



DESIGN OF FLEXIBLE PAVEMENT

**Jaspreet Singh, Lokesh Chauhan, Manoj Kumar, Mohd Juber,
Mohd Zuhaib**

*Department of Civil Engineering,
IIMT College of Engineering, Greater Noida, Uttar Pradesh, (India)*

ABSTRACT

Highway and pavement design plays an important role in the DPR projects. Regarding the pavement design, it forms an important part of detailed engineering study. The satisfactory performance of the pavement will result in higher savings in terms of vehicle operating costs and travel time, which has a bearing on the overall economic feasibility of the project. This project discusses about the design methods that are traditionally being followed and examines the relative merits of flexible pavement.

Currently, majority of the Indian roads are flexible pavements, the ones having bituminous layers. Earlier, there used to be scarcity of cement and India went for flexible pavements with bituminous toppings. Now, flexible pavement are preferred over cement concrete roads as they have a great advantage that these can be strengthened and improved in stages with the growth of traffic. Another major advantage of these roads is that their surfaces can be milled and recycled for rehabilitation. The flexible pavements are less expensive also with regard to initial investment and maintenance.

Main focus is on the Quality Control Management in a construction activity. Thesis is to be prepared on how the Quality control management exist and the way it is being functioned. It can be done by drawing comparisons with the standard way and practical way.

Keywords: Flexible Pavement, Bituminous Layer, Quality control management.

I. INTRODUCTION

Pavement is the durable surface material laid down on an area intended to sustain vehicular or foot traffic, such as a road or walkway. In the past cobblestones and granite sets were extensively used, but these surfaces have mostly been replaced by asphalt or concrete

There are two types of pavements: (i) Flexible pavement (ii) Rigid pavement

1.1 What is Flexible pavement?

Flexible pavements are those, which on the whole have low flexural strength and are rather flexible in their structural action under the loads. The flexible pavement layers reflect the deformation of the lower layers on to the surface of the layer.

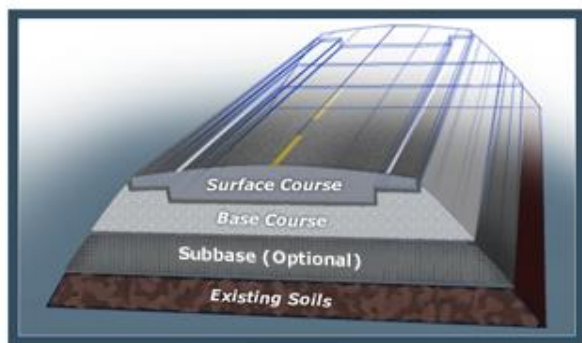
A typical Flexible pavement consists of four components:

- (i) surface course
- (ii) base course
- (iii) sub base course

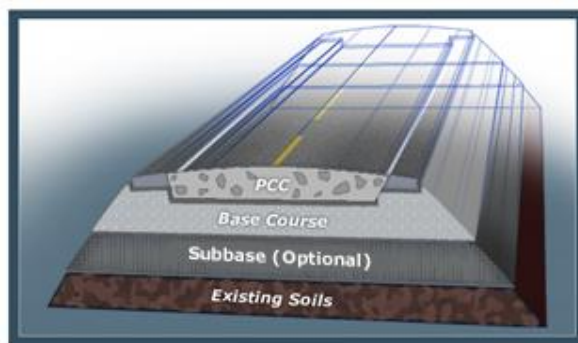
(iv) soil sub grade

1.2 What is Rigid pavement?

Rigid pavements are those possess noteworthy flexural strength. The stresses are not transferred from grain to the lower layers as in case of flexible pavement layers. The rigid pavements are made of Portland cement concrete-either plain, reinforced or prestressed concrete. The plain cement concrete slabs are expected to take up to about 40 kg/cm² flexural stress. The rigid pavement has the slab action and is capable of transmitting the wheel load stresses through a wide area below.



