UNIT V-HIGHWAY

MAINTENANCE PART - A (2 mark)

1. Mention the reason for the development of cracks in rigid pavement. **(APRIL/MAY 10)** Cracks formed in rigid pavement are shrinkage cracks, warping cracks and structural cracks. Shrinkage cracks are formed in cement concrete pavements during curing operation. These cracks develop both in longitudinal and transverse directions.

Formation of excess warping stress at the edge causes the slab to develop cracks at the edges in an irregular pattern. Design of thickness should be made property considering different aspects like wheel load, temperature, sub grade conditions, etc…if the thickness is inadequate structural cracks are liable to occur.

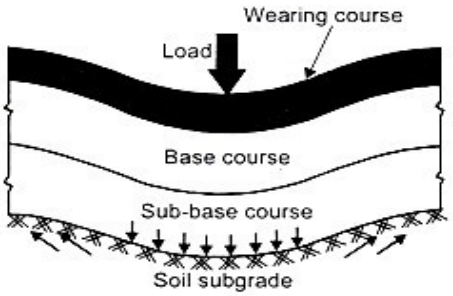
2. What is unevenness index? **(APRIL/MAY 10)**

Unevenness index is the cumulative vertical undulations of the pavement surface recorded per unit horizontal length of the road. This may be mentioned as cm per km. it is desirable that the pavement surface an unevenness index less than 150 cm/km.

3. What is mean by mud pumping? **(APRIL/MAY 11)**

Ejection of soil slurry through cracks formed on the pavement slab due to wheel load or otherwise.This is caused due to more slab deflection, type of sub grade soil and amount of free water.

4. Draw the figure for failure in sub grade of flexible pavement. **(APRIL/MAY 11)**



Failure of subgrade

5. What is mean by spalling of joint? **(MAY/JUNE 12**) During construction time cement concrete pavements are sometimes provided with preformed filler material at the joints. During concreting these filler materials may be disturbed and placed at an angle.

As the filler materials are not properly alignment, which form an overhang of a concrete layer on the top side and the joint later on shows excessive cracking and subsidence**.**

6. What are the causes of scalling? **(MAY/JUNE 12**) Presence of chemical impurities in the mixture or due to poor mixture designed scalling of cement concrete generally occurs. Further, over finishing at the edges and abrasion action of traffic are other causes.

7. Give examples for surface defects in pavements. **(MAY/JUNE 13)**

- Cracks
- Uneven undulations
- Patches
- Lake of binding
- Ruts

8. What is pavement evaluation? **(MAY/JUNE 13)**

Pavement evaluation involves a thorough study of various factors such as sub grade support, pavement composition and its thickness, traffic and environmental conditions. The primary objective of pavement condition evaluation is to asses as to whether and to what extent the pavement fulfils the intended requirements so that the maintenance and strengthening jobs could be planned in time.

The studies therefore investigate the structural adequacy of pavements and also the requirements for providing safe and comfortable traffic operations.

9. List out the types of defects in flexible pavements. **(NOV/DEC 13)**

- Cracks
- Spalling
- Ruts
- Scalling
- Lack of binding

10. Name the two methods for pavement evaluation. **(NOV/DEC 13)**

The various methods may be broadly classified into two groups:

1) Structural evaluation of pavements
2) Evaluation of pavement surface condition

11. What are the operations involve in road construction?

The operations are:

1) Assessment of road construction
2) Diagnosis of the problem

12. Define the various general causes in pavement failures?

The general causes are:

a) Defects in the quality of materials used

b) Effects in construction method and quality control c) Inadequate surface (or) Sub surface drainage

d) Increase in the magnitude of wheel loads e) Settlement of foundation of embankment f) Environmental factors.

13. What is mean by special repair?

Special repair means strengthening of pavement structure or overlay construction, reconstruction of pavement, widening of roads repairs of damages caused by floods etc.

14. Give any two factors in maintenance management system? The factors are:

- Field surveys for the evaluation of maintenance requirements.
- Estimation of rate of deterioration of the pavement under the prevailing set of conditions.
- Availability of funds.

15. What are the failures in flexible pavement? The failures are

1) Failures in sub grade
2) Failures in sub base
3) Failure in wearing course.

16. Mention the various types of failure in sub base?

- Inadequate stability or strength
- Loss of binding action
- Loss of base course materials
- Inadequate wearing course
- Use of inferior materials and base course materials

17. What are the failures in wearing course?

Failures of wearing course are observed due to lack of proper mix design. Improper gradation of aggregate, binder content and inferior types of binder result in a poor bituminous surfacing.

The design aspect the bituminous construction requires a high degree of quality control since over or under estimated binder content are both damaging to the resulting paving mix including temperature controls.

18. Give some typical flexible pavement failures?

Following are some of the typical flexible pavement failures:

i) Alligator cracking
ii) Consolidation of pavement layers iii) Shear failure
iv) Longitudinal cracking
v) Frost heaving
vi) Lack of binding
vii) Reflection cracking
viii) Formation of waves and corrugation.

19. Define frost heaving.

Frost heaving is often misunderstood for shear or other types of failure. 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.

