BRUHAT BENGALURU MAHANAGARA PALIKE

GUIDELINES FOR CONSTRUCTION AND MAINTENANCE OF CITY ROADS

2009

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FOREWORD

Dr. S.Subramanya, I.A.S
Commissioner

One of the recommendations of the Expert Committee constituted by Hon'ble High Court is to have Technical Advisory Committee of Experts to Guide BBMP in Engineering Works. This Expert Committee, in addition to other recommendations, has suggested bringing out set of guidelines for Construction and Maintenance of City Roads.

Technical Advisory Committee thus created includes members of the Experts Committee also as per directions of the Hon'ble High Court. The Technical Advisory Committee requested one of its members Shri.K.N. Shivashankara Rao to prepare guidelines.

The guidelines prepared by Shri.K.N. Shivashankara Rao was reviewed by the Technical Advisory Committee and complimented the author on the excellent work done. The Committee also recommended that the guidelines be published and distributed to all the Engineers of BBMP with directions to follow the recommended guidelines. I thank the TAC chaired by Prof: C.E.G. Justo for the keen interest shown and I also thank the author.

I recommend that the guidelines be followed by our Engineers scrupulously for construction and maintenance of City Roads.

Commissioner

PREAMBLE

With the main grievance that the roads in Bangalore are not being properly maintained by BBMP, a writ petition was filed in the Hon'ble High Court of Karnataka, an Expert Committee of three engineers was then constituted which inspected the works undertaken by BBMP and submitted five bimonthly reports.

These reports contain a number of recommendations for implementation by the BBMP. The Technical Advisory Committee constituted based on one of these recommendations desired that the task of developing a set of guidelines for use by the engineers of BBMP in the construction and maintenance of roads in its jurisdiction be entrusted to one of its members Shri. K.N Shivashankara Rao, Retd Chief Engineer, PWD, Govt of Karnataka.

It was desired that the guidelines may cover the various aspects of quality control in the construction process of roads, maintenance steps necessary during the life time of the roads and any specific needs in the light of the implementation of the expert committee reports submitted on the directions of the Hon'ble High Court.

In the meanwhile and after the submission of the reports by the Expert Committee new areas have been added to the BBMP. It has been observed that some of these new areas lack basic amenities like water supply, UGD, lighting & roads. So, it was desirable for developing guidelines for one of the basic needs namely construction of new roads in addition to the tasks of maintenance of existing ones .

The task involved a detailed examination of the voluminous reports made by the Expert Committee and providing guidelines wherever found necessary duly taking into account the existing practices in the BBMP and the opinions of the various engineer officers involved in the implementation of the recommendations. Care is also taken to follow the guidelines provided by IRC and MORT&H

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ACKNOWLEDGEMENTS

Sincere thanks are expressed to the Bengaluru Mahanagara Palike and Dr.S. Subramanya, Commissioner, for giving this opportunity of formulating the guidelines for Road Construction and Maintenance in the city of Bangalore.

The confidence reposed by the Technical Advisory Committee of the BBMP chaired by Prof. C.E.G. Justo is gratefully acknowledged. Sri.R. Jai Prasad, Technical Advisor, BBMP has always been a source of support and strength. The excellent work done and the exhaustive reports furnished by the Expert Committee appointed by the Honourable High Court of Karnataka was the main source of information on the prevailing conditions and the possible solutions. Grateful thanks are due to the committee chaired by Capt.S.Raja Rao.

The co-operation extended by the entire team of Engineers of BBMP headed by Sri. A. K. Gopalaswamy, Engineer-in-chief and Sri S. Somashekara S.E, Convener, TAC are duly acknowledged.

Mrs. Latha Mahesh, engineering assistant was associated throughout the period of work and her services are appreciated.

Any Comments, suggestions may be sent to under signed or Engineer-in-chief, BBMP, NR Square, Bangalore 560002 by mail.

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CONTENTS **PAGE NOS.**

Preamble
Acknowledgments

Chapter 1. Introduction 1-2

Chapter 2. Scenario of Bengaluru city 3-5

2.6. Classification of city roads
2.7. Basis for treatment / type
2.8. Maintenance actions

Chapter 3. Development of roads in new areas 6-12

3.1. Planning
3.2. Construction of Water Bound Macadam roads
3.3. Wet Mix Macadam
3.4. Stabilization to improve CBR values
3.5. Re-metalling
3.6. Preparation for surface dressing
3.7. Under wet conditions
3.8. Overlays

Chapter 4. Recommendations of Expert Committee 13-24

4.1. Drainage system
4.1.1. Desilting
4.1.2. Openings
4.1.3. Drops
4.1.4. Covering drains
4.1.5. Reuse of released materials
4.1.6. Preventing choking of drains
4.1.7. Major open drains
4.1.8. Disposal of construction debris
4.1.9. Solid Waste Management
4.1.10. Ground water recharge

