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Design and Construction of Bituminous Pavements

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Abstract

The objective of pavement design is to develop pavement constructions in a way that stresses and strains within the constructions due to traffic and climatic conditions do not exceed certain limits, or – in other words – to design pavements, which are able to resist appearing loads during the intended life time. As failure due to fatigue is regarded as relevant for the determination of the thickness of the bituminous layers, several criteria exist to predict the technical life time on the basis of empirical observations of the fatigue behaviour in the laboratory or in full-scale tests. All these criteria have in common that relevant stresses or strains within the construction are considered, which appear, in general, either as tensile load at the bottom of the bituminous base course or as compressive load at the top of the subgrade. For bituminous layers, for example, single cracks emerging at the bottom of the base course and developing to the surface are regarded as relevant for the structural fatigue of the pavement. At the surface, these single cracks lead to so-called alligator cracking and, hence, decreasing bearing capacity of the pavement construction.

Keywords

Bituminous pavements, polymer admixtures, Sub-grade, *Bituminous strength properties,*

1. Introduction

This Article is on the design and construction of Bituminous pavements by Rural Engineering Department. The department was created by the Uttar Pradesh (U.P.) Government to strengthen Rural Infrastructure in the year 1972 administratively controlled under the Ministry of Rural Development. A separate Ministry is created as Ministry of Minor Irrigation and Rural Engineering Department and finally Rural Engineering Department. This department mainly executes the construction works on deposit basis and is providing technical guidance to district and block level administrative officers as & when required.

It mainly executes the construction works of departments like Medical and Health, Primary and Secondary Education, Tourism, Milk and Dairy, Industries and Fisheries. Proper Time Management, Contract Management and Project Management are basic essence of successful implementation of various schemes. Rural Engineering Department is acting as important construction agency of U.P. Govt.Rural Road connectivity is a key component of Rural Development by promoting access to economic and social Department and they're by generating increased agricultural incomes and productive employment opportunities in Uttar Pradesh. Rural Engineering Department is implementing centrally sponsored rural connectivity, a ambitious plan called as "PMGSY" (PradhanMantri Gram SadakYojana) in 31 Districts since year 2002. Out of which 15 Districts are World Bank aided.

Figure 1. A bridge in a rural area

At Directorate level department is headed by Director cum Chief Engineer (Gr-I) and assisted by following:

* Chief Engineer (Gr-II) (East)
* Chief Engineer (Gr-II) (West)
* Finance Controller
* Superintending Engineer (Monitoring)
* Executive Engineer cum PA-1 (Establishment Officers)
* Executive Engineer cum PA-2 (Establishment Clerical Staff)
* Executive Engineer cum PA-3 (Establishment Junior Engineers)
* Executive Engineer cum PA (Planning)
* At Circle level the department is headed by a Superintending Engineer Established at Revenue Mandals.
* At District level the department is headed by Executive Engineer and assisted by Assistant Engineers and Junior Engineers.

2. Road widening PROJECT

2.1. From Selection Point Tower to Dharamkanta Intersection

- 3 meters wide.
- Average 50-centimetre depth.
- 26-centimeter RBM or GSB and 25-centimeter WMM.
- After the widening 1.5-meter footpath.
- Widening of 3 m on both sides.
- 1.5 m footpath on both sides.
- Proper compaction of the soil and material to avoid cracks.
- Excessive soil is removed to avoid cracks.
- Air pressure is applied before and after construction of roads to remove excessive soil and material to avoid cracks.
- After putting GSB and WMM, roller is moved on the surface to level it.
- Avoid manholes.
- Avoid pipelines if possible.
- Divider of width 1.5 meter is made.
- The carriage way on either side of the divider is 8m.
- Main Delapeer intersection is of 14-meter diameter – three-way route.
- First find the center of the circle by assuming a circle of unknown diameter.