20. What are the main factors in cement concrete pavements?

The factors are:

a) Deficiency of pavement materials
b) Structural inadequacy of the pavement system.

21. Give the various defects in cement concrete pavement?

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

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

22. What are the failures in rigid pavement?

The failures are:

i) Scaling of cement concrete ii) Shrinkage cracks
iii) Spalling of joints
iv) Warping cracks
v) Mud pumping
vi) Structural cracks

23. What is mean by shrinkage cracks?

The operation of cement concrete pavements immediately after the construction. The shrinkage cracks normally develop. The placement of cracks is in longitudinal as well as in transverse direction.

24. Define mud pumping.

It 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. It is called as mud pumping.

25. What are the factors considered to be mud pumping?

The factors are:

i) Extent of slab deflection *ii)*

Type of sub grade soil *iii)*

Amount of free water

26. Define patch repairs.

Patch repair are carried out in the damaged or improper road surface. Localized depression and pot holes may be formed in the surface layers due to defects in materials and construction.

27. Give the various types of routine maintenance?

ii) Maintenance of shoulders and sub grade i)

Upkeep of carriageway

iii) Maintenance o side drains and other ancillary works

iv) Patch repair of pot holes and localized failures.

28. Define overlay.

It means the additional thickness of the pavement of adequate thickness in one or more layers over the existing pavement which is called overlay.

29. Give the various types of overlay.

The overlay combination is divided into four categories based on the type of existing pavement and the overlay.

i) Flexible overlay over flexible pavements

ii) Cement concrete or rigid overlay over flexible pavement iii)

Flexible overlays over cement concrete or rigid pavement

iv) Cement concrete or rigid overlay over rigid pavement.

PART B (16 MARKS)

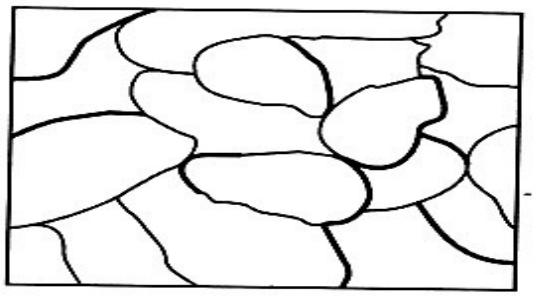
1. Classify the different types of failures in flexible pavement and mention the important causes of each. (APRIL/MAY 10) (MAY/JUNE 13)

Following are the some of the flexible pavement failures:

- Alligator (map) cracking
- Consolidation of pavement layers
- Shear failure
- Longitudinal cracking
- Frost heaving
- Lack of binding to the lower course
- Reflection cracking
- Formation of waves and corrugation.

Alligator (map) cracking

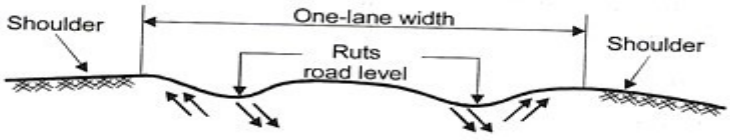
This is the most common type of failure and occurs due to relative movement of pavement layer materials. This may be caused by the repeated application of heavy wheel load resulting in fatigue failure or due to the moisture variations resulting in swelling and shrinkage of sub grade and other pavement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



Map cracking

Consolidation of pavement layers

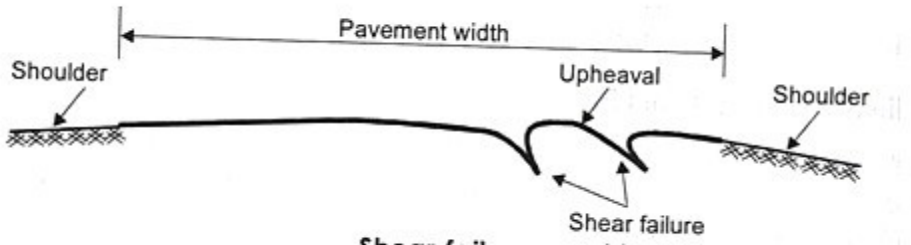
Formations of ruts are mainly attributed to the consolidation of one or more layers of pavement. The repeated application of loads along the same wheel path cause cumulative deformation resulting in consolidation deformation or longitudinal ruts. Shallow ruts on the surfacing course can also be due to wearing along the wheel path. Depending upon the depth and width of ruts, it can be estimated whether the consolidation deformation has been caused in the sub grade or in subsequent layers.



Formation of ruts due to consolidation

Shear failure and cracking

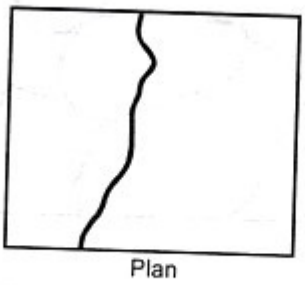
Shear failures are associated with the inherent weakness of pavement mixtures, the shearing resistance being low due to inadequate stability or excessively heavy loading. The shear failure causes upheaval of pavement materials by forming a fracture or cracking.