Typical Flexible Pavement



Typical Rigid Pavement

II. DESIGN FACTORS

Factors to be considered in Design of Pavements

Pavement Design consists of two parts:

- (i) Mix design of materials to be used in each pavement components layer.
- (ii) Thickness design of the pavement and the component layers.

The various factors to be considered for the design of pavements are given below:

- a) Design wheel load
- b) Subgrade soil
- c) Climatic factors
- d) Pavement component materials
- e) Environmental factors
- f) Special factors in the design of different types of pavement.

III. ROAD CONSTRUCTION ACTIVITY

3.1 Earthwork Excavation

General: This item of work deals with earthworks in excavation in all types of soils if it is for stacking of suitable soils or disposal of unsuitable soils inclusive of necessary lead for transporting materials as per the terms in contract documents.

Procedure:

1. These excavation works referred to herein shall be either pointing to the trench cutting at the existing ground level in order to engage in sand blanketing (in case of meeting with unsuitable soil) or this could be the case of



excavations necessary to trim down the excessive earth masses in order to prepare the base for pavement layers.

Or else this may be the case of excavation necessary for construction of side drains & waterways.

2. All the excavations shall be carried out in conformity with the directions laid down herein under and in a manner as approved by the Engineer. The work shall be so done that the suitable materials available from excavation works are satisfactorily utilized as decided upon beforehand.

3. Dealing generally herein with the trench excavation for sand blanketing and applying generally the same mode of procedure in other forms of excavation, we append hereunder the broad steps of construction in this regard.

4. On completion of site clearance, necessary ground survey shall be done in order to mark the lines of toe excavation.

5. This shall be followed further by laboratory tests with regards to the samples of soil materials collected randomly (under the proximity of Engineer's representative) from the respective stretches. Existing ground levels contours shall be jointly recorded in the form of cross sections at 10 m intervals with the origin of base line being the proposed center line of the road sector.

6. While the joint survey recording is being plotted the laboratory tests shall be carried out and the results obtained thus submitted to the Engineer for further instructions. On instructions by the Engineer, necessary excavation works shall be commenced. Prior to such commencement, however, necessary lines shall be marked and jointly recorded for extension of excavation works.

7. Excavation shall be done with the help of excavators EX-200, EX-100 or other suitable plants depending upon the stretches & quantum of work.

8. Excavated earth shall either be required to be disposed off or stacked at site. This shall be done as per the directions of the Engineer. In case of disposal of materials to other place, required number of tippers compatible with the capacity of excavator & the haulage shall be engaged to do the job.

9. Excavation shall be done up to the depths as detailed in the drawings or as directed by the Engineer. However the works in normal course shall conform to the lines, grades & slopes as specified.

10. While planning or executing excavations we will take adequate precautions against causing of any water stagnation or soil erosion or water pollution.

11. Under special circumstances, not in the case of excavation for sand blanketing, where we require blasting of rocks for excavation works, this shall be done only with the written permission of the Engineer after complying with the necessary state formalities.

12. In the case of intercepting with water table, water pumps shall be deployed immediately to pump out the excessive water for working conditions. However no delay shall be caused in this regard for obtaining further instructions from safety of works and plant considerations.

3.2 Embankment Construction

This item of work deals with construction of road embankment with approved materials as per the terms of contract agreement.

General:

This item of work shall be dealt with in complete compliance to the technical specifications; placement and compaction shall be carried out in accordance with clause 305 of specifications.



Drawings used for construction in respect of the alignment, level, cross sections in respective stretches and other survey detail and relevant technical specifications viz. clause 305 of technical specification in terms of mandatory guidelines for ensuring the quality of work.