Figure 2. Plan of the main intersection

- Centre of that circle will be the centre point of intersection to be made.
- Alignment of the divider is according to the position of the intersection to be made.
- Alignment can be straight or slightly circular.
- Then we mark the alignment of the divider from the centre of the divider earlier marked
- The surface of the WMM or the road surface on which a new bitumen layer is to be laid is checked for defects.
- Surface is thoroughly cleaned free of dust and loose material by applying air pressure or using brush wires.
- A tack coat is applied by spraying liquid bituminous binder or coal tar.

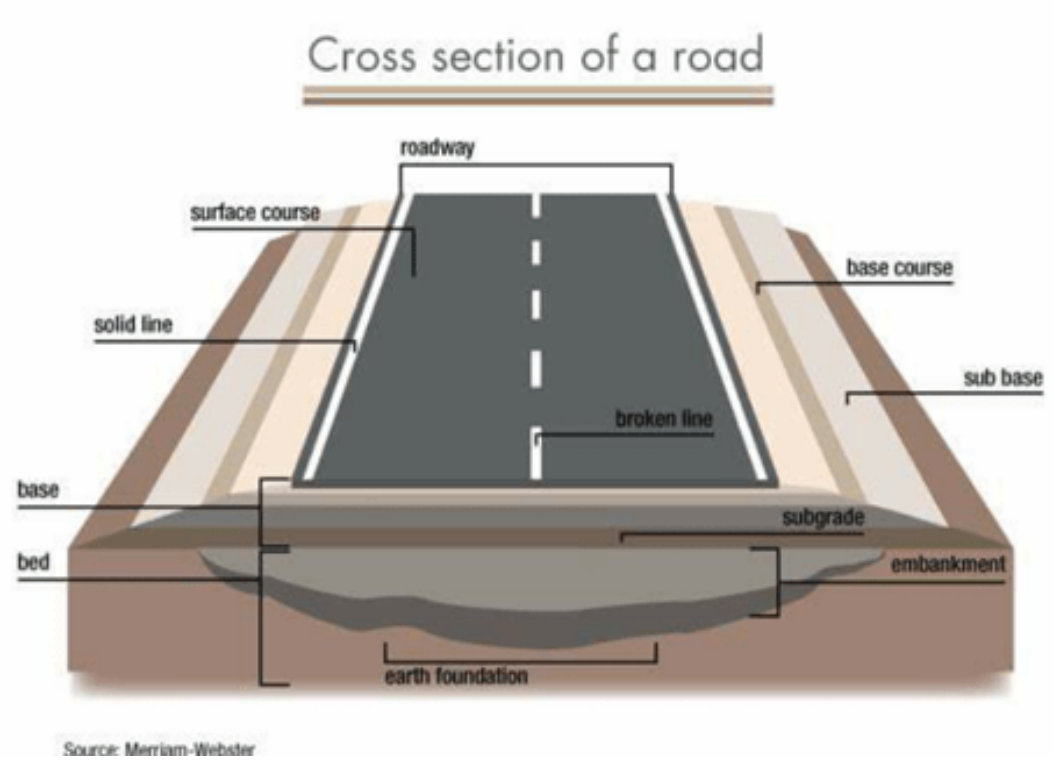

Figure 3. Cross section of a road

- Two layers of bitumen are spread.
- The first layer is Bituminous Macadam.
- Bituminous Macadam contains stone grade of various sizes such as 12mm, 10mmand 6mm.
- Bituminous macadam contains coal tar of 3% of the weight of the mixture.
- Weight of the bituminous macadam in first layer is 0.5 kg/m^2.
- The thickness of the first layer which is spread is 75 mm.
- Second layer is of Semi dense macadam concrete.
- Semi dense macadam concrete contains 6mm stone grade.
- Semi dense macadam concrete contains coal tar of 5% of the weight of the mixture.
- Weight of the semi dense Macadam concrete is 0.2 kg/m^2.
- The thickness of the second layer which is spread is 30 mm.
- The first layer or Bituminous Macadam when spread on the surface is loose. It is then compacted using rollers.
- Bituminous macadam is spread by putting the BM from the carrier trucks into a compartment in mechanical paver.