Shear failure cracking

Longitudinal cracking

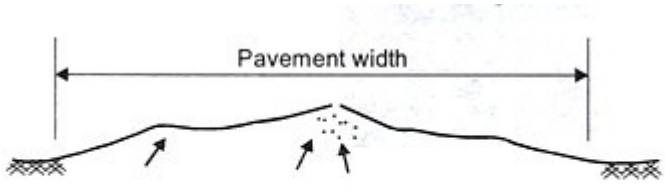
Due to frost action and differential volume changes in sub grade longitudinal cracking is caused in pavement traversing through the fall pavement thickness. Settlement of fill and sliding of side slopes also would cause this type of failure.



Longitudinal cracking due to differential volume change

Frost heaving

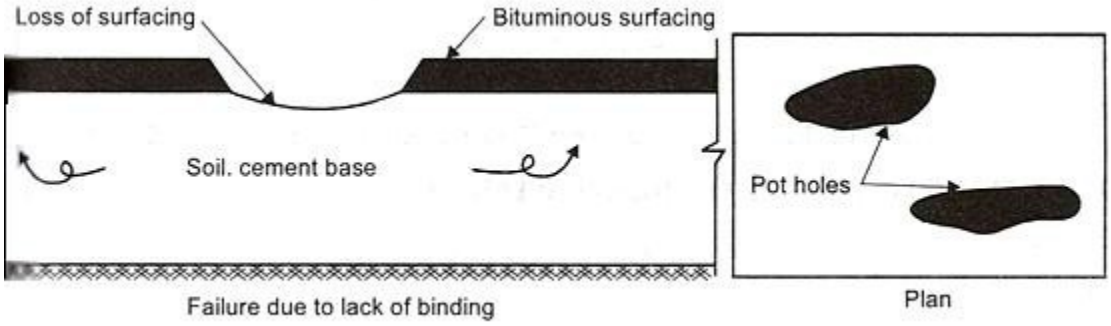
Frost heaving is often misunderstood for shear or other types of failure. In shear failure, the upheaval of portion of pavement is followed with a depression. In the case of frost heaving, there is mostly a localized heaving up pavement portion depending upon the ground water and climate conditions.



Failure due to frost heave

Lack of binding with lower layer

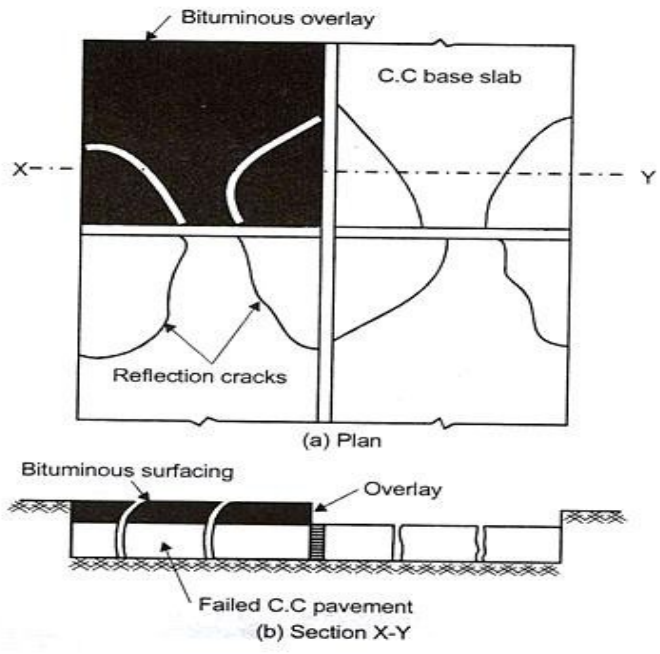
Slipping occurs when the surface course is not keyed/bound with the under laying base. This results in opening up and loss of pavement materials forming patches or pot holes. Such conditions are more frequent in case when the bituminous surfacing is provided over the existing cement concrete base course or soil cement course. This condition is more pronounced when the prime/tack coat in between two layers is lacking.



Reflection cracking

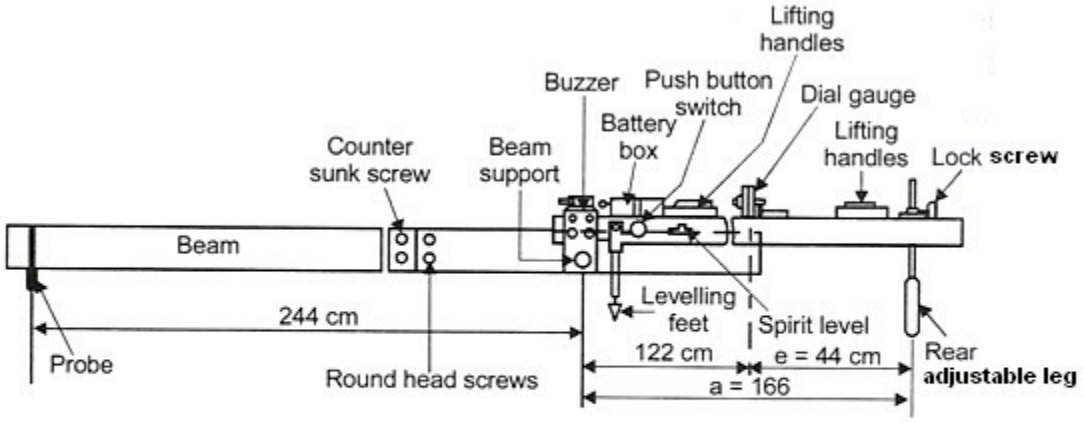
This type of cracking is observed in bituminous overlays provided over existing cement concrete pavements. The crack patterns as existing in cement concrete pavements are mostly reflected on bituminous surfacing in the same pattern. Structural action of the total pavement section is not much influenced 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 sub grade or resulting in mud pumping.