4.2. Treatment of roads

4.2.1. Investigations
4.2.2. History register
4.2.3. Thickness measurement
4.2.4. Contractor's responsibility to maintain
4.2.5. Clearing foot paths and roadways
4.2.6. Road cuttings
4.2.7. IRC guidelines for road maintenance
4.2.8. Co-ordination among service providers

4.3. Administrative actions needed

4.3.1. Environmental cell
4.3.2. Road arboriculture
4.3.3. Regulation of office hours in wards
4.3.4. Tender processing
4.3.5. Awarding on Piece work System
4.3.6. Cartel formation
4.3.7. Enhanced power delegation
4.3.8. Programme of works
4.3.9. Master file of sanctioned estimates
4.3.10. Letter of intent to be stopped
4.3.11. Streamlining of office procedure
4.3.12. Establishment of "Vigilance cell"
4.3.13. Inspection by senior officers
4.3.14. Staffing in BBMP
4.3.15. Equipment supply to sub-ordinate offices
4.3.16. Responsibility of engineer in charge
4.3.17. Dairy of Engineers
4.3.18. Field book for major projects
4.3.19. Awareness campaign
4.3.20. Audit of BBMP accounts
4.3.21. Training needed

Chapter 5. Preventive maintenance 25-34

5.1. Drainage system
5.1.9.1. Recharge wells
5.1.9.2. Drops in drains

5.2. Road cutting

5.2.1. Recommended practices
5.2.2. Utility ducts

5.3. Handling different situations

5.3.1. Blockage or Breach
5.3.2. Repairs to CD works
5.3.3. Surface defects
5.3.4. Cracks
5.3.4.1. Hairline cracks
5.3.4.2. Alligator cracks
5.3.4.3. Longitudinal cracks
5.3.4.4. Reflection cracks
5.3.5. Depressions, Rutting
5.3.6. Potholes
5.3.7. Pedestrian facilities
5.3.7.1. Footpaths-Encroachment etc
5.3.7.2. Side Walks (Pavement Materials
5.3.7.2. Road humps and Rumblers
5.3.7.3. Raised pedestrian crossing

Chapter 6. Bituminous Pavements 35-44

6.1. Binders:

6.1.1. Road tar
6.1.2. Bitumen
6.1.3. Asphalt
6.1.4. Coal tar

6.2. Bitumen emulsion

6.2.1.1. Rapid setting
6.2.1.2. Medium setting
6.2.1.3. Slow setting
6.2.2. Prime coat
6.2.3. Tack coat

6.3. Types of Bituminous Surfaces

6.3.1. Physical requirements of aggregates
6.3.2. Surface dressing
6.3.3. Other base courses
6.3.4. Built up spray grout
6.3.5. Semi dense bituminous concrete
6.3.6. Close graded premix surfacing/mixed seal surfacing
6.3.7. Bituminous concrete
6.3.8. Standards of surface evenness
6.3.9. Field tests for bituminous works
6.3.10. Other control measures
6.4. Treatment of existing surfaces
6.5. Bituminous penetration macadam
6.6. Bituminous macadam
6.7. Premix carpet
6.8. Bituminous concrete
6.9. Mastic asphalt
6.10. Recycling bituminous pavement

Chapter 7. Concrete pavements 45-47

7.1. Maintenance of concrete roads
7.2. Joining concrete and asphalt roads
7.3. Geotextiles for pavements
7.4. White topping

Chapter 8. Assessment of maintenance needs 48-53

8.1. Pavement condition index study
- 8.1.1. Alligator cracks

8.1.2. Distortions
8.1.3. Rutting
8.1.4. Raveling
8.2. Symptoms, causes and treatment of defects in bituminous surfaces

Chapter 9. Construction supervision 54-58

9.1. Granular sub base and Wet Mix Macadam
9.2. Hot mix plant and accessories
9.3. Bituminous mix
9.4. Prime coat and tack coat
9.5. Bituminous paving works
9.6. Cement concrete works
9.6.1. Form works
9.6.2. Reinforcement
9.7. Laying of cement concrete works
9.8. Completed concrete works
9.9. Stone masonry

Chapter 10. Quality management 59-60

10.1. Quality control
10.2. CBR requirements
10.3. BBD technique

Chapter 11. Quality control in bituminous road construction 61-74

11.1. Types of Tests and frequency
11.2. Procedure for field control tests
11.2.1. Test for checking rate of spread of bitumen in surface dressing
11.2.2. Test for checking rate of spread of aggregates in surface dressing
11.2.3>. Test for determination of bitumen content in bituminous mix
11.2.4. Test for determination of In-situ density of asphaltic concrete
11.2.5. Procedure for Surface irregularity using straight edge
11.2.6. Tolerance in surface levels
11.2.7. Surface regularity of pavement courses

Chapter 12. Test procedures 75-93

12.1. Tests on soils
12.1.1. Determination of CBR values
12.2. Test on aggregates
12.2.1. Aggregate crushing test
12.2.2. Abrasion test
12.2.3. Aggregate impact value
12.2.4. Soundness test
12.2.5. Sieve analysis
12.3. Shape tests
12.3.1. Flakiness index
12.3.2. Elongation index
12.3.3. Bitumen adhesion test
12.4. Tests on Bituminous materials
12.4.1. Penetration test
12.4.2. Softening point
12.4.3. Ductility test
12.4.4. Viscosity test
12.4.5. Determination of optimum bitumen content

