UNIT-6

INTRODUCTION:

The Highway construction may be taken up in two stages.

A) Earth work and preparation of sub grade B) Pavement Structure.

The Earth work mainly consists of preparation of the sub grade to be suitable to the subsequent construction of the pavement structure.

Various types of roads that are preferred to construct in Highways are

1) Earthen roads & Gravel roads,

2) Soil stabilized roads,

3) Water bound macadam (WBM) roads,

4) Bituminous or Black top roads,

5) Cement Concrete roads etc.

The selection of a base course and the surface course depends upon the factors like

1) Type and Intensity of Traffic,

2) Funds available for the construction of the project and for the subsequent maintenance,

3) Sub grade soil and drainage conditions,

4) Availability of construction materials at the site,

5) Climatic condition,

6) Plants and Equipment available,

7) Time available for completing the project,

8) Altitude at which the construction has to be done.

Earth Work: The sub grade soil is prepared by bringing it to the desired grade and camber and by compacting adequately. The sub grade may be either in Embankment or in Excavation,

depending on the topography and the finalized vertical alignment of the road to be constructed. In the Earth work Excavation process is taken up and it is the cutting or loosening and removing earth including rock from its original position, transporting and dumping it as a fill or spoil bank..

Excavation Equipment: The Excavation equipment commonly used in highway projects includes bull dozers, scrapers, power shovels, drag lines, clamshells and hoes. However in small projects excavation is carried out manually using hand tools.

Embankment: When it is required to raise the grade line of a highway above the existing ground level it becomes necessary to construct embankments. The grade lines may be raised due to any of the following reasons:

a) to keep the sub grade above the high ground water table,

b) To prevent damage to pavement due to surface water and capillary water,

c) To maintain the design standards of highway with respect to the vertical alignment,

The design elements in the Highway embankments are,

i) Height

ii) Fill material

iii) Settlement

iv) Stability of Foundation

v) Stability of Slopes

Construction of Embankments: The Embankment may be constructed either by rolling in relatively thin layers or by hydraulic fills. The Former is called rolled –earth method and is preferred in high way embankments. Each layer is compacted by rolling to a satisfactory degree or to a desired density before the next layer is placed. Compaction is carried out at optimum moisture content so as to take advantages of MDD using a specified compacting effort and equipment. The thickness of the layers may vary between 10 – 30 cm depending on various factors such as soil type, equipment, specifications etc.

Preparation of Sub Grade: The preparation of sub grade includes all operations before the pavement structure could be laid over it and compacted. Thus the preparation of sub grade would include site clearance, grading and compaction.

Soil Compaction: By compaction of soil the particles are mechanically constrained to be packed more closely by expelling part of the air voids. Compaction increases the density and stability, reduces the settlement and lowers the adverse effects of moisture. Hence proper compaction of fills, sub grade, sub-base and base course are considered essential for proper highway construction.

Compacting Equipment: Soil compaction is achieved in the field either by rolling, ramming or by vibration. Hence the compacting equipment may also be classified as rollers, rammers and vibrators. Compaction of sands is also achieved by watering, ponding and jetting. The principle of rollers is the application of pressure which is slowly increased and then decreased. The various types of rollers which are used for compaction are smooth wheel, pneumatic tyred and sheep foot rollers. Further the construction equipment such as trucks, tractors and bull dozers also help in compaction of the materials to some extent.

Construction of Gravel Roads:

General roads are considered superior to the earth roads as they can carry heavier traffic. The road consists of a carriageway constructed using the gravels. The camber may be between 1 in 25 and 1 in 30.

A well compacted crushed rock or gravel road is fairly resilient and does not become slippery when wet. This type of road can cater for about 100 tonnes of pneumatic tyred vehicle or 60 tonnes of iron tyred vehicles per day per lane. Two types of construction methods are generally followed. They are the feather edge type and the trench type .The feather edge type is constructed over the sub grade with varying thickness so as to obtain the desired cross slope for the pavement surface. In the trench type, the sub grade is prepared by excavating a shallow trench.

<u>The construction procedure is as follows:</u>

i) Material gravel to be used for the construction is stacked along the sides of the proposed road,

ii) Location pegs are driven,

iii) Site is cleared and fills and cuts are completed. Trench is formed to the desired depth of

Construction; the width of the trench is made equal to that of the carriage way. The trench is

brought to the desired grade and is compacted,

iv) Crushed gravel aggregates are placed carefully in the trench so as to avoid segregation. Aggregates are spread with greater thickness at centre and less towards the edges so as to obtain the desired camber. The layer is rolled using the smooth wheeled roller starting from the edges and proceeding towards the centre with an overlap of at least half the width of roller in the longitudinal direction. Some quantity of water may also e sprayed and rolling is done again so that the compaction is effective. The camber is checked and corrected from time to time using a template or camber board,

v) A few days after the final rolling and drying out the road is opened to the traffic.