(a) and (b) show the pattern of reflection cracking.



Reflection cracking

2. Explain the principle and uses of Benkelman beam test and Describe the complete procedure of carrying out Benkelman beam test to evaluate the pavement with model calculation (APRIL/MAY 10) 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 equipment consists of a slender beam of length 3.66m which is pivoted to a datum frame at a distance 2.44m from the probe end. The datum frame rests on a pair of front leveling leg with adjustable height. The probe end of the beam is inserted between the dual rear wheels of truck and rests on the pavement surface at the center of the loading area of the dual wheel load assembly. a dial gauge is fixed on the datum frame with its spindle in contact with the other end of the beam in such a way that the distance between the probe end and the fulcrum of the beam is twice the distance between the fulcrum and the dial gauge spindle. Thus the rebound deflection reading measured at the dial gauge is to be multiplied by two to get the actual movement of the probe end due to the rebound deflection of the pavement surface when the dial wheel load is moved forward. a loaded truck with rear axle load of 8170kg is used for the deflection study. The design wheel load is a dual wheel load assembly of gross weight 4085kg/cm^2.



Benkelman Beam

Procedure

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. Based on the above pavement condition survey, the pavement stretches are classified and grouped into different classes such as good, fair and poor for the purpose of Benkelman beam deflection studies. The loading points on the pavement for deflection measurements are located along the wheel paths, on a line 0.9 m 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 narrower pavements. The number of loading points in a stretch and the spacing between them for the deflection measurements are to be decided depending on the objective of the project and the precision desired. A minimum of 10 deflection observations may be taken on each of the selected stretch of pavement. The deflection

observation points may also be staggered if necessary and taken along the wheel path on both the edges of the pavement. After marking the deflection observation points, the study is carried out in the following steps:

- 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 gaps of the dual wheel and is placed exactly over the deflection observation point.
- When the dial gauge reading is stationary or when the rate of change of pavement deflection is less than 0.025mm per minute, the initial dial gauge reading D_O is noted. Both the readings of the large and small needles of the dial gauge may be noted. The large needle may also be set to zero if necessary at this stage.
- The truck is moved forward slowly through a distance of 2.7m from the point and stopped. The intermediate dial gauge reading D_i is noted. When the rate of recovery of the pavement is less than 0.025mm per minute.
- The truck is then driven forward through a further distance of 9.0m and final dial gauge reading D_f is recovered as before.
- The three deflection dial reading D_O, D_i and D_f from a set of readings at one deflection point under consideration. Similarly the truck is moved forward to the next deflection point, the probe of the Benkelman beam inserted and the procedure of noting the set of three deflection observations is repeated. The deflection observations are continued at all the desired points.
- The temperatures of the pavement surface are recorded at intervals of one hour during the study. The tyre pressure is checked and adjusted if necessary, at intervals of about three hours during the deflection study. The moisture content in the sub grade soil is also to be determined at suitable intervals.
- The rebound deflection value D at any point is given by one of the following two conditions:

i) If $D_i - D_f \leq 2.5$ divisions of the dial gauge or 0.025mm, $D=2(D_O - D_f)$ divisions of 0.01mm units$=0.02(D_O - D_f)$ mm.

ii) If $D_i - D_f \geq 2.5$ division, this indicates that correction is needed for the vertical movement of the front legs. Therefore,
$D=2(D_O - D_f)+2K(D_i - D_f)$ divisions.

The value of K is to be determined for every make of the Benkelman beam and is given by the relation:

$$K=\frac{3d \; e}{f}$$

Where

d=distance between the bearing of the beam and the rear adjusting leg. e=the distance between the dial gauge and rear adjusting leg
f=distance between the front and rear legs.

The value of K of Benkelman beam generally available in India is found to be 2.91.therefore, the deflection value D in case (ii) with leg correction is given by:

$D=0.02(D_O - D_f) +0.0582(D_i - D_f)$ mm.

3. Describe the symptoms, causes and remedial measures for the different types of failure in flexible pavements. (APRIL/MAY 11)

Refer the question no: 1

4. i) Briefly explain the procedure of overlap design by Benkelman beam method.

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:

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

Where

h_0=thickness of bituminous overlay in cm

R=deflection reduction factor depending on the overlay material (usual values for Bituminous overlays range from 10 to 15, the average value that may be generally taken being 12)

D_a=allowable deflection which depends upon the pavement type and the desired design life, values ranging from 0.75 to 1.25mm are generally used in flexible pavements for overlay design.