12.5. Tests on Bituminous paving mixes
12.5.1. Determination of Specific gravity
12.5.2. Proportioning of aggregates
12.5.3. Marshall stability test
12.5.4. Specific gravity of compacted specimens
12.5.5. Density and voids analysis

Chapter 13. Miscellaneous 94-98

13.1 Some common deficiencies observed in construction procedures and remedial measures suggested. 13.2. Some additional steps suggested for implementation

Chapter 14. Task 99

Appendices 100-129

App 1. Output of machines

App 2. List of IRC publications for road and bridge works

App 3. List of IS publications for road and bridge works

App 4. List of important tests on pavement layers and concrete works

App 5. Manufacturing and rolling temperature

App 6. Base and Surface Courses (Bituminous)

App 7. List of Plates

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CHAPTER 1.

INTRODUCTION

1.1. Roads are being constructed, rehabilitated /upgraded and maintained to cope up with growing economy, traffic and population. Proper construction ofroads and their maintenance has become a costly process. It is therefore a prerequisite, that the best construction technologies are introduced, the best quality construction materials are used and suitable specifications are followed to ensure durability and performance of the road to serve its designed purpose.

1.2. The road system in our Country has graduated from cart tracks and is inadequate for catering to the phenomenal growth of traffic in recent years. While adequate funds are not available for improving the structural capacity of our road system and for the maintenance of the existing facilities, it has become necessary to build up confidence in the eyes of the public, the administrators and the politicians that whatever funds are made available are spent efficiently and optimally.

1.3. There is a large network of unsurfaced roads particularly those with gravel and earth surface. These are common in the newly added areas of the CMC's.

1.4. The city roads on the other hand pose special problems of maintenance because of their high intensity and varied pattern of traffic. The road pavements are often ripped open by service providers like electricity companies, telephone and water supply in addition new lines require opening of roads for utility connections, etc. These openings allow rainwater to infiltrate the base course material and the potholes grow rapidly with the passage of traffic. The cost of repair also grows rapidly with the time interval before remedial measures are taken. It is therefore important, that maintenance intervention is taken at the optimum point.

1.5. This has become all the more important in recent years in the wake of the phenomenal growth of traffic on the roads accomplished by the steady increase in the axle loads of commercial vehicles.

1.6. Maintenance under the present conditions cannot be limited to isolated actions like filling up potholes etc; and a system approach, involving a series of sequential operations would be obligatory. Proper assessment of the present road condition and diagnosis of the malady should lead to the selection of appropriate treatment.

1.7. The different items of maintenance work being carried out fall under headings as under:

1.7.1. Routine repairs: These include filling up of potholes, patches, repairs to side berms, improving surface drainage, clearing choked culverts and drains, painting sign boards etc; all these are short term measures.

1.7.2. Periodical repairs: Surface renewals and strengthening by way of providing overlays, which are considered as long time measures, are included in this category.

1.7.3. Special repairs: Widening of roads, improvement of cross drainage works, special drainage measures, providing new signs boards etc, could be classified under this head. Sometimes these could be influenced by environmental conditions. For example, stretches of roads subjected to frequent flooding and consequential deposition of sand and silt etc, may require to be tackled separately.

1.8. Maintenance is therefore defined as a combination of many actions carried out to restore an item in, or restore it to an acceptable condition- the condition agreed upon for each particular aspect of usage at each stage. This includes carrying out any necessary work to keep the facility in a sound and serviceable condition and to serve its life. It starts the day the builder leaves the site.

1.9. While repair means carrying out local work to remedy damage, neglect or unsatisfactory initial work, rehabilitation or restoration is meant to carry out work to bring the structure back to its original state. Strengthening means improvement of the ability of the structure to carry heavier loads than originally envisaged. Upgrading or improvement on the other hand means raising the standard or increasing the facility from the level originally envisaged.

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CHAPTER 2. SCENARIO OF

BENGALURU CITY

2.1. Bengaluru is one of the fastest growing cities in the world and its growth is related to many factors such as its salubrious climate, availability of resources, the pleasing manners of Kannadigas, its tradition etc. Meeting the civic needs, keeping the city clean and to maintain the serene climatic conditions are causing a lot of concern to the authorities in the backdrop of the city being termed the **"Garden city of India".**

2.2. "Gone are the flowers; Gone are the trees, Gone are the spaces; we are now greeted with puffing chimneys and high rise buildings both designed to hurt the eye and the environment and the man" observed Justice Chinappa Reddy in one of his judgments on the city development plan.