Construction of Earth roads:

These are considered to be the cheapest roads as they are prepared from the natural soil. The pavement section is totally made out of the soil available at site and at near by borrows pits. The type of construction by and large depends upon the type of the soil at site. The camber provided to the earth roads is very steep and ranges between 1 in 20 to 1 in 33.The steep cross slope also helps in keeping the pavement surface free of standing water, otherwise the soil being pervious the water would damage the pavement section by softening it. The maximum cross slope of 1 in 20 is recommended to avoid erosion due to rain waters and formation of cross ruts.

The construction procedure is as follows:

i)Material: The soil survey has to be carried out and suitable borrow pits are located within economical haulage distances. The borrow pits are usually selected out side the land width. The trees, shrubs, grass roots and other organic matter including the top soil are removed before excavating earth for construction.

ii) Location: The centre line of road edges are marked on the ground along the alignment by driving the wooden pegs. Reference pegs are also driven to help in following the desired vertical profile of the road during construction. The spacing of the reference pegs depends on the estimated length of road construction per day.

iii) Preparation of Sub Grade: The various operations involved in the preparation of the sub

grade are as follows:

a) Clearing the site

b) Excavating and construction of fills to bring the road to a desired grade

c) Shaping of sub grade

The site clearance may be carried out manually using the appliances like spade, pick and hand shovel. Mechanical equipment like dozer, scraper and ripper may also be used for the purpose.

iv)Pavement Construction: The borrowed soil is dumped on the prepared sub grade and pulverized. The field moisture content is checked and additional water content is added if necessary to bring it up to OMC. The soil is mixed, spread and rolled in layers such that the compacted thickness of each layer does not exceed 10 cm. The type of roller for compaction is decided based on soil type, desired amount of compaction and availability of equipment. At least 95 % of dry density of I.S light compaction is considered desirable. The camber of the finished pavement surface is checked and corrected if necessary.

v) Opening to Traffic: The compacted earth road is allowed to dry out for a few days before opening it to traffic.

Construction of WBM roads:

The term Macadam resembles the pavement base course made of crushed or broken aggregate mechanically interlocked by rolling and the voids filled with screening and binding material with the assistance of water. WBM may be used as base course, sub base course and surface course. The thickness of each compacted layer of WBM ranges from 10 cm to 7.5 cm depending on the size and gradation of the aggregates used. The number of layers and total thickness of WBM construction depends on the design details of the pavement.

The construction procedure is as follows

a) Preparation of foundation for receiving the WBM course

b) Provision of lateral confinement

c) Spreading of coarse aggregate

d) Rolling

e) Application of screening, sprinkling and grouting and application of binding material along with the properties of setting and drying.

Checking of surface evenness and rectification of defects:

The surface evenness of longitudinal direction is checked by 3 m straight edge and the number of undulations exceeding 12 mm in the case of WBM layer of grading no.1 and 10 mm in the case of grading nos.2 and 3 are recorded in each completed length of 300 m, the maximum number of undulations permitted in each case is 30.The spots with 15mm undulations are marked for rectification of defects. The cross profile is checked using the camber template and the maximum variation from special profile should not exceed 12 mm in the case of aggregate grading no.1 and 8 mm in the case of gradings 2 and 3. Where the unevenness exceeds the specified limits the defective area with a minimum area of 10 m2 at a spot is scarified, reshaped with added material or fresh material and re-compacted properly.

Bituminous Pavements:

Bituminous pavements are in common use in India and Abroad. It is possible to construct relatively thin bituminous pavement layers over an existing pavement. Therefore these are commonly adopted as wearing course. Flexible pavement could be strengthened in stages by constructing bituminous pavement layers one after another in a certain period of time unlike the cement concrete pavement construction.

The black top construction is in extensive use in developing nations like India where the cement as a construction material is in great demand for large number of other engineering projects. Also stage development is possible in the case of bituminous roads, depending on traffic demands.

Various types of techniques are available for bituminous pavement constructions are

1) Interface treatments like prime coat and tack coat

2) Surface dressing and seal coat

3) Grouted or penetration type of construction

a) Penetration macadam b) Built-up Spray grout

4) Premix like

a)bituminous macadam, d)sheet asphalt or rolled asphalt,

b)carpet, e)mastic asphalt,

c)bituminous concrete,

In the above methods the bituminous binders used are either straight run bitumen, road tar, cutback or emulsion.Surface dressing is done to provide dust free pavement surface over abase course like WBM. It is also done to prevent the infiltration of surface water and to protect the base course.