The Indian road congress suggests the following formula for the design of overlay thickness equivalent to granular material of WBM layer. When superior materials are used in the overlay layer; the thickness value has to be suitably decreased taking equivalency factor of the material into consideration.

$$h_0 = 50\log_{10}\frac{D_c}{D_a} mm$$

Where

h_0=thickness of granular or WBM overlay in mm

D_c=(D+ρ), after applying the corrections for pavement temperature and sub grade moisture.

D_a=1.00, 1.25 and 1.5mm, 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 equivalently factor o0f 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.

ii) Explain how resealing of cracks may be carried out in rigid pavements.

(APRIL/MAY 11) (NOV/DEC 13)

In cement concrete roads, the main defects are formation of cracks. Cracks are temperature cracks and structural cracks.

Temperature cracks initially form as fine cracks or hair cracks across the slab, in between a pair of transverse or longitudinal joints. These cracks divide the slab length into two or more parts due to temperature, shrinkage and warping stresses.

Structural cracks form near the edge or corner regions of the slab due to combined action of stress due to wheel load and warping stresses in the slab.

Shrinkage cracks form at the bottom portion of slab and propagate upwards. With the continued wheel load, temperature and moisture, the slab deteriorates further and the bottom portion goes on increasing. The situation becomes worst when water gets entry through the cracks into the sub grade.

Then the shrinkage cracks are cleaned by removing dirt, sand and other loose materials using sharp tool, stiff brush and a pressure brush. Kerosene oil is spread on the cleaned cracks so as to make proper bonding of the sealing material. Suitable grade bituminous sealing compound, heatyede to liquid consistency is filled. The sealer is placed 3mm above the level of the slab along the cracks. A layer of sand is then spread over the sealer so as to protect sealer temporarily.

Structural cracks have to be viewed seriously. Before attending to the repair, the causes for the cracks have to be analyzed first. The cracks may be due to some weak spot in the sub grade or due to localized settlement of embankment or underground drainage problem.

The maintenance work involves in attending to the basic cause of the failure of the pavement and then recasting the failed portion of the slab. For a general distress of pavement, immediate steps are to be taken to strengthening the pavement by providing a flexible or rigid overlay. Over a badly cracked and damaged slab it is not advisable to go in for an overlay instead the whole slab has to be replaced fully.

5. Explain any two commonly employed methods for the structural evaluation of flexible and rigid pavements. (MAY/JUNE 12)

There are various approaches and methods of pavement evaluation. The various methods may be broadly classified into two groups:

- Structural evaluation of pavement
- Evaluation of pavement surface condition

Structural evaluation of pavement

The structural evaluation of both flexible and rigid pavement may be carried out by plate bearing test. The structural capacity of the pavement may be assessed by the load carried at a specified deflection of the plate or by the amount of deflection at a specified load on the plate.

Field investigations and test carried out in various countries have shown that the performance of a flexible pavement is closely related to be elastic deflection under loads or its rebound deflection. Measurement of transient deflection of pavement under design wheel loads serves as an index of the pavement to carry traffic loads under the prevailing conditions. Assessment of flexible pavement overlay thickness requirements by Benkelman beam method. There are number of other non destructive testing techniques for assessing the load carrying capacity of pavements.

Evaluation of pavement surface condition

The surface condition of flexible pavement may be evaluated by the unevenness, ruts, patches and caracks.the surface condition of rigid pavement may be assessed by the cracks developed and by faulty affecting the riding quality of the pavement.

The pavement unevenness may be using unevenness indicator, profilograph, profilometer or rough meter. Equipment capable of integrating the unevenness of pavement surface to a

cumulative scale and that gives the unevenness index of the surface in cm/km length of the 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 section during periods. The present serviceability of a pavement is related to a pre determined scale by a panel of judges sensitive to the wishes of motor vehicle users by actually riding over the pavement. The present serviceability rating is the mean opinion of the members of the rating panel and this is corrected with the physical measurements such as longitudinal and transverse profile of the pavement, degree of cracking and patching etc… affecting pavement serviceability. Mathematical models are evolved for determining serviceability rating of pavements based on the physical measurements made on the pavement surface.

6. i)Explain briefly the maintenance of bituminous surface. (MAY/JUNE 12)

Bituminous road generally need repair of only surface distress, viz., patches, pot holes, bleeding and resurfacing. Damaged or improper road surface forms patches which are repaired.

Using a cold premix the localized patches are made good.

Localized deep depressions are caused due to inadequate or defective binding material by removing aggregates during monsoons. Such depression causes pot holes. These pot holes are cut and made to rectangular shape and the affected material is removal till the sound materials are reached. These holes are cleaned well and some primer is applied. The material used to fill the holes is cutback or emulsion. The filled materials are well rammed to avoid any revelling.the finished level of patches is kept slightly above original level to allow for subsequent settlement if any to occur.

During original construction, if any excess bitumen materials are provided which bleed with time and the pavement becomes patchy and slippery. In such pavement surfaces corrugations or rutting shoving develop. In such places blotting materials, like aggregate chips of maximum size about 10mm or courses sand are spread. Then it is rolled to bind the new material with the old one. If necessary the surface is heated.