Procedure:

1. The toe line and centre line are marked and pegs will be driven.
2. The material shall be dumped in site at respective location.
3. The material shall be spread in layers of uniform thickness not exceeding 200 mm compacted thicknesses over the entire width of the embankment by mechanical means and will be graded with motor grader to the required camber.
4. Moisture content of the material shall be checked and extra required will be added.
5. The moisture content of each layer shall be checked and it should be within the range of OMC +1% to OMC -2 percent. If moisture content is found out of these limits the same will be brought within limits by addition of water or by aeration as the case may be.
6. The compaction shall be done with the help of vibratory roller of 8 to 10 ton static weight. Each layer shall be thoroughly compacted to the densities specified in the specifications which are mentioned at the end of this document for reference. The rolling pattern will be finalized in trial stretch.
7. On compaction of the particular stretch, necessary field testing shall be carried out Field density shall be done in the manner and frequency as specified below.
8. If the required field density is not achieved, compaction shall be continued till required density is achieved.
9. Loose pockets if any will be removed and replaced with approved material.
10. The above stages shall be repeated till the top level of the embankment is reached to the specified levels and grades. The top levels shall be checked and shall be within +20mm and -25mm of designed level.
11. All relevant QA and QC documents will be maintained for all stages of Embankment Construction.

Equipment/Machinery:

Motor Grader	: 1 No. as a minimum
Tipplers	: 10 -20 No. as a minimum
Water Sprinkler	: 1 No. as a minimum
Vibratory Roller	: 80 to 100KN 1 No. as a minimum

3.3 Subgrade Construction

This item of work deals with construction of Subgrade (minimum 10% CBR) with approved materials as per the terms of contract agreement.

General: This item of work shall be dealt with in complete compliance to the technical specifications; placement and compaction shall be carried out in accordance with clause 305 of specifications.

The construction shall conform to the specific alignment, lines and grades given in the drawing.

Prior to the commencement of this work, the materials proposed to be used for such subgrade shall be sourced suitably. Different sources shall be earmarked for different stretches giving due regard to the load of haulage and most importantly the suitability and quantum of material availability.

Procedure:



1. The toe line and centre line are marked and pegs will be driven.
2. The material shall be dumped in site at respective location.
3. The material shall be spread in layers of uniform thickness not exceeding 200 mm compacted thicknesses over the entire width of the subgrade by mechanical means and will be graded with grader to the required camber.
4. Moisture content of the material shall be checked and extra required will be added.
5. The moisture content of each layer shall be checked and it should be within the range of OMC +1% to OMC -2 percent. If moisture content is found out of these limits the same will be brought within limits by addition of water or by aeration as the case may be.
6. The compaction shall be done with the help of vibratory roller of 8 to 10 ton static weight. Each layer shall be thoroughly compacted to the densities specified in the specifications which are mentioned at the end of this document for reference. The rolling pattern will be finalized in trial stretch.
7. On compaction of the particular stretch necessary field testing shall be carried out Field density shall be done in the manner and frequency as specified below.
8. If the required field density is not achieved, compaction shall be continued till required density is achieved.
9. Loose pockets if any will be removed and replaced with approved material.
10. The above stages shall be repeated till the top level of the subgrade is reached to the specified levels and grades. The top levels shall be checked and shall be within +20mm to -25mm of designed level.
11. All relevant QA and QC documents will be maintained for all stages of subgrade Construction.

Equipment/Machinery:

Motor Grader	: 1 No. as a minimum
Tipppers	: 10 – 20 No. as a minimum
Water Sprinkler	: 1 No. as a minimum
Vibratory Roller	: 80 to 100KN 1 No. as a minimum

3.4 Granular Sub Base Construction

This item of work deals with construction of Granular sub base with approved materials as per the terms of contract agreement.

General: This item of work shall be dealt in compliance to the clause 401 of specifications.

The construction shall confirm to the specific alignment, lines and grades given in the drawing.

Prior to the commencement of this work, the materials proposed to be used for such work shall be sourced suitably. Different sources shall be earmarked for different stretches giving due regard to the load of haulage and most importantly the suitability and quantum of material availability.

The material used in Granular sub base shall be as per technical specification.

