UNIT-V

EVALUATION AND MAINTENANCE OF PAVEMENTS

1. **List any 4 types of failures observed in flexible pavement (NOV/DEC 2019)**

   The failures are
   1) Failures in sub-grade
   2) Failures in sub-base
   3) Failure in wearing course
   4) Failure in Cracking, Potholes , Rutting and Ravelling

2. **What are the causes of cracks in Pavement? (NOV/DEC 2019),(April/May 2019)**

   Over loading
   Sub -Grade weak
   Improper compaction

3. **Differentiable delamination and depression (April/May 2019), (May/June 2016)**

Delamination	Depression
Loss of a discrete and large (Minimum $0.01m^2$) area of the top bituminous layer	Localized area within a pavement with elevations lower than the surrounding area

4. **Differentiate between Spalling and Traverse crack (April/May 2018)**

Spalling	Traverse crack
Breaking or cutting off small pieces from the pavement surface	Perpendicular to the centre line of the pavement

5. **What is meant by mud pumping? (April/May 2018), (Nov/Dec 2017)**

   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.

6. **Write down the works under routine repairs (Nov/Dec 2017)**

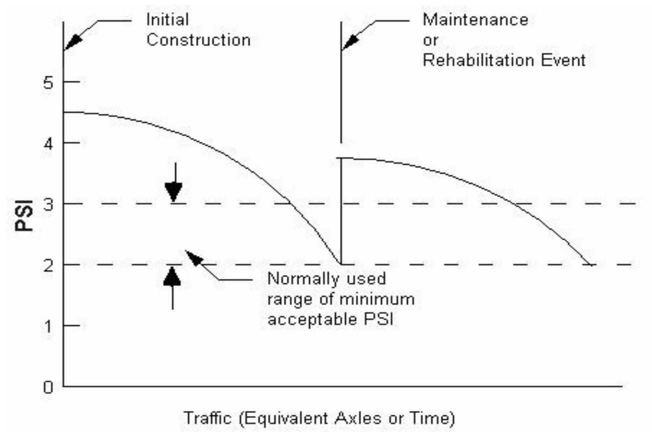
   Routine road maintenance works are usually non-structural in nature and are meant to extend the life of the pavement, to enhance the performance and to reduce user delays in road use.

7. Define Bleeding (Nov/Dec 2016)

It is identified by a film of bituminous material on the pavement surface that creates a shiny, glass like, reflective surface.

8. Define the terms Present Serviceability Index with its importance (Nov/Dec 2018)

The present serviceability index (PSI) is based on the original AASHO Road Test PSR. Basically, the PSR was a ride quality rating that required a panel of observers to actually ride in an automobile over the pavement.



9. What do you mean by the term Highway Project Formulation (Nov/Dec 2018)

i) Taking a first look carefully and critically at the project idea
ii) Carefully weighing its various components
iii) Analysing with the assistance of specialists or consultants
iv) Assessment of the various aspects of an investment proposition
v) It is an important stage in the pre-investment phase

10. What are the parameters that should be observed for evaluating a rigid pavement? (April/May 2017)

i) Scaling
ii) Faulting
iii) Roughness
iv) Skid resistance
v) Cracking

11. What are the causes of cracks? (April/May 2017), (May/June 2016)

A common defect in bituminous pavements is formation of cracks. The crack pattern can, in many cases indicate the causes of the defect, As soon as the cracks are observed, it is necessary to study the pattern in detail. Cracks are very serious defects be it is vulnerable for ingress of water through the cracks.

Causes of cracks

Over loading
Sub -Grade weak
Improper compaction

12. Differentiate Pumping and Ravelling (Nov/ Dec 2016)

Pumping	Ravelling
The ejection of water and fine materials under pressure through cracks under moving loads	The weather away of the pavement surface causes by the loss of binder or the dislodging of aggregate particles of both.

13. What is alligator Crack? (Nov/Dec 2015)

The general pattern of alligator or map cracking of the bituminous surfacing. This is the most common type of failure and occurs due to the relative movement of pavement layer materials.