Interface treatment:

Interface treatment is the process of cleaning and removing the dust and dirt followed byspraying a thin layer of bituminous binder of any type over the existing surface. This can be done by a prime coat or a tack coat and in some cases the prime coat followed by a tack coat.

a) **Prime coat:** Used when the base surface is the WBM and the Bitumen being applied for the first time. Its main functioning is to seal the voids or pores and to make the under lying layers as water proof courses.

b) **Tack coat:** It is the coat applied over an already existing bituminous pavement or CC pavement. Its functions are similar to prime coat. It is usually applied by spraying bituminous material of higher viscosity like the hot bitumen at the rate of 4.9 to 9.8 kg per 10 m2 area depending on the type of the surface. However in some special cases a tack coat of bituminous emulsion may be applied in cold state.

Bituminous surface dressing (BSD): Bituminous surface dressing is provided over an existing pavement to serve as thin wearing coat. The single coat surface dressing consists of a single application of bituminous binder material followed by spreading of aggregate cover and rolling. When the surface dressing is similarly done in two layers it is called two coat bituminous surface dressing. Where better adhesion is required aggregates precoated with bituminous binder are used in lieu of conventional surface dressing and this technique is called Bituminous Surface Dressing with Precoated Aggregates. The main functions of the BSD are

a) To serve as a thin wearing surface and to prevent infiltration of surface water

b) To water proof the pavement surface and to prevent infiltration of surface water

c) To provide dust-free pavement surface in dry weather and mud-free pavement in

wet weather.

The functions of the seal coat are to seal the surface of the pavement against the infiltration of water to develop skid resistance and to make existing dry or weathered surface .In grouted or penetration macadam the material is spread over the aggregate. It is mostly used for the inferior roads .The bituminous macadam is used for base course construction. Bituminous carpet is a premix of 10-12 mm size chip along with the mixing of bitumen. Total thickness is of 20-25 mm. This is used as a surface layer.

The other Techniques are like penetration macadam, seal coat, Built-up spray grout, premix methods, bituminous macadam, bituminous premix carpet, bituminous concrete or asphalt concrete, Sheet asphalt, Mastic asphalt etc.

The bituminous concrete materials used are coarse aggregates, fine aggregates, mineral filler like cement lime and bitumen. Bituminous concrete is equivalent to two times water bound macadam surface.

A carpet of sand and bitumen is called as sheet or rolled asphalt. No coarse aggregate is used in this. It is used for wearing course.

Bitumen mixed with fine aggregate, filler in suitable proportions yielding void less and impermeable mass. It can absorb vibrations.

Bituminous Construction Procedure:

a) Surface Dressing

b) Grouted or Penetration macadam

c) Built-up spray grout

d) Bitumen bound macadam

e) Bituminous carpet

f) Bituminous concrete

Cement concrete roads:

The Cement Concrete pavement maintains a very high recognition among the engineer and the road users alike. Due to the excellent riding surface and pleasing appearance the cement concrete roads are very much preferred. It is true that the life a cement concrete road is much more than any other type of constructionTransverse and longitudinal joints are unavoidable in this construction. The joints as such provide additional planes of weaknesses. The maintenance and repair if any required in cement concrete pavements are mostly associated with joints. The numbers of joints provided are also kept to a minimum as the construction of joints involves substantial extra work. A minimum period of 28 days curing is required before the cement concrete pavement could be opened to the traffic. The cement concrete pavements are constructed with or without the sub base course. This decision is made depending upon the soil type, design load, economic consideration etc. The various purpose of the sub-base course beneath the cement concrete pavements are

a) To provide a strong supporting layer

b) To provide a capillary cut-off preventing the damages due to mud –pumping

c) To increase the service life of the CC pavement

d) To reduce the thickness requirements of cement concrete slab and lower the cost of construction. WBM is the most popular type of underlying layer generally adopted. Soil stabilized layers can also be used with advantage.

Construction of Cement Concrete Pavements:

The construction of cement concrete pavements is grouped under the following categories:

1) Construction of pavement slabs

2) Construction of Joints.

Various specifications for construction of CC pavement are like

a) cement grouted layer

b) rolled concrete layer

c) cement concrete slab.

The available methods of constructing a slab are

1) Alternate bay method 2) Continuous bay method.

The construction steps for the cement concrete pavement slab are

1) preparation of sub grade and sub base

2) placing of forms

3) batching of material and mixing

4) Transporting and placing of concrete

5) Compaction of finishing

6) Curing of cement concrete.