Figure 4. First layer Of Bituminous Macadam

- In mechanical paver, through rotating belts the bituminous macadam goes to the rectangular back part of the mechanical paver and from there BM is spread uniformly of certain thickness.
- While spreading the Bituminous Macadam we need to constantly check the depth of the BM surface spreading by using a measuring gauge.
- First layer when spread is loose. It is then compacted using rollers.
- First, we use vibratory rollers of 8 to 12 tones to achieve a higher degree of densification. The aggregate particles move in every possible direction. Vibrations are produced by eccentric loading system. Pavement layer requires high amplitude and low frequency of vibration.
- After vibratory rollers, ordinary rollers are used for further compaction. Tyres of both the types of rollers are wet for smooth compaction and to avoid sticking of bituminous macadam on its tyres.
- First the Bituminous Macadam is spread on both sides of the already built pavement surface. Then it is spread in a similar way on the widening part of 3 meters on either side of the road.
- When spreading of the first layer of Bituminous Macadam on pavement surface and widening part on either of the road is complete, construction of divider is started according to the alignment marked and calculations taken.

Figure 5. Gap left for the divider to be made after spreading the Bitumen Macadam

- When the construction of divider is complete, the second layer which is of Semi dense macadam concrete of 30 mm thickness is spread in a similar way as of the Bituminous Macadam and then compacted using rollers.
- Then it is allowed to sit before it is open to traffic.
- Camber is taken to be 2% of the total width of the road. Here the camber is 6 inches.
- The amount of work done is calculated by calculating the area in which bitumen is spread.

3. Excavation

Excavation is the process of cutting or loosening and removing earth including rock from its original position, transporting and dumping is as a fill or spoil bank. The excavation or cutting may be needed in soil, soft rock or even in hard rock, before preparing the formation of a new highway. The selection of excavation equipment and the cost analysis is made based on the stiffness and hardness of the materials to be excavation.

3.1. Methods of excavation of earth

Earth work excavation involves cutting and grading the soil to enable highway construction in cutting. The depth of the excavation is decided among other factors, on requirement of vertical profile of the road. The slope to be provided is governed by the type of soil including stratification, if any and the depth of the cutting. The stability computations are made for arriving at the maximum permissible safe slope for deep cuttings. However, highway cuts with much flatter slopes are preferred from other considerations such as aesthetics and visibility/sight distance requirement at horizontal curve.

Figure 6. Excavation being carried out at the site

4. Types of Layers

4.1. Granular sub-base (GSB)

The granular sub-base course is laid in between the subgrade and the base course of all highway pavements, in one or more layers. The GSB layer should be laid over the full width of the prepared subgrade extending up to the side drains to serve as a 'drainage layer' of the pavement.

It serves as a structural component of the flexible pavement structure by distributing the wheel load stresses transmitted through the surface course and granular base course, to a still larger area before passing on the compressive stresses on the top of the subgrade.

Figure 7. MATERIALS FOR GSB LAYERS

The materials used for the construction of the GSB layers are,

a. Crushed stone aggregates
b. Gravel
c. Coarse sand, and
d. Selected soils such as moorum with less fines.

The material should not contain organic matter or other deleterious constituents.

5. Construction method

The GSB layer is constructed on the top of the prepared subgrade.

i. The subbase material is spread to uniform thickness and specified cross slope.
ii. The moisture content of the material is checked, and an additional quantity of water required is added.
iii. The watered material is mixed properly using machinery.
iv. The mixed material is spread to the desired thickness.
v. The loose GSB layer is compacted by rolling.
vi. Rolling is continued till at least 98 percent of maximum density of the material is achieved.