2.3. Absence of natural barriers has encouraged the restless sprawls of the city in all directions. The phenomenal increase in population, the unabated outward sprawl of the city and the high concentration of economic activities have all contributed to a sudden spurt in the number of motor vehicles using the road system. The limited road space available is getting choked day by day. The increase in commercial and industrial activities has placed additional demand on the existing urban transport system which is mainly road based. Shortage in mass transport and other related facilities has resulted in an alarming increase in the personalized mode.

2.4. This has resulted in non systematic and uncontrolled traffic. A number of additional problems have also been observed. Footpaths are occupied by vendors, telephone booths; corporation bins etc. Builders heap stones, bricks, sand, cement mixer and debris. There are shops which use footpaths as workshops. Two wheelers and bicycles use footpaths as parking places. House owners construct ramps on footpaths instead of within their own areas.

2.5. Parked cars and other vehicles on roads reduce the width available for traffic. There are transport companies who park their vehicles on both sides of the road. Autos add to the problem. Obviously, people have to walk on roads. This is compounded by jay walkers in all roads, especially on commercial roads.

2.6. Classification of city roads:

2.6.1. High density corridors and municipal link roads to the national highways, state highways and other PWD roads, ring roads, airport, railway stations and bus stations are considered as arterial roads. These roads provide the principlenetwork for through traffic and may include intra urban routes between the centre of the city and prominent residential areas as well as between major suburban centres. Roads connecting two state highways/national highways/ ring roads may also be considered as arterial roads.

2.6.2. Such of the roads with comparatively medium density traffic are considered sub arterial roads and these link arterial roads. Feeder roads to these are considered as collector streets. The roads primarily intended for access to private properties which do not carry large traffic volumes are considered as local streets.
BBMP has already categorised the roads in the earlier BMP area.

2.6.3. The right ofway of the city roads can be divided into

1. Carriage way- bituminous, concrete, metal, gravel paved.
2. Tertiary drains, shoulder drains, appurtenances like signages, trees, street furniture, street light etc.
3. Sidewalks and foot paths.

In the city network of roads, there are roads with bituminous surfaces, concrete surfaces, metal surfaces, gravel surfaces and even burnt stone slab surfaces.

2.7. Basis for treatment & type:

2.7.1. It is obvious that there should be a scientific basis for determining the type and thickness of bituminous overlay to be provided to a particular road. It depends mainly on the nature of sub base (CBR value), the density and type of vehicular traffic, pavement condition index.

2.7.2. For this purpose, an inventory of the road has to be taken. This should contain all details of the existing road including its physical condition, its structural capacity, surface profile and its roughness. The road register maintained as per the lines of the MORT&H provides these details.

2.7.3. Condition surveys are conducted by visual inspection and by mechanical evaluation. The magnitude and location of the deficiency or distress has to be noted along with the likely causes of distress. The surface conditions like cracking, patching, riding quality, skid resistance etc, should provide the basis for taking the decision on the maintenance needs. While inspecting the road, the senior engineers should go through the notes of the juniors and make suitable suggestions so that the inspections are meaningful.

2.7.4. Based on these observations, the causes for the defects could be explained and decisions taken to initiate, a specific maintenance activity. If a more detailed investigation is found necessary, it should be done before taking maintenance rehabilitation works.

2.7.5. The basic considerations in taking up any work would be

I. the safe and unobstructed smooth flow of traffic
ii. preservation of roadway and appurtenances and
iii. preventive maintenance to avoid any further deterioration

2.8. Maintenance actions:

2.8.1. The criteria for maintenance actions could now be dealt with. The foremost is the safety of the traffic.

The aspects which require to be taken care of are the following

I. Blockade or break of a road.
ii. Damage to a culvert.
iii. Branches of trees at low heights.
iv. Side berms at very low levels compared to the carriage way.

2.8.2. If a road is blocked or if there is a breach, there should be a display board at both ends of the road as the first step. All out arrangements and efforts for restoration of traffic have to be made after reconstructing the breached portion of this road. The blockade if any has to be got removed at the earliest and cuts repaired. If branches of trees have come to lower levels (lower than about 4.5 mtrs) they should be pruned in order of lower ones first.

2.8.3. If the carriage way has cracked or if there is stripping in local areas equal to or less than 25 percent of the total area, local sealing or filling of the cracks would be necessary. If cracking or stripping is in larger areas chippings (6 to 10mm) for local surfacing repairs after local sealing with binder would be required. If there is bleeding, 6mm size aggregate could be heated to about 60° C, spread and rolled. If the bleeding is in large areas, surface dressing would be required.

2.8.4. To treat rutting a binder coat at 0.5 kg/m^2 is applied first and above this, a bituminous mix is filled to an excess of one third thickness oyer the rut and compacted to bring it to surface level. A local sealing is then applied over that.

2.8.5. Pot holes should be treated as soon as they occur by local patching. If shoulders have scoured, they should be filled and compacted. Similarly, if there is loss of material from an unpaved road, it has to be regravelled. If road signs are missing, they should be replaced.

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CHAPTER .3

DEVELOPMENT OF ROADS IN NEW AREAS

This section deals with the construction activities needed in the new areas added to the BBMP in the respect past.