14. What is FWD and state its use? (Nov/Dec 2015)

A falling weight deflectometer (FWD) is a testing device used to evaluate the physical properties of pavement. FWD is used in highways, airport pavements, harbor areas and railway track.

15. List the types of pavements (April/May 2015)

(i) Flexible pavement
(ii) Rigid pavement
(iii) Semi rigid pavement

16. Brief the Pavement Evaluation (April/May 2015)

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.

PART-B

1. **Explain in detail the possible causes and remedial measures of rigid pavement failure (Nov/Dec 2019), (April/May 2018), (Nov/Dec 2017)**
   Common failures of Rigid Pavements

i) Spalling joint
ii) Faulting Joint
iii) Shrinkage Cracking
iv) Longitudinal cracks
v) Slab cracking

(i) Spalling Joint

- Cracking, breaking or chipping of joint/crack edges. Usually occurs within about 0.6 m (2 ft.) of joint/crack edge.
- Loose debris on the pavement, roughness, generally an indicator of advanced joint/crack deterioration.
- Excessive stresses at the joint/crack caused by infiltration of incompressible materials and subsequent expansion (can also cause blowups).

(ii) Faulting Joint

- A difference in elevation across a joint or crack usually associated with undoweled JPCP. Usually the approach slab is higher than the leave slab due to pumping, the most common faulting mechanism.
- Faulting is noticeable when the average faulting in the pavement section reaches about 2.5 mm (0.1 inch). When the average faulting reaches 4 mm (0.15 in), diamond grinding or other rehabilitation measures should be considered.

(iii) Longitudinal cracks

Longitudinal cracks not associated with corner breaks or blowups that extend across the entire slab. Typically, these cracks divide an individual slab into two to four pieces. often referred to as "panel cracking".

iv) Shrinkage Cracking

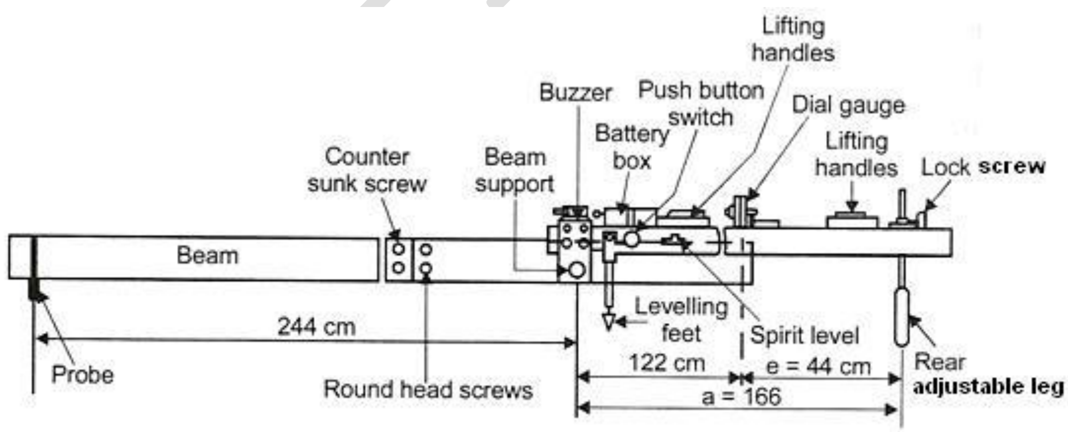
Hairline cracks formed during PCC setting and curing that are not located at joints. Usually, they do not extend through the entire depth of the slab. Shrinkage cracks are considered a distress if they occur in an uncontrolled manner (e.g., at locations outside of contraction joints in JPCP or too close together in CRCP).

Possible causes-

- Contraction joints sawed too late.
- Poor reinforcing steel design.
- Improper curing technique.
- High early strength PCC.

2. **Explain the methods employed for evaluation of pavements and explain the evaluation of pavement by BENKELMAN Beam method and deflection measurement. (Nov/Dec 2019), (April/May 2017), (April/May 2015)**

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_0 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_0, 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, $D=2(D_0 - D_f)$ divisions of 0.01mm units $=0.02(D_0 - D_f)$ 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,
$D=2(D_0 - D_f)+2K(D_i - D_f)$ divisions.