5.1. Quality control checks

1. Check the values of liquid limit, plasticity index, gradation, and deleterious constituents.
2. CBR value of the selected material is determined in the laboratory.
3. Laboratory compaction tests are carried out to determine the maximum dry density.
4. The field moisture content of the material is determined prior to compaction by any rapid test method.
5. After rolling, the field density and moisture content are determined to ensure that the dry density achieved is not less than 98 % of the laboratory method.

5.2. Water mix macadam (WMM)

The common types of base course materials used in India for the construction of flexible pavements are 'Wet Mix Macadam'(WMM). Wet Mix Macadam (WMM) base consists of a well graded hard crushed aggregates and adequate proportion of water mixed thoroughly in a mixing plant; the wet mix is spread over the prepared sub-base course with a mechanical paver and rolled to a dense mix.

5.3. Physical properties

a. Los Angeles Abrasion value: less than 40 %
b. Aggregate impact value: less than 30 %
c. Combined flakiness and elongation index: less than 30 %
d. Plasticity Index of material: less than 6.0

Figure 8. Water mix macadam used at the construction site

5.4. Construction steps

i. Compaction test is carried out in the laboratory using the selected grade of WMM material, removing the aggregates retained on 19 mm sieve and replacing it with material passing 19 mm sieve and retained on 4.75 mm sieve.
ii. The selected WMM mix is prepared in a suitable mixing plant like the 'pug mill'.
iii. The WMM mix is transported to the site and is spread to the required thickness.
iv. The WMM layer is compacted using a roller weight of 10 tones.
v. The WMM layer is checked for defects, if any, and allowed to dry; no traffic shall be allowed before a bituminous surface is constructed.
vi. After the WMM layer is dried for at least 24 hours in dry weather, the preparation for laying a bituminous pavement layer may start by applying the prime coat.

5.5. Quality control checks

i. The samples of coarse aggregates collected are subjected to relevant laboratory tests to check the values of Los Angles abrasion value or aggregate impact value, combined flakiness, and elongation index.
ii. Plasticity index is checked on the fraction of course and fine aggregates.
iii. The gradation of the combined mix of course and fine aggregates is checked.
iv. The field density and moisture content of the WMM mix is determined while being fed into the mechanical paver.

6. Bituminous macadam base course

'Bituminous Macadam' (BM) consists of crushed aggregates and bituminous binder heated and mixed in a hot mix plant at specified temperature, transported to the construction site, laid with a mechanical paver, and compacted by rollers. The BM is laid in compact thickness of 50 to 100 mm. Two different gradations of aggregates have been suggested by the IRC to provide open graded mixture suitable for base course of highway pavements. Therefore, the BM layer should be covered by a suitable surfacing course before exposure to weather or traffic. In case there is delay in laying appropriate bituminous layers above the BM layer, at least a seal coat should be applied to prevent ingress of water during unexpected rains and possible damage to the BM layer.

6.1. Materials

The specifications of materials used in the construction of BM such as bitumen binder and aggregates are given under.

6.2. Bitumen Binder

Paving bitumen of viscosity grade VG- 30 is recommended for use in most of the regions in India. However, in regions with cold weather or in high altitude, the IRC has recommended the use of VG- 20 grade bitumen.

6.3. Aggregates

The coarse aggregates used for BM layer shall consist of hard crushed rock retained on 2.36 mm sieve. The fine aggregate shall consist of either crushed rock, or a combination of natural sand and crushed rock passing 2.36 mm and retained on 0.075 mm sieve.

6.4. Physical properties

a. Los Angeles abrasion value: less than 40 percent.
b. Aggregate impact value: less than 30 percent.
c. Combined flakiness and elongation index: less than 40per cent.
d. Water absorption: less than 2 percent.
e. Coating and stripping of bitumen: minimum coating retained 95percent.
f. Soundness test with sodium sulphate and magnesium sulphate: less than 12 percent and 18 percent respectively.