3.1. Planning:

The preconstruction activities required to be taken up include the following;

i. Setting up work plan as per standard specifications.
ii. Marking centerline and alignment.
iii. Longitudinal section and cross sections of the existing" road at required intervals including adjoining ground levels, iv. Fixing temporary benchmarks and finished road levels. v. Scheduling for cross drainage works with detailed drawings, vi. In-situ soil testing for ascertaining the CBR values and finalizing sub grade treatment, vii. Finalizing job mix formula for WMM.BM and MSS. viii. Removal of encroachments, shifting of service mains, electrical posts etc ' wherever necessary.

3.2. Construction of water bound macadam roads:

3.2.1. Water bound macadam is the most common base course laid. This is constructed by mechanically interlocking clean, crushed coarse aggregates (road metal) and filling the voids with screening and binding material using water.

3.2.2. The required gradations of the coarse aggregates are given in IRC 19. These are spread over the prepared base with bigger sized aggregates at the bottom. To achieve this, it is preferable to take out the aggregates from the sides of the heaps.

3.2.3. First of all, the base to receive the macadam coarse should be prepared to the required grade and camber and cleaned well. Weak locations should be strengthened with suitable materials and rolled. Care should be taken to see that water does not stagnate anywhere. There should be a slope of 1:48 towards the sides. If asphalting is being taken up, this may be 1:60. A camber board to control this is necessary.

3.2.4. The lateral confinement of aggregates may be achieved by constructing side shoulders in advance to the thickness of the compacted layer of water bound macadam. The inside edges of the shoulders should be vertical and loose earth removed. The practice of excavating a trench in the finished formation to construct water bound macadamshould be avoided. Using templates at 6 mtrs interval across the road, aggregates are now spread. Pouring the aggregates directly from the lorries is not allowed. The thickness of the layers may be controlled by keeping depth blocks at frequent intervals. For a 75mm compacted thickness, the loose layer may be about 100mm. Care should be taken to see that proper gradation is maintained at all locations with no pockets of fine materials only. Normally not more than 3 days time should be taken for rolling the spread layers.

3.2.5. Rolling with a 10 ton roller begins from edges. After the edges are compacted, the roller gradually moves towards the centre parallel to the axis of the road duly lapping the compacted area by nearly 50 percent. Rolling has to be stopped when there is sufficient space for adding the screenings and when a loose stone gets crushed under the wheel. When there should be a super elevation as in curves, rolling has to continue from lower levels to higher levels.

3.2.6. During rolling, if there is either a depression or an elevation of more than 12mm when tested with a straight edge of about 3m length, the aggregates have to be removed from the area and either additional quantity is added or some quantity removed as the case may be and re-rolled. On no account depressions should be corrected by adding additional material without removing the already compacted aggregates.

3.2.7. Gravel is now added in three thin layers and rolling continued pushing the gravel to fill the voids using coir brushes. Wet gravel should not be used and gravel should not be dumped at any particular location. The whole work should be completed within a day in each bit of the road.

3.2.8. Gravel to be used should have 55 to 75 percent higher than 6.3mm size. At least 15% of the gravel should contain 20mm size aggregates. Fines should be about 10 to 15%, sand content being more than clay content. The plasticity index of these fines should be about 6. If such gravels are not available, screenings may be used subject to the stipulations of the IRC code.

3.2.9. After packing with gravel as indicated above, water may be sprinkled, swept and rolled so that all crevices are filled completely adding gravel wherever found necessary. Rolling may be continued till a mixture of gravel and water is seen as a wave at the edge of the wheel. Water should not be poured to the extent of damaging the foundation of the road.

3.2.10. The road is now allowed for an overnight curing. After that, any pits observed should be filled with gravel, watered and rolled. Traffic should not be allowed till the road surface is strong enough. If asphalting has to be taken up immediately, it may be done after the surface has completely dried.

3.2.11. The unevenness allowed in a water bound macadam surface is subjected to the limitation of about 30 variations of less than 1 cm in a length of 300 metres. To correct the unevenness, an area of about 10 sq.m has to be removed and redone.

3.2.12. The WBM surface has to be maintained till surface protection course by asphalting etc, is done. The pits observed have to be cut to a regular shape and filled with suitable aggregates and compacted well. If fines are lost, suitable gravel has to be used and compacted. If the surface is beyond repairs, then the surface has to be completely redone.

GRANULAR SUB BASE:

Well graded material is laid and compacted on a prepared sub grade in one or

more layers as sub base according to lines, grades and cross sections, the material shall be natural sand, moorum, gravel, crushed stone or crushed concrete or kankar free from deleterious matter. The grading has to be as in table 400-1 of MORTH specifications.