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

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

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.Explain the details the possible causes and remedial measures for Joint failures (April/May 2017)

Refer Part-B, Question .1

4. Explain any three non-destructive testing methods of pavement deflection (Nov/Dec 2017)

- i. **The IDOT road rater**
- ii. **The falling weight deflect meter**
- iii. **Accelerometer measurements**

i) 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.

ii) 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.

iii) 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 Medium Heavy	5100 9000 18000

4. Describe the objectives of Pavement Evaluation (April/May 2018)

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

i) Structural evaluation of pavement
ii) Evaluation of pavement surface condition

i) **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.

ii) 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 roughness cumulative scale and that gives the unevenness index of the surface in cm/km length of the road may be rough meter. Equipment capable of integrating the unevenness of pavement surface 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.

5. Explain in details the possible causes and remedial measures for joint failure (May/June 2016)

(Refer Part-B, Question No. 1)

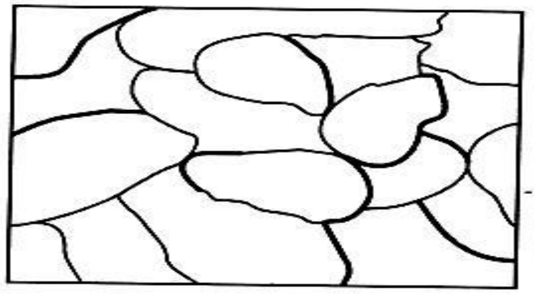
7. Explain the different types of failures in flexible pavement (April/May 2019), (April/May 2018), (Nov/Dec 2018), (Nov/Dec 2016), (Nov/Dec 2015),(April/May 2015),

Following are the some of the flexible pavement failures:

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

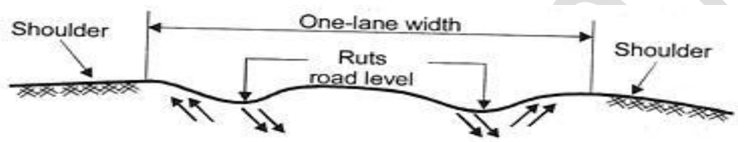
Alligator (map) cracking

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.



Consolidation of pavement layers

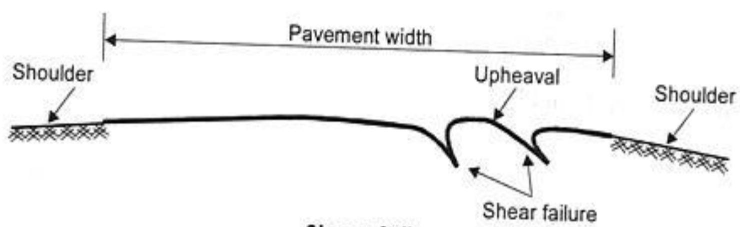
Formations of ruts are mainly attributed to the consolidation of one or more layers of pavement. The repeated application of loads along the same wheel path cause cumulative deformation resulting in consolidation deformation or longitudinal ruts. Shallow ruts on the surfacing course can also be due to 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

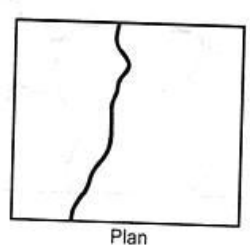
Shear failures are associated with the inherent weakness of pavement mixtures, the shearing resistance being low due to inadequate stability or excessively heavy loading. The shear failure causes upheaval of pavement materials by forming a fracture or cracking.



Shear failure cracking

Longitudinal cracking

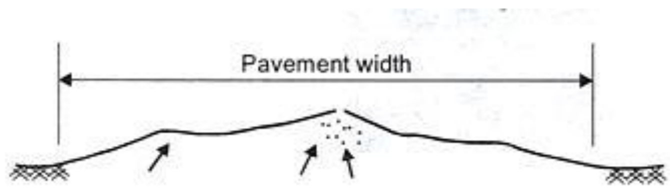
Due to frost action and differential volume changes in sub grade longitudinal cracking is caused in pavement traversing through the fall pavement thickness. Settlement of fill and sliding of side slopes also would cause this type of failure.