Sometimes the black top surface gets oxidized due to ageing. This development minute cracks on the pavement surface. On such surfaces a renewal coat or seal coat is applied. More than one layer of surface treatment may be needed on the surface is damaged seriously.

If the surface has totally worn out and poor riding surface is formed, then it may be more economical to provide an additional surface course on the existing surface.

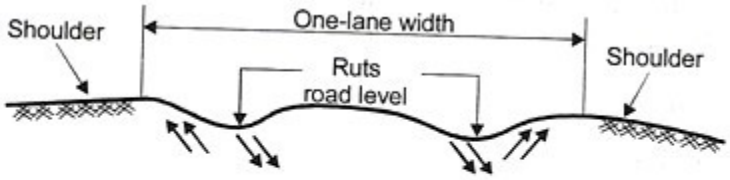
ii) What is meant by rutting? Explain the symptoms, causes and treatment.

Repeated application of wheel loads on the same location of the road cause cumulative deformation called as consolidation deformation. Such consolidations of one or more layers of pavement leads to formation of ruts. Based on the width of the ruts it could be assessed whether the ruts are formed due to consolidation of sub grade or in subsequent layer.

Rutting is defined as the consolidation deformation is occurred in pavements the repair for the ruts is called rutting.

The main symptom is the surface of the pavement is look like a undulations in the top surface. The surface is uneven in various places like waves in the surface due to wheel load.

The treatment is over lay the existing surface by a new repair surface. The pavement surface is provided with addional load carrying capacity. The surface treatment is required for that type of failure.



Formation of ruts due to consolidation

7. Explain the methods of strengthening damaged pavements. (MAY/JUNE 13)

i) Flexible overlay over flexible pavement ii) Flexible overlay over rigid pavement iii) Rigid overlay over flexible pavement iv) Rigid overlay over rigid pavement.

Flexible overlay over flexible pavement:

The total thickness requirement is designed for the design traffic and the existing conditions of sub grade. Any one of the design methods is chosen for the design and appropriate strength test is carried out in the soil collected from the sub grade.

The existing thickness of the pavement is found from test pits dug along the wheel path on the pavement. The overlay thickness required is given by the relation:

$$h_0 = h_d - h_c$$

Where,

h_0 =overlay thickness required, cm

h_d = total design thickness required, presently determined, cm h_c = Total thickness of the existing pavement, cm

Rigid overlay over rigid pavement:

When a rigid or CC is constructed over and existing rigid or CC pavement. The interface between the old and new concrete cannot have perfect n\bond such that the two slabs could act as a monolithic one.

Two typical types of interface are possible;

i) Providing maximum possible interface bond by making the old surface rough ii) Separating the two slabs at the interface by thin layer of bituminous material

To obtain the overlay thickness the following relationship may be used:

$$h_o = (ha^d - Xh_c^b)^n$$

Here,

h_0= rigid pavement thickness h_d = design thickness

h_e = existing pavement thickness.

Flexible overlay over rigid pavement:

A flexible overlay when provided over a rigid pavement, the wheel load is distributed through larger area by the overlay, thus slightly reducing the wheel load stress in the old rigid pavement. For calculating the thickness of flexible overlay over rigid pavement 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.

Rigid overlay over flexible pavement:

The thickness of rigid overlay is calculated by using the design criteria for rigid pavement as laid down, the plate bearing test is conducted on the existing flexible pavement and K value is thus obtained. The design is made for this K value and the design wheel load.

8. Explain any three non-destructive testing methods of pavement deflection.(NOV/DEC 13)

- **The Benkelman beam method**
- **The IDOT road rater**
- **The falling weight deflect meter**
- **Accelerometer measurements**

The IDOT road rater

The road rater was the main testing device used in the program. The road rater is an electro hydraulic vibrator with the capability of generating harmonic loads of up to 8kips at driving frequencies between 6 and 60 Hz. When the vibrator is set over the testing point a static preload of 5kips is applied through the 12 inch diameter circular loading plate.

The desired peak to peak load is then generated at the preselected driving frequency, and peak to peak deflections are recorded with velocity transducers. The IDOT road rater has four deflection sensors located at the centre of the loading plate, and 1, 2, and 3 feet away from the centre. The following procedure for road rater deflection measurements were used in the program:

Road rater was operated at an 8kips peak to peak load and 15 Hz driving frequency. This type of testing was performed in the first 12 sections in table 1between four and six times during the program. The same 20points, 10 in each traffic lane, 10 feet, in a 100 feet stretch of pavement were tested on every occasion.

FST (frequency sweep test) selected stations were subjected to a frequency sweep test. The road rater peak to peak load was kept constant at 8 kips and driving frequency was varied in increments of 2 Hz from 6 to 30 Hz.

LFST (load frequency sweep test)the road rater was operated at peak to peak loads of 1, 2, 4, 6, and 8 kips, and the driving frequency was incremented at 2 Hz intervals from 6 to 30 Hz.