GRADING FOR CLOSE-GRADED GRANULA SUB-BASE MATERIALS

IS Sieve	Per cent by	weight passing	the IS sieve
Designation	**Grading I**	**Grading II**	**Grading III**
75.0 mm	100	100	_
53.0 mm	80-100	80-100	-
26.5 mm	55-90	55-90	100
9.50 mm •	35-65	35-65	65-95
4.75 mm	25-55	25-55	50-80
2.36 mm	20-40	20-40	40-65
0.425 mm	10-25	10-25	20-35
0.075 mm	3-10	3-10	3-10
CBR Value (Minimum)	30	25	20

The finished sub grade shall be prepared by removing all vegetation etc.,Lightly sprinkled with water and rolled with a smooth wheeled roller, now the subbase material is spread with the help of a motor grader. The moisture content of material shall be checked and adjusted by sprinkling additional water so that it is about 1 to 2% below the optimum moisture content.

Compaction has to be done with a vibratory roller is in thickness is above 100mm. below this thickness a smooth wheeled roller could be used rolling shall be started at the lower edge and proceed towards upper edge tongitntinally. Rolling has to proceed till the densit achieved is at least 98% of is maximum dry densits (Ref. cl.401 of MORTH-IV revised).

3.3. WET MIX MACADAM:

3.3.1: WBM construction is time consuming and there could be non uniformity in the surface. Wet mix macadam is more durable and an improvement over WBM. Here, crushed graded aggregates and graded coarse sand is mixed with water in a mixing plant and rolled to a dense mass on a prepared surface. This is generally adopted for subbase and base courses. IRC 109-1997 provides the details of gradations required.

3.3.2. WMM provides a speedier and more durable method of construction compared to WBM. Here, graded aggregates and granular materials are mixed with the required quantity of water in a mixing plant. The dense mass is then spread and rolled.

The grading requirements of Aggregates for WMM is as follows-

IS sieve Designation	Percent by weight passing the IS sieve
53.00 mm	100
45.00 mm	95-100
26.50mm	-
22.40mm	60-80
11.20mm	40-60
4.75mm	25-40
2.36mm	15-30
600.00micron	8-22
75.00micron	0-8

3.3.3. WMM may also be laid over an existing thin bituminous surface by cutting furrows at 45° to the centre line at about 1m intervals. This is to provide adequate bondage and for drainage. The shoulders and the pavement layers have to go side by side so that lateral confinement is available for the wet mix.

3.3.4. After mixing in the plant, the material is transported to the site and spread uniformly using a paver finisher which is self propelled and with necessary control mechanism. Thickness has to be controlled with depth blocks. Compaction may be done with a smooth wheel roller of 8 to 10 T weight if the layer thickness is 10 cm and with a vibratory roller of the same weight if the layer thickness is upto 20 cms. Roller speed should be less than 5 km/hour. Rolling has to proceed from lower edge towards upper edge and parallel to the centre line of the road. Rolling should be continued till 98% of the maximum dry density is achieved. It is preferable to use a single paver of 7M or two pavers of 3.5 M width working in tandem within short distances so that the number of joints is kept to the minimum. Bituminous layer can be placed above the finished surface after a minimum of 24 hours. Traffic could be allowed after placement of the bituminous layer.

3.4. Stabilization to improve CBR values:

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3\4.1. Compaction or mechanical stabilization is one of the oldest means of stabilization. The desired stabilization may also be achieved by blending two soils.The benefits of using chemical or bitumen additives to improve the soil strength and consequently reduce the pavement thickness have made them considerably beneficial in road and airfield pavement foundations.

3.4.2. There are soils such as expansive and high plasticity clays which are expansive and increase in volume when exposed to water. Expansive soils shrink in volume when water is not present and they cause severe damage to the roads which may give a roller coaster ride.

3.4.3. It has been found that these soils can also be used as successful sub grade material if properly stabilized by using locally available cheap materials like fly ash and lime.

The following table indicates the result of one such study on the CBR values of the soils. CBR values:

Soil only	**Soil + fly ash 15%**	**Soil + fly ash 15% + 3% lime**	**Fly ash+15% fly ash + 3% lime + 2% Portland cement**
1	**2**	**21**	52
4	**2**	**54**	68
2	**2**	**20**	56
1	**4**	**42**	51
2	**9**	**46**	74

3.4.4. Injection systems using lime or lime plus fly ash or potassium chloride have been used for over three decades to improve the sub grades. When lime and fly ash are injected, the water is displaced and a chemical reaction takes place forming a cementing compound which is non expansive.

3.5. Re-metalling:

3.5.1. The old road surface should be roughened with pick axes before spreading the new metal. All dirt, dust, animal dropping, vegetation etc; should be removed from the surface. Normally, there will be a thin crust of hard metal on the existing road and scarification would not be possible. So criss cross lines are made with pick axes for the full width of the road diagonally i.e. at about 45° to the centre line. These may be at 30 to 40 cms intervals and about 40mm deep. These lines have to provide the key so that proper bonding is achieved between the existing and the new materials.

3.5.2. Sometimes, it becomes necessary to scarify the whole existing road and screen the metal removed. Chips from 20mm downwards are spread over the subgrade so that a thick cushion is formed under the metal. It is then watered and the old metal is spread and managed to get the bigger metal to the top surface. New metal is now added and compacted. It may be observed that compaction is achieved very quickly as the base is wet and graded metal is used. Earth from the base fills up the interstices. Screenings may now be spread over the surface and thoroughly watered and allowed for 24 hours before providing a final round of rolling. Traffic may now be allowed only after two more days.