Construction of Joints in Cement Concrete Pavements:

Joints are provided in cement concrete roads for expansion, contraction and warping of the slabs due to the variation in the temperature of the slabs. Changes in the atmospheric temperatures in turn reduce the changes in the temperatures in the slab. Such changes of temperature cause expansion of the slab horizontally if there is an increase in the slab temperature above the temperature during which the slab was laid. Similarly there is contraction of slab also when the temperature falls below this temperature.

The slab movements also take place in vertical direction which is due to the temperature differential between top and bottom of pavement slab. During the mid-day the top of the pavement slab has higher temperature than the bottom of the slab. This causes the top fibers of the slab to expand more than the bottom fibers, and the slab curls at the edges. This phenomenon is known as warping down of the slab. By about midnight the temperature of the bottom of the slab is higher than the temperature of the slab top. The slab warps up during this time.

To minimize the temperature stresses in the pavement slab, expansion contraction and warping joints may be provided transversely across the full width of pavement.

Apart from this construction joints are also provided. The compulsory break provided in continuity of the slabs is due to the close of day's job and the commencement of the same the next day with a construction joint. Normally the construction joint is planned to coincide with an expansion joint. It is customary to provide concreting of one lane at a time which may be of width 3.5 m for highway pavements. Thus two lanes are also jointed together by a joint known as longitudinal joints. Joints are also classified depending upon their direction of placement. They are

a) Transverse joints b) Longitudinal joints

Transverse joints are again classified as Expansion joint, Contraction joint, Warping joint, and Construction joint

Requirements of a good joint:

a) Joint must move freely,

b) Joint must not allow infiltration of rain water and ingress of stone grits,

c) Joints must not protrude out of the general level of the slab.

Expansion joint: These are provided to allow for the expansion of the slabs due to the rise in slab temperature above the construction temperature of the cement concrete. These joints also permit the contraction of the slabs. These are provided at an interval of 50m -60 m for smooth interface laid in winter and 90m-120m in summer. However for the rough interface the spacing between expansion joints may be 140m.

Contraction joint: These are provided to permit the contraction of the slabs and are spaced closer than the expansion joints. Load transference of these joints is provided through thephysical interlocking by the aggregates projecting out of the joint faces. As per IRC the maximum spacing of contraction joints in unreinforced CC slabs is 4.5 m and in reinforced slabs of thickness 20 cm is 14 m.

Warping joint: These are provided to relieve stresses included due to the warping. These are known as hinged joints. Longitudinal joints with tie bars fall in this class of joints. These joints are rarely needed if the suitably designed expansion and contraction joints are provided to prevent cracking.

Longitudinal joints: These joints are provided in CC roads which have width over 4.5m.On soil sub grade of clay, such joints are provided to allow differential shrinkage and swelling due to rapid changes in sub grade moisture under the edges than under the centre of road. The longitudinal joints are provided to prevent longitudinal cracking in the CC pavement. This type of joint acts as a hinge and helps to maintain the two slabs together at the same level.

FLEXIBLE PAVEMENT FAILURES

The maintenance operation of the roads involves the assessment of road condition, diagnosis of the problem and adopting the most appropriate maintenance steps. Various types of failures in pavements ranging from minor and localized failure to major and general failures do take place on roads. The failures may be due to one or a combination of several causes.

General causes of Pavement Failures:

a) Defects in the quality of materials used

b) Defects in the construction methods and quality control during construction

c) Settlement of foundation of embankment of the fill material itself

d) 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

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

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

Classification of the maintenance works:

The highway maintenance works may be broadly classified under three heads, namely

a) Routine maintenance/repairs: These will include filling up of pot holes and patch repairs, maintenance of shoulders and the cross slope etc.

b) Periodic maintenance: These include renewals of wearing courses of pavement surface and preventive maintenance of various items.

c) Special repairs: These include strengthening of pavement structure of overlay construction, reconstruction of pavement, widening of roads, repairs of damages caused by floods, providing additional safety measures.

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 pavement distress and the failure is considered complex as several factors contribute to the pavement deterioration and the failure. The aging and oxidation of bituminous films leads to the deterioration of bituminous pavements. Detrimental 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 CC pavements.

One of the prime causes of the failure of the flexible pavement failure is excessive deformation in sub grade soil. This can be noticed in the form of excessive undulations or waves and corrugations in the pavement surface and also the depressions followed by heaving of pavement surface. The failure of sub grade may be attributed to two basic reasons like

a) Inadequate stability

b) Excessive stress application. Similarly the failures in the Subbase and Base courses are due to
i) Inadequate strength or stability

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 internal confinement for the granular base

course.