Procedure:

1. The toe line and centre line are marked and pegs will be driven.
2. The material shall be dumped in site at respective location.
3. The material shall be spread in layers of uniform thickness not exceeding 200 mm compacted thicknesses over the entire width of the subgrade by mechanical means and will be graded with grader to the required camber.
4. Moisture content of the material shall be checked and extra required will be added.



5. The moisture content of each layer shall be checked and it should be within the range of OMC +1% to OMC - 2 percent. If moisture content is found out of these limits the same will be brought within limits by addition of water or by aeration as the case may be.
6. The compaction shall be done with the help of vibratory roller of 8 to 10 ton static weight. Layer shall be thoroughly compacted to the densities specified in the specifications which are mentioned at the end of this document for reference. The rolling pattern will be finalized in trial stretch.
7. On compaction of the particular stretch necessary field testing shall be carried out Field density shall be done in the manner and frequency as specified below.
8. If the required field density is not achieved, compaction shall be continued till required density is achieved.

Equipment/Machinery:

Motor Grader	: 1 No. as a minimum
Tippers	: 10 - 20 No. as a minimum
Water Sprinkler	: 1 No. as a minimum
Vibratory Roller	: 80 to 100KN 1 No. as a minimum

3.5 Wet Mix Macadam Construction

This item of work deals with construction of Wet mix macadam with approved materials as per the specifications of contract agreement.

General: This item of work shall be dealt in compliance to the clause 406 of specifications.

The construction shall confirm to the specific alignment, lines and grades given in the drawing.

Procedure:

Preparation of Mix:

The individual materials gradation shall be checked combined, proportions shall be fixed and combined gradation confirming to table 400-11 shall be arrived. The individual bins of wet mix plant shall be calibrated for the particular size of material. Material shall be fed to the mixing plant bins provided for individual sizes of aggregates to meet the required gradation. Mixing plant shall be of suitable capacity having provision for controlled addition of water. While adding water, loss due to evaporation shall be taken in account. Water in the wet mix shall not vary from the optimum by more than in the limits of ± 2 of OMC.

Preparation of Base:

The sub base shall be checked for proper lines and levels.

It shall be made free from dust. Before the laying starts it should be made slightly wet and shall be given one plain pass. The lateral confinement for wet mix shall be provided by placing material before laying WMM in the adjoining shoulder portion.

Laying of Wet Mix Macadam:

The wet mix shall be transported from the mixing plant to the site with trippers. The mix shall be laid with paver finisher. The paver shall have suitable loading hoppers and distribution mechanism. The mix shall be laid manually in places where the paver movement is not possible. High or low spots shall be rectified as per MORTH clause No 406.6. The material shall be uniform and shall be free of pockets of fine material. The compaction of wet mix shall be done as per clause 406.3.5. The rolling shall be done with 80-100KN vibratory



roller. The rolling pattern shall be established in the trial stretch. Care shall be given at every stage so that there will not be any segregation. The finished layer shall be checked for compaction in accordance to the specifications given below. The top shall be checked for level control and shall be within +10mm and -10mm of designed level. All relevant QA and QC documents will be maintained for all stages of construction.

Equipment/Machinery:

WMM Plant	: 1 No.
Grader	: 1 No. as a minimum.
Tippers	: 10 - 20 No. as a minimum
Roller (Vibratory)	: 80 to 100KN 1 No. as a minimum
Paver Finisher	: 1 No.

3.6 Application of Prime Coat

General: The work is consisting of applying a single coat primer of approved quality Produced by refinery, the primer used shall be bitumen emulsion complying IS : 8887 & CSS1 grade confirming to ASTM D 2397 / AASHTO M140, the particular grade to be used for the work shall be got approved by the Engineer. The prime coat will be done only in good weather condition.

Machinery:

For this primer distributor of capacity '4 MT' shall be used. This distributing unit, so called as primer tanker is facilitating pneumatic tyre and self-propelled pressure distributor for spraying the material uniformly at the rate of 6 to 9 Kg/10 Sq .m under normal temperature and pressures. Sometimes few small patches near junctions, or narrow space where the primer tanker is not reachable then for those areas spraying of primer shall be done manually, after approval from the engineer.