3.6. Preparations for surface dressing:

3.6.1 This may be resorted to in newly added areas where WS/UGD facilities are laid & surface is likely to be opened later, to provide these facilities & traffic is localised such as subarterial, delese local streets.

3.6.2. The WBM surface has to be reconditioned by touching up depressions, pot holes, ruts and other irregularities and correcting the camber to about 1 in 60. The untreated road should be exposed to about 10mm by brushing, brooming etc; so that the binder penetrates the road.

3.6.3. After allowing traffic for about a week, the surface should be thoroughly cleaned before applying the binder. It is particularly important to eliminate all the loose dust and ensure absolute dryness at the surface.

3.6.4. A two coat surface dressing is necessary on untreated WBM road subject to heavy traffic. A thin carpet is of course preferable to this surface dressing. The second coat of surface dressing has to be applied after allowing traffic for a day and making good for depressions, if any.

3.7. Under wet conditions:

3.7.1. Sometimes, it may become necessary to treat the road under wet conditions only, although dry weather conditions are essential for satisfactory work. Bituminous emulsion may be used for moderately damp conditions. But this may be acceptable only for light traffic condition. Emulsion is not suitable for heavy axle loading condition.

3.7.2. However, if it is absolutely necessary to handle the work in wet conditions; one possible method is to use freshly slaked lime powder. After sprinkling this lime aggregates mixed with white slaked lime powder may be used for mixing with bitumen and spread over the prepared surface and rolled. If there is rain immediately after this, traffic should not be allowed till the surface dries.

3.8. Overlays:

3.8.1. A pavement layer constructed on top of an existing pavement is called an overlay. An overlay is meant to restore or increase the load carrying capacity or life, which restores the riding quality of the pavement which might have suffered rutting and other deformations. The overlay is not considered as a part of the periodic maintenance work, but it is an effort in the rehabilitation or strengthening of the road.

3.8.2. There are two types of overlays

1. Flexible overlay and
2. Rigid overlay(concrete)

3.8.3. Bituminous overlays on the existing black topped surfaces is the common practice in the country as these provide amenability to stage construction, is cheaper and results in very little traffic dislocation.

3.8.4. The alternatives available to make up for the additional thickness required are the following:

i) Adding WBM over the existing bituminous surface and finishing with bituminous surfacing, ii) Making up the deficiency of thickness by 'built up spray grout' (BUSG) and finishing with bituminous surfacing.

iii) Providing an additional bituminous layer directly on the top of the existini surface.

iv) Providing cement concrete overlays (also called white topping). Many advantages are claimed for this like-(a)long life (b) no maintenance (c) good riding quality, hard surface (d) no penetration of water (e) good reflectivity and (f) even economics. Among the disadvantages, mention may be made of (a) trouble some repair of the concrete if the slab breaks, (b) joints in pavement providing rough riding, (c) skid prone smooth surface after some time and (d) long initial curing period postponing traffic for a long time.

CHAPTER 4

RECOMMENDATIONS MADE BY THE EXPERT COMMITTEE

Some of the recommendations made by the expert committee do not need any further arguments, but may need some elucidation and elaboration.

4.1. Drainage system

4.1.1 Desilting:

Premonsoon inspection is mandatory to find out the conditions of the drains, kerb openings etc. The longitudinal and shoulder drains require to be desilted at regular intervals, especially before and after monsoon periods. Simultaneously, the kerb stone entrance should be cleared to facilitate easy flow of storm water. Wherever there are longer lengths of covering over the drains and it has been found to be difficult to desilt effectively, hydraulic tests have to be conducted to verify whether the drain is functioning effectively. In any case, such instances should be reduced to the minimum, if it is impossible to avoid.

4.1.2 Openings:

Wider kerb openings at close intervals (say 5 mtrs) especially at lower ends of roads, saddle portions and at junctions of roads have to be ensured. Where bigger and wider traffic islands exist especially with many roads intersecting, it is advisable to provide one to two bigger openings (0.6 mtr to 1.5 mtr) in the middle of the island with suitable gratings and a masonry drain below to lead the rainwater to the longitudinal drain and on to the nearest valley.

4.1.3 Drops:

In order to regulate the velocity and to avoid scours, it is necessary to provide drops in the drains wherever slopes are steep. (The details of these drops have been provided separately).

4.1.4 Covering drains:

The ramp for entrance to a building should start from right of way at the edge of the individual property and should not be allowed to encroach, the right of way/side walk. The roadside drain should be kept free from obstruction for the rain water to flow down. Water from individual property should not be allowed to flow on to the road directly and it should find the way only to the drain.

Wherever drains have been covered by individual property owners, it should be ensured that desilting work is not hampered. In any case, cast in situ concrete slab covering should not be allowed. B.S slab or precast RCC slabs could be allowed so that during desilting, it becomes easy to displace them whenever required. Wherever the covering is used as footpath, it should be ensured that it is kept horizontal and not sloping.

