frost heaving, there is mostly a localized heaving-up pavement portion depending upon the ground water and climatic conditions.



Frost heave failure

Lack of Binding with Lower Layer

- Slipping occurs when the surface course is not keyed/bound with the underlying base. This results in opening up and loss of pavement materials forming patches or pot holes.
- Such conditions are more frequent in case when the bituminous surfacing is provided over the existing cement concrete base course or soil-cement base course.

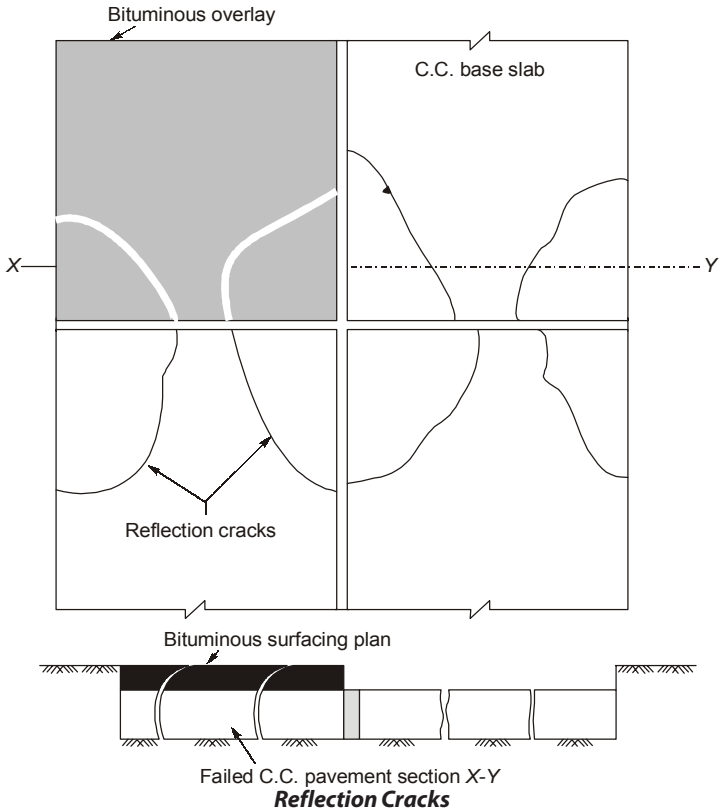


Failure due to lack of binding

Do you know? This condition is more pronounced when the prime/tack coat in between two layers is lacking.

Reflection Cracking

- This type of cracking is observed in bituminous overlays provided over existing cement concrete pavements.
- The crack pattern as existing in cement concrete pavements are mostly reflected on bituminous surfacing in the same pattern.
- Structural action of the total pavement section is not much influenced by the presence of reflection cracks but since the cracks appear at the surface, these allow surface water to seep through and cause damage to the soil subgrade or result in mud pumping.



Reflection Cracks

Failure in Cement Concrete Pavements

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

1. Deficiency of pavement materials
2. Structural inadequacy of the pavement system

Deficiency of Pavement Materials

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

1. Soft aggregates
2. Poor workmanship in joint construction
3. Poor joint filler and sealer material
4. Poor surface finish
5. Improper and insufficient curing

The various defects that creep in due to the above are:

1. Disintegration of cement concrete
2. Formation of cracking
3. Spalling of joints
4. Poor riding surface
5. Slippery surface
6. Formation of shrinkage cracks
7. Ingress of surface water and further progressive failures.

Structural Inadequacy of Pavement System

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

1. Inadequate pavement thickness
2. Inadequate subgrade support and poor subgrade soil
3. Incorrect spacings of joints.

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

1. Cracking of slab corners
2. Cracking of pavements longitudinally.
3. Settlement of slabs
4. Widening of joints
5. Mud pumping

6.4 Typical Rigid Pavement Failures

6.4.1 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.

6.4.2 Shrinkage Cracks

During the curing operation of cement concrete pavements immediately after the construction, the shrinkage cracks normally develop.

6.4.3 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 develops cracking at the edges in an irregular pattern.
- Hinge joints are generally provided for relieving the slabs of warping stresses.

6.4.4 Mud Pumping

- Mud pumping is recognized 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 are the factors which cause the mud pumping:
  1. Extent of slab deflection 2. Type of subgrade soil 3. 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 repeated 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 fine grained type, it holds water and forms the soil slurry or soil suspension in water or the mud.