Longitudinal cracking due to differential volume change

Frost heaving

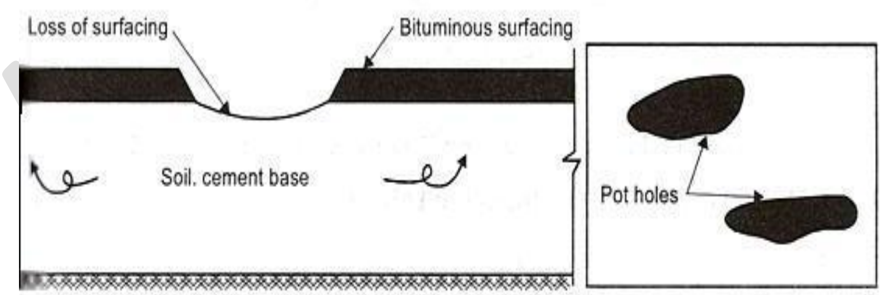
Frost heaving is often misunderstood for shear or other types of failure. In shear failure, the upheaval of portion of pavement is followed with a depression. In the case of frost heaving, there is mostly a localized heaving up pavement portion depending upon the ground water and climate conditions.



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.



Failure due to lack of binding

8. Define overlay and the procedure for design and construction of overlays (Nov/Dec 2015), (April/May 2019).

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.

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.**

(i) 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

(ii) 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;

a. Providing maximum possible interface bond by making the old surface rough

b. 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.

(iii) **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.

(iv) **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 in details the possible causes and remedial measures for joint spalling (May/June 2016)

(Refer Part-B, Question No. 1)

9. Briefly explain the procedure of overlay design by Benkelman beam method. (April/May 2015),

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:

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

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.

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

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.

10. Explain the detail about any four methods of strengthening damaged pavements (Nov/Dec 2016)

Refer Part-B, Question No. 6

11. Explain in details the pavement management system (PMS) with its effectiveness in pavement maintenance? (Nov/Dec 2018)

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

- Defects in the quality of materials used.
- Defects in construction method and quality control during construction
- 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.
- Increase in the magnitude of wheel loads and the number of load repetitions due to increase in traffic volume.
- Settlement of foundation of embankment of the fill material itself.
- 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.

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.

12. Describe about Mud Jacking.(April/May 2018)

Mud jacking is a process of lifting concrete slabs that have settled by drilling holes through the slab and pumping a sand or cement mixture under the slabs. Mud jacking allows the slab to be maneuvered back to it's original location.

Fill Voids

Frequently, foundation problems in the Metroplex are the result of the perimeter of the foundation settling. When the concrete piers are installed under the perimeter grade beam and the foundation is returned to its original position (raised), a void is created under the slab. In some instances, it may be necessary to fill this void to properly support the foundation. Mud jacking to fill this type of void is accomplished from the outside of your home by drilling 2″ holes through the perimeter grade beam and pumping a mixture of soil/cement grout into the void. This type of mud jacking uses a fluid mix of soil/cement grout and is not intended to raise the foundation.

Raise Interior Floors

In some situations, the interior portion of the slab foundation may have settled. Mud jacking may be used to return interior floors which have settled to their original position. Mud jacking to raise interior floors is accomplished from the inside of your home by drilling 2″ holes through the slab in the areas that have settled and pumping a mixture of soil/cement grout under the foundation. This type of mud jacking uses a stiff mix of soil/cement grout and is often associated with more complicated foundation problems. As a result, it is important to deal with experienced professionals and with a reputable company. Power Jack Foundation Repair personnel have extensive experience with the mud jacking process and monitor the work carefully while in progress. Power Jack Foundation Repair has an excellent reputation and stands behind its work.