The falling weight deflectometer

The falling weight deflectometer is an deflection testing device operating on the impulse loading principle. A mass is dropped from a preselected height onto a footpath that is connected to a base plate by a set of springs. The base plate is placed in contact with the pavement surface over the testing point. By varying the drop height, the impulse load can be varied from 2 to 11 kips. The duration of the impulse loading is essentially constant ranging from 30 to 40 msec.

The falling weight deflectometer are measured with velocity transducers. One of these sensors is located at the center of the loading plate. Two additional sensors are movable and can be placed at any desired distance away from the center of the plate. During this testing program the falling weight deflectometer sensors were placed at 1, 2, and 3 feet away from the center of loading plate, the same spacing used for the road rater. Four to six load magnitudes between 2 to 11 kips were used.

Accelerometer measurements

An accelerometer was implanted in the surface of selected test road section to measure deflections under moving trucks, and under the falling weight deflectometer loading plate. The accelerometer was placed in a 2 inch diameter by 2 inch depth hole in the outer wheel path. The single wire coming off the accelerometer was buried in a slot to the direction of travel.

The following trucks were used in the testing Truck

rear axle weight (lb)	Light
5100	
Medium	9000
Heavy	18000

9. Explain how the maintenance of the following pavements is carried out?

a) Earth roads
b) Bituminous surfaces
c) Cement concrete pavements

Earth roads:

The usual damages caused in the earth roads needing frequent maintenance are:

i) Formation of dust in dry weather.
ii) Formation of longitudinal ruts along wheel path or vehicles
iii) Formation of cross ruts along the surface after monsoons due to surface water. Thus, dust nuisance may be remedied y the following methods:

a) Frequent sprinkling of water

b) Treatment with calcium chloride c)
Use of other dust palliatives.

Application of calcium chloride retains some water due to the hygroscopic nature of mix. Oiled earth roads are also common these days.

Periodical maintenance by spreading moist soil along ruts and reshaping of the camber is necessary. Formation of cross ruts may be due to excessive cross slope.

Hence either these ruts should be repaired from time to time during and after the monsoon or a surface treatment or stabilized layer be provided on the top.

Maintenance of bituminous surfaces:

Mainly the maintenance works of bituminous surfacing consists of:

i) Patch repairs
ii) Surface treatments
iii) Resurfacing

Patch repairs:

Patch repairs are carried out on the damaged or improper roads surface. Localized depression and pot holes may be formed in the surface layers due to defects in materials and construction.

An inadequate or defective binding material causes removal of aggregates during monsoons. Patching may be done on affected localized area or sections using a cold premix.

Pot holes and repairs:

Pot holes are cut to rectangular shape and the affected materials in the section is removed until the sound materials are encountered.

The excavated patches are cleaned and painted with bituminous binder. A premixed material is then placed in the sections. Generally, cutback or emulsion is used as binder.

Bituminous emulsions could be used even when the pavement surface and the aggregates are wet during monsoons.

The materials so places in the pot hole, is well compacted by ramming to avoid any raveling. The materials in out holes are places in layers of thickness of 6 cm.

it is however necessary to replace the base course materials with similar new materials if the failure has been detected in the base curse layer. The finished level of the patched is kept slightly above original level to allow for subsequent compaction under traffic.

Surface treatment:

Excess of bitumen in the surface materials bleeds and the pavement becomes patchy and slippery. Corrugations or rutting or shoving develop in such pavement surface. It is customary to spread blotting materials such as aggregate chips of maximum size of about 10mm or coarse sand during summer.

Resurfacing:

In the event when the pavement surface is totally worn out and develops a poor riding surface, it may be more economical to provide an additional surface course on the existing surface.

In case of the pavement is of inadequate thickness due to increase in traffic loads and strengthening is necessary, than an overlay of adequate thickness should be designed and constructed.

Maintenance of cement concrete roads:

Various types of cracking have been explained:

Treatment of cracks:

The cracks are developed in cement concrete (CC) may be classified into two groups:

i) Temperature cracks which are initially fine cracks or hair cracks formed across the slab in between a pair of transverse or longitudinal joints, dividing the slab length into two or more approximately equal parts due to the temperature stresses like the shrinkage stress warping stress etc.

ii) Structural cracks formed near the edge and corner regions of the slabs, due to combined wheel load and warping stresses in the slab.

The repeated application of heavy wheel loads and the variations in temperature and moisture conditions the cracks get widened and further deterioration becomes repaid.

Once the surface water starts getting into the pavement and the sub grade through the widened cracks, progressive failure or the pavement is imminent.

Therefore before these cracks get wide enough to permit infiltration of water, they should be sealed off to prevent rapid deteriorations

The formation of structural rocks in CC slabs should be viewed seriously and needs immediate attention as these indicate possible beginning of pavement failure. The maintenance work in such a case involves first remedy of the basic cause of the failure and then recasting the failed slabs.

Maintenance of joints:

Joints are the weakest pars in CC pavements. The efficiency of the pavement is determined by the proper functioning of the joint.

During the summer the joint sealer material is squeezed out of the expansion joints due to the expansion of the slabs. Subsequently as the slabs contract during winter, the joint gap opens out and cracks are formed in the old sealer material.