6.5 Water Bound Macadam Road

- WBM roads are damaged rapidly due to the heavy mixed traffic and adverse climatic conditions. In dry weather dust is formed and during rains mud is formed. The steel tyred bullock carts cause severe wear and tear to the WBM surface.
- Dust nuisance can be effectively prevented by providing bituminous surface dressing course over WBM pavement. However temporary measures include spraying of dust palliatives.
- Pot holes and ruts formed should be patched up. The patch repair work is carried out by first cutting out a rectangular shape of the defective area to remove the stone up to the affected depth.
- It may be used as a sub-base, base-course or surfacing courge.
- The thickness of each compacted layer of WBM ranges from 7.5 cm to 10 cm depending on the size and gradation of aggregates used.
- Binding material in WBM: Kankar modules, gravel or lime stone dust.
- It prevents travelling of stones.
- If WBM is surface course then plasticity index of binding material shall be 4% to 9%.
- If used as base course or sub-base course with bituminous surfacing, plasticity index shall be less than 6%.

6.6 Bituminous Pavement

6.6.1 Surface Treatment:

(a) **Prime coat:** The first application of Bitumen on an existing or new WBM layer.

- A bitumen primer is a low viscosity cutback,

ISI recommends: RC - 0, MC - 1 and SC - 1 as Primers.

Function:

- To plug the capillary voids and water proof the existing base.
- It provides adhesion betwen new and old surfaces.
- It coats and blends dust and loose particles thereby hardening and toughening the surface.

(b) **Tack coat:** A bituminous treatment recommended when bituminous surfacing is done on and already existing black top road or over existing CC pavement.

(c) **Surface Dressing:** It is done in one or two layers and accordingly called single coat or double coat surface dressing. It includes the application of a thin layer of bitumen followed by cover material of stone clippings which is then rolled.

Purpose: To prevent removal of binding material between the stones in WBM road.

(d) **Seal coat:** A final thin coat over certain previous bituminous pavements or over an existing wornout bituminous pavement.

Purpose:

- To water proof the surface
- To develop skid resistance
- To provide a more desirable surface texture
- To enliven an existing dry or weathered surface

6.6.2 Grouted or Penetration Macadam:

(a) **Semi grouted macadam:** A bituminous binder applied in fluid state to partially compacted aggregate layer and penetrates to only half of depth

(b) **Fully grouted macadam:** If bituminous binder penetrates to full depth of aggregate layer, adopted in regions of very high rainfall.

6.6.3 High Type Bituminous Pavement:

- There are basically hot premixed surface.
- Premixing consumes less bitumen but results in more dense and stable layers.

(a) **Bitumen Macadam:**

- A premix treatment laid in thickness of 5 cm to 7.5 cm used for base course construction.
- Materials used: Bitumen, coarse aggregate and fine aggregate.
- As per IRC, it is equivalent to 1.5 times that of WBM.

(b) **Bituminous concrete or Asphaltic concrete:** A premix of coarse aggregate, fine aggregate, mineral filler (lime or cement) and bitumen. It results into very dense, stable resilient, water proof, dust proof and smooth riding surface.

(c) **Sheet asphalt or Rolled asphalt:** Carpet sand, bitumen mix containing no coarse aggregate and is used for a wearing course.

(d) **Mastic asphalt:** A mixture of bitumen, fine aggregate and filler in suitable proportions which yields void less and impermeable mass.

(c) **Bituminous carpet:** A premix of bitumen, stone chippings 10 to 12 mm with a premixed sand-bitumen seal coat to 25 mm thick. Recommended for surface course layer.

6.7 Type of Pavement Defects

1. **Distortion:**
   - Any deviation in the pavement surface from its original shape.
2. **Distress:** Any indication of poor or unfavourable pavement performance or sign of impending failure.
3. **Failures:** Two types
   (i) Structural failure:
   - Collapse of the entire pavement structure

   (ii) Functional failure:
   - Pavement is not able to serve the purpose for which it is intended without causing discomfort to users and vehicles on account of the vehicle.
4. **Roughness:** Irregularities in the pavement surface that adversely affect the riding quality of the vehicle.
5. **Stripping:** Separation of bituminous films from aggregate particles in the presence of moisture.

6.8 Pavement Evaluation

- There are two approaches of pavement evaluations
  (i) Structural evaluation of pavements (ii) Evaluation of pavement surface condition
- Structural evaluation of both flexible and rigid pavement may be carried out by plate bearing test.
- The performance of a flexible pavement is related to be elastic deflection under loads or its rebound deflection. **Benkelmann beam** is used for measurement of transient deflection.
- The pavement unevenness may be measured using **unevenness indicator**, **profilograph profilometer** or **roughometer**.
- Unevenness index of the surface in cm/km length of road may be called **bump integrator** or **unevenness integrator**.
- The pavement serviceability concept was introduced at the **AASHO** Road Test for comparing relative performance of various test sections during 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.