Generally these failures are in the form of local depressions called potholes or major continuous cracks. Some of the typical flexible pavement failures are

1) Alligator (map) cracking

2) Consolidation of pavement layers

3) Shear failure

4) Longitudinal cracking

5) Frost heaving

6) Lack of binding (keying) to the lower course

7) Reflection cracking

8) Formation of waves and corrugation.

All these types of failures may cause discomfort to riding and ultimately leading to failure.

Rigid pavement failures:

The CC pavements may develop cracks and deteriorate due to repeated loads and fatigue effects. A rigid pavement failure is observed by the development of structural crack or break resulting in progressive subsidence of some portions of pavement. More irregularities in the supporting layers beneath the cement concrete pavements are sustained due to inherent bending strength of these pavements.

Failures of CC pavements are recognized mainly by the formation of structural cracking. The failures are mainly due to the factors like i) deficiency of pavement failures ii) Structural inadequacy of the pavement system. The chief causes which would give rise to the different defects or failures of CC pavement are i) Soft aggregates ii) Poor workman ship in the joint construction iii)Poor joint filler and sealer material iv)poor surface finish v)improper and insufficient curing. The various defects that creep in due to the above are

a) Disintegration of the cement concrete

b) Formation of cracking

c) Spalling of joints

d) Poor riding surface

e) Slippery surface

f) Formation of shrinkage cracks

g) Ingress of surface water and further progressive failures

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

i) Inadequate pavement thickness

ii) Inadequate sub grade support and poor sub grade soil

iii) Incorrect spacing of joints.

These will give rise to the failures of the following types:

i) Cracking in the slab corners
ii) Cracking of pavements longitudinally
iii)Settlement of slabs
iv) Widening of joints
v)Mud pumping

Basically cement concrete pavements failures are structural failures in the form of cracks and

Spalling of joints. Typical rigid pavement failures are

1) Scaling of cement concrete
2) Warping cracks
3) Mud pumping
4) Shrinkage cracks
5) Spalling of joints
6) Structural cracking.

Pavement Evaluation:

Pavement evaluation involves a thorough study of various factors such as sub grade support, pavement composition and its thickness, traffic loading and environmental conditions. The primary objective of the pavement condition evaluation is to assess as to whether and to what

extent the pavement fulfills 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 the requirements of providing safe and comfortable traffic operations. The various methods of present evaluation are like structural evaluation of pavements, evaluation of pavement surface condition.

Structural evaluation of pavements: The structural evaluation of both flexible and rigid pavements 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 tests 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 re-bound deflection. Measurement of the transient deflection of the pavement under design wheel loads serves as an index of the pavement to carry traffic loads under the prevailing conditions. Out of the various equipment used for the purpose Benkelman beam is most commonly used as the measurements are simple and easy. Benkelman beam measurements are preceded by a rating survey of the road so as to divide it into homogeneous section of approximately similar serviceability. There are a number of other non-destructive testing techniques for assessing the load carrying capacity of the pavements.

Evaluation of pavement surface condition: The surface condition of flexible pavements may be evaluated by the unevenness, ruts, patches and cracks. The surface condition of rigid pavements may be assessed by the cracks developed and by faulty joints affecting the riding quality of the pavement. The pavement unevenness may be measured using unevenness indicator, profilograph, profilometer, or roughometer. An 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. Roughometer is one such device which could be towed by an automobile. Profilometer was used to record the variable slope angle of the surface formed bytwo probe wheels spaced 13.5 cm apart. The pavement unevenness criteria to indicate the pavement riding qualities expressed in terms of unevenness index.

Strengthening of Existing pavements: For the successful maintenance of pavements it is essential that they have adequate stability to with stand the design traffic under the prevailing climatic and sub grade conditions. If the pavements have to support increased wheel loads and load repetitions the pavement rapidly undergo the distress and no amount of routine and periodic maintenance can

help them. Due to the unexpected economic developments in the region the loading conditions may becomes severe and the alternative would be either to divert the traffic on some adjacent routes or to strengthen the existing pavements. Strengthening may be done by providing additional thickness of the pavement of adequate thickness in one or more layers over the existing pavements which is called as overlay. If the existing pavement has completely deteriorated an overlay did not serve the purpose and the solution would be to remove the existing damaged pavement structure and to rebuild the same. In partially damaged pavement sections patch repair works are carried out before constructing the overlay. The various types of over lay combinations are

i)Flexible overlay over flexible pavements

ii) Cement concrete or rigid overlay over flexible pavements

iii) Flexible overlays over cement concrete or rigid pavements,

iv)Cement concrete or rigid over lay over rigid pavements