The joint filler material at the expansion joints may get damaged or deteriorated after several years of pavement life. The repair consist of removal of the sealer and deteriorated filler and sealer materials from the expansion joints cleaning up replacement with new filter board a sealing the top of the joints with suitable sealer materials.

10. What are the various types of General failures in flexible pavement? Explain the causes?

A flexible pavement failure is defined by formation of pot holes, ruts, cracks, localized depressions and settlements. The localized depression normally is followed with heaving in the vicinity.

The failure of any one or more components of the pavement structure develops the waves and corrugations on the pavement surface or longitudinal ruts and shoving. Pavement unevenness may itself be considered, as a failure, when it is excessive.

The aging and oxidation of bituminous films lead to the deterioration of bituminous pavements. Deterioration actions in pavements are rapidly increased when excess water is retained in the void spaces of bituminous pavements or in the cracks and joint of the cement concrete pavements.

The cement concrete pavement may develop cracks and deteriorate due to repeated loads and fatigue effects. A rigid pavement failure is observed by the development of structural crack of break resulting in progressive subsidence of some portions of pavement.

Pavements are therefore capable of withstanding slight variations in the underlying support and they bridge the localized gaps moderately.

It is the combination of many factors that induce the failure conditions in the rigid pavement. Due to the temperature effects, the newly constructed cement concrete pavement may also crack even if no vehicle moves on them.

Failures in flexible pavements:

The localized settlement of any one component layer of the flexible pavement structure could be enough to cause pavement failure. This demands that each one of the layers should be carefully designed and laid.

Thus to maintain the stability of the pavement structure as a whole, each layer should be stable within itself and thereby make the total pavement mainta9n its stability.

In this fig shows the failures in soil subgrade, base course and the surface wearing course. It may see that ultimately there is surface deformation when failure takes place either in sub grade or base or surface.

Failures in sub grade:

One of the prime causes of flexible pavement failure is excessive deformation in sub grade soil. It is the form of excessive undulation or waves and corrugations in the pavement surface and also depressions followed by heaving of 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 sub grade soil.

The failure of sub grade maybe attributed due to two basic reasons:

i) Inadequate stability
ii) Excessive pavement thickness

Inadequate stability may be due to inherent of the soil and excessive moisture condition and improper compaction. Stability is the resistance to deformation under the stress.

Excessive stress application is due to inadequate pavement thickness or loads in excess of design value.

The deformation due to the load would be elastic or fully recovered when the load is released. In part of the compaction of the layers is not adequate with reference to subsequent loading part of the deformation may be permanent due to compaction of soil this may be called as consolidation deformation.

The applied stress is excessive with respect to the stability and plastic flow takes place as in the case of we t clay soil, this deformation is called plastic deformation.

The type of damage in flexible pavement than can be caused by traffic due to sub grade failure r due to inadequate and improper compaction of sub grade and other pavement layers.

Failures in sub base or base course:

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

i) Inadequate stability or strength ii)
Loss of binding action.
iii) Loss of base course materials iv)
Inadequate wearing course
v) Use of inferior materials and crushing of base course materials vi)
Lack of lateral confinement for the granular bass course.

Failures of wearing course:

Failure of wearing course is observed due to lack of proper mix design. Improper gradation of aggregates, inadequate binder content and inferior type of binder result in a poor bituminous surfacing.

Besides the design project the bituminous construction requires a high degree of quality control since over or under estimated binder content are both greatly damaging to the resulting paving mix including temperature controls.

Vocalization and oxidation of binder also makes the bituminous surfacing brittle and cause cracking of the pavement surface which further allows seepage of rain water to harm the underlying layers.

11. a) what are the 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 sub grade 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 fill material itself.

f) Environmental factors including heavy rainfall, spil erosion, high water table, snow fall, frost action etc.

The various items of highway maintenance works may be broadly classified under three heads:

Routine maintenance:

These include filling up of pot holes and patch repairs, maintenance of shoulders and the cross slope, up-keep of the road side drains and clearing choked culverts, maintenance of miscellaneous items like road signs, arboriculture, inspection bungalows etc.

Periodic maintenance:

These include renewals of wearing course of pavement surface and preventive maintenance of various items.

Special repair:

These include strengthening of pavement structure or overlay construction, reconstruction of pavement, widening of roads, repairs of damages caused by floods, providing additional safety measures like islands, sings.etc.

b) Write short notes on maintenance management system?

The type and extent of maintenance requirement for a road depend on the serviceability standard laid down, the maintenance needs funds available and the priorities for the maintenance operarions.As several interlinked factors are involved in the maintenance works of road net work consisting of different categories of road, a system approach is appropriate for the road maintenance management.

The various factors to be included in the maintenance management system are:

- Minimum acceptable serviceability standards for the maintenance of different categories of roads.
- Field surveys for the evaluation of maintenance requirements.

- Various factors influencing the maintenance needs such as sub grade soil, drainage, climate, traffic, environmental conditions.
- Estimation of rate of deterioration of the pavement under the prevailing set of conditions. Type and extent of maintenance requirements and various possible alternatives and their economic evaluation.
- Availability of funds.
- Maintenance cost, availability of materials, man power and equipment.