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)

6.9 Overlay Thickness Design

- According to Ruiz's equation, overlay thickness h_o in cm is given by:

$$h_o = \frac{R}{0.434}\log_{10}\frac{D_c}{D_a}, \text{m}$$

where, h_o = Thickness of bituminous overlay in cm, R = Deflection reduction factor depending on the overlay material.

The Indian Road Congress suggests the following formula.

$$h_o = 550 \log_{10}\frac{D_c}{D_a}, \text{mm} \qquad ...(1)$$

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

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

D_a = 1.00, 1.25 and 1.5 mm, if the projected design traffic A is 1500 to 4500, 450 to 1500 and 150 to 450 respectively. Here, A = Design traffic = $P[1 + r]^{(n + 10)}$

- 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 $\frac{h_o}{2}$ when the value of h_o is determined from Eq. (1).

6.9.1 Rigid Overlay Over Rigid Pavement

- Overlay thickness,

$$h_o = (h_d^n - Xh_e^b)^n$$

Here, h_o = rigid overlay thickness, h_d = design thickness and h_e = existing pavement thickness

- Values of a, b, X and n depend upon the pavement and the method of overlay construction.

6.9.2 Flexible Overlay Over Rigid Pavement

For calculating the thickness of flexible overlay over rigid pavements the following relationship is employed.

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

Here, h_f = Flexible overlay thickness ; h_e = Existing rigid pavement thickness

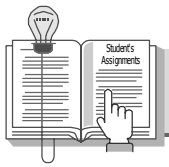
h_d = Design thickness of rigid pavement

F = Factor which depends upon modulus of existing pavement

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

$$h_b = \frac{h_i}{1.5}$$

i.e., $$h_b = 1.66\,(Fh_d - h_c)$$



Student's Assignments

Q.1 The phenomenon of reflection cracking is observed in which one of the following?
(a) Bituminous overlays provided over cracked cement concrete or bituminous pavements
(b) Cement concrete overlays provided over cracked bituminous pavements
(c) Bituminous overlays constructed in cold weather
(d) Cement concrete overlays provided over cement concrete pavements

Q.2 Reflection cracking is observed in
(a) flexible pavement
(b) rigid pavement
(c) bituminous overlay over cement concrete surface
(d) rigid overlay over flexible pavement

Q.3 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. Pot holes
C. Ravelling
D. Subsidence

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

Codes:

	A	B	C	D
(a)	1	4	5	3
(b)	2	1	3	5
(c)	5	2	4	3
(d)	2	1	4	5

Q.4 The corrected characteristic rebound deflection on a pavement, using Bankelman beam study is 2 mm. The equivalent granular overlay thickness required for an allowable deflection of 1 mm as per original IRC guidelines is
(a) 33 mm
(b) 66 mm
(c) 133 mm
(d) 166 mm

Q.5 A road surface is corrected by spreading a layer of dry sand in a thickness varying from 5 mm to 10 mm and rolling the surface by heavy rollers. Which one of the following maintenance works does it apply to?
(a) Repair of ruts and patches
(b) Repairing of blow ups
(c) Repair of bleeding surface
(d) Sealing of joints and cracks

Q.6 For carrying out bituminous patch work during rainy season, the most suitable binder is:
(a) road tar
(b) hot bitumen
(c) cutback bitumen
(d) bituminous emulsion

Q.7 On a national-highway, GSB may be used as:
(a) sub-base and drainage layer
(b) drainage layer and prime coat
(c) wearing course and drainage layer
(d) sub-base and tack coat

Q.8 Which type of pavement overlay needs to be designed by Benkelman beam deflection method?

(a) Rigid overlay on rigid pavement
(b) Flexible overlay on rigid pavement
(c) Rigid overlay on flexible pavement
(d) Flexible overlay on flexible pavement

Q.9 Which of the following is useful in functional evaluation of pavement?

(a) PCU (b) PSR
(c) PIEV (d) Benkelman beam

Q.10 Which one of the following defects indicates progressive disintegration of bituminous premix carpet surfacing by loss of aggregates?

(a) pot holes (b) revelling
(c) edge breaking (d) rutting

ANSWER KEY // STUDENT'S ASSIGNMENTS

1. (a)	**2.** (a)	**3.** (a)	**4.** (d)	**5.** (b)
6. (d)	**7.** (a)	**8.** (d)	**9.** (b)	**10.** (a)

■■■■