6.5. Construction steps

i. The surface on which BM base course is to be laid is prepared by patching potholes, filling up the depressions and making profile correction.
ii. The surface is cleaned with a mechanical broom to remove loose materials and dust.
iii. The prime coat and tack coat are applied as specified if the receiving surface is granular sub-base or base course; if it is a bituminous surface, a tack coat is sufficient
iv. After ensuring that the prepared surface is dry, the BM mix is prepared in a hot mix plant at specified temperature, depending on the grade of the bitumen used. The recommended temperatures are 160 to 170 degrees Celsius for viscosity grade VG-10 and 150 to 165 degrees Celsius for VG-20.
v. The bitumen mixture is hot after being taken out from the plant.
vi. The hot mix is transported to the construction site in a clean, insulated covered truck.
vii. The BM mix is spread using a mechanical paver.
viii. Rolling is started soon after laying the mix and compaction is completed before the mix cools down to the minimum specified temperature of 100 degree Celsius in VG-10 grade and 90 degrees Celsius in VG-20 grade bitumen.
ix. Compaction is done by rolling in three stages:
    a. 'Break down' rolling using either a heavy static roller of dead weight 8 to 10 tones or a vibratory roller.
    b. Intermediate rolling using vibratory roller at high frequency and low amplitude.
    c. Final rolling by a light roller of weight 6 to 8 tones.
x. The surface finish of the rolled pavement layer is checked, the finished surface is corrected soon after rolling where necessary.

xi. The maximum permissible unevenness is 6 mm under a 3 m straight edge and number of undulations of magnitude 4 to 6 mm shall not exceed 20 per 300 m stretch of road surface.

xii. The finished BM layer shall not be opened to traffic but shall be covered with the next pavement layer or shall be covered with a seal coat.

6.6. Quality control tests

i. The coarse aggregates are subjected to Los Angeles abrasion test or aggregate impact test, flakiness index test, elongation index, water absorption and soundness tests.

ii. Coarse aggregates are subjected to stripping value test on bitumen coated aggregates and water sensitivity test on bituminous mix.

iii. The bituminous binder is checked for viscosity and ductility value.

iv. The temperature of the binder and aggregate are checked at the time of mixing.

v. The thickness of the BM layer just after spreading is checked at regular intervals.

vi. The density of compacted BM layer is checked.

7. Prime coat

Spraying of liquid bituminous binder of low viscosity over a granular or non-granular bituminous surface is called application of prime coat or 'priming'; this is an important part of preparations before laying a bituminous pavement layer over a granular base course. The objectives of priming the granular surface are to:

a. Penetrate deep into the surface and plug or seal the voids on the surface.

b. Coat and bond the loose particles on the surface.

c. Render the surface of the base course water resistant and

d. Permit the tack coat to be applied over the primed surface to provide proper adhesion between the base and the bituminous pavement layer constructed above the treated granular base.

7.1. Method of application of primer

The surface of the base course is swept clean and made dust free. If bitumen emulsion is used as a primer, no heating of the binder shall be done; the surface of the granular base shall be slightly dumped. Since emulsions contain fine bitumen particles suspended in water, generally, there is no need to add water to the emulsion before it is sprayed on the surface. The primed surface is allowed to cure for a minimum of 24 hours; the traffic shall not be allowed over the primed surface. After curing, the tack coat is applied, and this is followed by laying of the required bituminous pavement layer.

8. Tack coat

A tack coat is the application of a small quantity of liquid bituminous binder of low viscosity over either a primed granular surface or over an existing bituminous or cement concrete surface. Application of tack coat is also an important part of preparations before laying a bituminous pavement layer over any other pavement layer. The main objective of the tack coat is to provide adequate interface bond between the receiving pavement surface and the new bituminous layer being overlaid. The binder of the tack coat is not expected to penetrate the pavement surface and plug the voids.