Preparation of Road Surface:

Make clean the top surface of wet mix macadam by engaging labours with wire brush and all organic contents shall be blown up by using compressed air. The surface to be primed will be swept clean, free from dust and will remain dry.

Application of Primer: The primer will be sprayed uniformly over the dry surface using a self – propelled sprayer with the distribution bar. The sprayer proposed to use is having a self heating arrangement, with spraying bar with nozzles having constant pressure system and is capable of supplying primer at 6 to 9 Kg / 10 Sq meter and at temperature 30 degree C to 60 degree C, so that distributor will spray uniformly unbroken spread of primer. Some times during summer we will come across the surface to be primed will found, so dry or dusty in that case damp the surface with water lightly and uniformly because the dry or dusty surface will cause freckling of primer. All these exercises prior to priming will be done as directed by the Engineer. The primed surface will be allowed to cure for 24 hours minimum or even more as directed by Engineer, so that the primer will penetrate in to the base of wet mix macadam layer. In case the primer is not absorbed beyond 24-hours after applying then we will spray sand over the surface to blot the excess primer. We will take care that there will not be over priming or any pools of excess primer left any part of the surface, which will be swept-out over the adjacent surface before spreading sand.

Curing:



The Primed surface will be allowed to cure for not less than 24 hours or as directed by Engineer and during this period no vehicles of any kind will be permitted.

3.7 Dense Bituminous Macadam Construction

This item of work deals with construction of Dense Bituminous Macadam with approved materials as per the specifications of contract agreement.

General: This item of work shall be dealt in compliance to the clause 507 of specifications.

The construction shall confirm to the specific alignment, lines and grades given in the drawing.

Procedure:

Mix Design: The mix design shall be carried out according to MS-2 of Asphalt Institute. The optimum bitumen content and job mix formula are arrived. The physical requirements of the aggregate shall confirm to table 500-8 and job mix shall confirm to grading 2 of table 500-10 of technical specifications. The mix properties shall confirm to table 500-11 of technical specifications. The permissible variations from the job mix formula shall be according to table 500-13.

Preparation and Transportation of Mix: The individual bins of hot mix plant shall be calibrated for the particular size of material. Material shall be fed to the mixing plant bins provided for individual sizes of aggregates to meet the required gradation.

The temperature of binder at the time of mixing shall be in the range of 150°C-165°C and the aggregate in the range 150°C to 170°C. The difference between and the aggregate temperature shall not exceed 14°C any time.

The mix shall be transported to the site with trippers properly covered with tarpaulins.

Preparation of Base:

The sub base shall be checked for proper lines and levels.

The surface shall be swept free from dust with air compressor.

The tack coat shall be done if the WMM surface was primed and left for quite some time.

Laying of Dense Bituminous Macadam:

The mix shall be laid with paver finisher. The paver shall have suitable loading hoppers and distribution mechanism. The paver shall have electronic sensor paver and string wire shall be run on steel pegs driven on both sides at 10m interval in straight portions and 5m interval in curved portions. The mix shall be laid manually in places where the paver movement is not possible. The compaction of DBM shall be done as per clause 501.6 and 501.7. The rolling shall be done with 80-100KN smooth wheeled tandem roller, 12-15 tones pneumatic tired roller. The rolling pattern shall be established in the trial stretch. The DBM shall be laid in 2 layers or as per the GFC drawings. The finished layer shall be checked for compaction. The compaction shall be checked by taking cores for every 250sq.m area and the degree of compaction shall not be less than 98% of lab Marshall Density or as specified by technical specification. The top shall be checked for level control and the levels shall be within $\pm 6\text{mm}$ of designed level.

Equipment/Machinery:

Hot Mix Plant (Batch Mix Type) : 1 No.

Trippers : 10 - 20 No. as a minimum

Rollers : 80 to 100KN Smooth wheeled tandem rollers 2



No. as a minimum & 12-15Tones PTR 2 No. Min

Paver Finisher (Hydraulic)	: 1 No.
Steel pegs	: 50 No. minimum.
Mechanical broomer/Air Compressor	: 1 No.
Wheel borrow	: 2 No.
Edge cutter	: 1 No.

3.8 Bituminous Concrete Construction

This item of work deals with construction of Bituminous Concrete with approved materials as per the specifications of contract agreement.

General: This item of work shall be dealt in compliance to the clause 509 of specifications.

The construction shall confirm to the specific alignment, lines and grades given in the drawing.

Procedure:

Mix Design: The mix design shall be carried out according to MS-2 of Asphalt Institute. The optimum bitumen content and job mix formula are arrived. The physical requirements of the aggregate shall confirm to table 500-17 and job mix shall confirm to grading 1 of table 500-18 of technical specifications. The mix properties shall confirm to table 500-19 of technical specifications. The permissible variations from the job mix formula shall be according to table 500-13.

In case of modified binders the mix shall be conformed as per IRC:SP:53-2002.

Preparation and Transportation of Mix: The individual bins of hot mix plant shall be calibrated for the particular size of material. Material shall be fed to the mixing plant bins provided for individual sizes of aggregates to meet the required gradation.

The temperature of binder at the time of mixing shall be in the range of 150°C-165°C and the aggregate in the range 150°C to 170°C. The difference between and the aggregate temperature shall not exceed 14°C any time. In case of modified binder the temperature shall be maintained as per IRC:SP:53-2002.

The mix shall be transported to the site with trippers properly covered with tarpaulins.

Preparation of Base: The base shall be checked for proper lines and levels. The surface shall be swept free from dust with air compressor. The tack coat shall be done if the DBM surface was old for quite some time.

Laying of Bituminous Concrete: The mix shall be laid with paver finisher. The paver shall have suitable loading hoppers and distribution mechanism. The paver shall be electronic sensor paver and string wire shall be run on steel pegs driven on both sides at 10m interval in straight portions and 5m interval in curved portions. The mix shall be laid manually in places where the paver movement is not possible. The compaction of BC shall be done as per clause 501.6 and 501.7. The rolling shall be done with 80-100KN smooth wheeled tandem roller, 12-15 tones pneumatic tyred roller. The rolling pattern shall be established in the trial stretch. The finished layer shall be checked for compaction. The compaction shall be checked by taking cores for every 250sq.m area and the degree of compaction shall not be less than 98% of lab Marshall Density or as specified in technical specification. The top shall be checked for level control and the levels shall be within ± 6 mm of designed level.

Equipment/Machinery:



Hot Mix Plant(Batch Mix Type)	: 1 No.
Tippers	: 10 - 20 No. as a minimum
Rollers	: 80 to 100KN Smooth wheeled tandem rollers 2 No. as a minimum & 12-15Tones PTR 2 No. Minimum
Paver Finisher (Hydraulic)	: 1 No.
Steel pegs	: 50 No. minimum.
Mechanical broomer/Air Compressor	: 1 No.
Wheel borrows	: 2 No.
Edge cutter	: 1 No.

IV. CONCLUSION

The pavement is designed as a flexible pavement upon a black cotton soil sub grade, the CBR method as per IRC 37-2001 is most appropriate method than available methods. The pavement is designed as a flexible method from which each method is designed on the basis of their design thickness from which each method has different cost analysis of a section, from which CBR as per IRC is most appropriate in terms of cost analysis. The pavement is designed as a rigid pavement, the method suggested by IRC is most suitable. It is observed that flexible pavements are more economical for lesser volume of traffic. The life of flexible pavement is near about 15 years whose initial cost is low needs a periodic maintenance after a certain period and maintenance costs very high. The life of rigid pavement is much more than the flexible pavement of about 40 years approx 2.5 times life of flexible pavement whose initial cost is much more than the flexible pavement but maintenance cost is very less.

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