8.1. Method of application of tack coat

The bituminous emulsion is sprayed uniformly over the clean receiving surface. The bituminous emulsion tack coat is cured by allowing it to break, indicated by the color turning from chocolate brown to black; the bituminous layer is placed over this surface soon after.

Figure 9. A tack coat is being applied before spreading the bitumen macadam on the pavement surface.

9. Types of machinery used

9.1. Earth excavator

Excavators are heavy equipment consisting of a boom, bucket, and cab on a rotating platform. All functions and movements of the excavator are accomplished using hydraulic fluid, be it with ram or motors.

9.2. Types of earth excavator

a. Compact excavator.
b. Crawled excavator.
c. Wheeled excavator.
d. Backhoe excavator.
e. Dragline excavator.
f. Bucket Wheel excavator.
g. Long Reach excavator.

Figure 10. Earth excavator

9.3. Bulldozer

Most often bulldozers are large and powerful tracked heavy equipment. The tracks give them excellent ground holding capability and mobility through very rough terrain. Bulldozers have transmission systems designed to take advantage of the track system and provide excellent reactive force.

Because of these attributes, bulldozers are often used in road building, construction, mining, forestry, land clearing, infrastructure development, and any other projects requiring highly mobile, powerful, and stable earth moving equipment. The bulldozer's primary tools are the blade and the ripper.

Figure 11. Bulldozer

9.4. Mechanical paver

A mechanical paver (paver finisher, asphalt finisher, paving machine) is a piece of construction equipment used to lay asphalt or bitumen on roads, bridges, parking lots, and other such places. It lays the asphalt or bitumen mix flat.

Figure 12. Mechanical paver is being used to spread the bitumen macadam.

Mechanical paver finisher is a unique paver with combination of features designed and engineered to give maximum output with comforts. The hydraulically extendable screed allows step less and hassle-free width adjustment. The higher H.P. engine ensures smooth paving in gradients. Paver finishers are used in the road construction industry for paving or laying hot mixed material on constructed surface.

9.5. Road rollers

The principle of compaction by rollers is by application of pressure on the layer; as the roller moves, the pressure applied at point within the layer is gradually increased and then decreased. The loose soil particles get packed closer during the rolling process.

9.6. Ordinary smooth wheeled rollers (Static rollers)

The gross weight of a three wheeled roller varies from 8 to 15 tones and two wheeled roller varies from 3 to 14 tones. The compaction efficiency of the smooth wheeled roller depends on the weight, width, and diameter of each roller wheel. The smooth wheeled rollers are suitable to compact a wide range of soils, particularly granular soils, aggregates, and other pavement materials.

Figure 13. An ordinary road roller is being used to compact the WMM surface.

9.6.1. Vibratory rollers

In vibratory rollers, compaction is affected due to both dynamic effect of the vibratory force and the static weight of the roller. In vibratory rollers generally it is possible to vary the amplitude and frequency of vibration within a certain range; varied depending on the type of material to be compacted. During compaction the soil and aggregate particles or the aggregates in the bitumen mix can move in all possible directions under the combined effect of vibration and pressure; thus, it is possible to achieve a higher degree of densification.

Figure 14. A vibratory roller is being used to compact the bitumen macadam surface.

10. Conclusions

It has been observed that, Bitumen shows a versatile physical and rheological properties used in road construction as a binder. The melting point of Bitumen is low and hence it is suitable for country like India for construction of Roads. One of the most important properties of Bitumen is that it can be Recycled. Bitumen is adhesive in nature and hence very suitable for binding aggregates used in road construction. The use of Bitumen as a binder in road makes it more economical than any other type of binding material as production of Bitumen is very economical and easily available. Bitumen pavement provides a smooth surface to ride because it does not make use of any joints and as compared with concrete pavements, it also gives less sound emission. It maintains smoothness because the wear and tear are less on the bitumen road.

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