4.1.5 Reusage of released materials:

The various items of materials removed from the drain, footpaths, kerbs and covered drains etc, where upgradation is proposed should be properly accounted for and as far as possible reused or auctioned and recorded.

4.1.6 Preventing choking of drains:

When a building construction work is taken up adjacent to a drain, all precautions have to be taken to prevent filling of the drain as approach by the land owners. The owner of the building has to be instructed to cover the drain in the area and construct parapets at both edges to prevent debris or construction material from entering the drain. The materials, should as far as possible be stored within the site. In case this is found impossible, permission could be accorded to use a percentage of the foot path and road way areas for a restricted time span. The width that could be allowed for this purpose depends on the importance of the road, its width etc, and in any case, there should not be a major inconvenience for the pedestrians and traffic. This requires to be properly monitored.

4.1.7 (a) Major open drains (SWD/ Tertiary):

Wherever-major open drains exist, it is necessary to provide high barricading using chain link fencing all along the drain in order to prevent indiscriminate disposal of solid wastes. It is also necessary to provide automatic bar screens of the type used in sewage treatment plants.

4.1.7(b) Incase of minor drains along side roads, culverts at crossings parapet or edge stones be provided to warn public & prevent accident of slipping in to the drain, instead of covering.

4.1.8 Disposal of construction debris:

Since the individual citizen is not in a position to dispose off the debris, he dumps in front of his property side walk/roads only leading to congestion of the roads. It is therefore necessary for BBMP to identify suitable lands in each ward where citizens can dump the debris by paying a certain charge depending on the quantity. These could be transported out of the city to dumping yards periodically.

4.1.9. Solid waste management:

Sites have to be identified around the city where comprehensive solid waste disposal is possible. These sites have to be notified after environmental impact assessment is made as per Environmental Protection Act 1986.

4.1.10. Groundwater recharge:

It is mandatory for all the owners constructing new buildings, to provide for rainwater harvesting. In addition to this, it is necessary to consider groundwater recharge measures wherever possible, one such method is to construct recharge wells in the drains where rainwater is carried. Details of these wells are explained else where in the manual. These require to be constructed invariably in drains where sewage is not carried by them. That means, in areas where underground drainage system is fully operational, it would be

advisable to construct as many recharge wells as funds permit and ideally at every intersection of roads.

4.2. Treatment for roads

4.2.1. Investigations:

The type and thickness of bitumen treatment has to be decided based on the nature of subbase, the CBR value and density and more importantly the pavement condition index. This has been explained elsewhere in the manual. In addition to these, detailed soil investigations have also to be carried out.

Before preparing an estimate, it is necessary to take core samples at suitable intervals along the road to know the existing conditions and to determine the thickness needed, for strengthening BBD tests with survey of commercial traffic is to be carried out & design period of pavement to be termed up. This has to be decided after getting all the required information about the treatments already made earlier from the history register of the particular road.

4.2.2 History register:

The road history register should indicate the length, width, nature of the surface, the drainage, kerb openings, culverts right of way etc. Details of periodical repairs, maintenance and upgradation of all the components have to be found in it. This requires to be audited before passing any bill. The details of the history register have to be made available for the public scrutiny through the website. These steps are necessary to avoid infructious expenditure due to asphalting the same roads even when not required. It also helps in avoiding wasteful expenditure by providing unnecessary higher specifications, refer the table at the end of the chapter)

4.2.3 Thickness measurement:

For measurement of WBM, WMM, BM, DBM, BC and depression filling items, levels have to be taken before and after construction at grid of points at 10 mtrs in straight reaches and at 5 mtrs in curves (vide IRC 113.3). For profile corrective course, it would be necessary to take the levels at closer intervals. Cores may also be taken to check the thickness after the completion of the work. The same procedure of taking pre and post levels has to be followed for works like silt removal.

4.2.4 Contractor's responsibility to maintain:

It is advisable to include a clause in the agreement with the contractors entrusted with the work of asphalting the roads so that it becomes their responsibility to maintain the road without potholes etc,. This could be for a period of three years. The final payment to the contractor has to be released at the end of the maintenance period and proportionate payments at the end of each year.

4.2.5 Clearing foot paths and roadways:

Except with prior license from the BBMP, no one should be allowed to dump either construction materials, debris or anything else on the foot paths and roadways. The norms for permitting these encroachments are discussed elsewhere in the manual.

All other encroachments should be continuously monitored and removed. Special attention is required to remove permanent encroachments by individual owners, hawkers, garages, petty shops etc. If necessary local resident associations, elected representatives etc, may also be involved in addition to exercising the available authority with the BBMP.

4.2.6 Road cutting:

Road cutting without prior approval from BBMP has to be prohibited. This requires proper enforcement by fixing responsibility on the concerned officers of the area. Anyone attempting to either cut or encroach upon a road should face legal action in addition to confiscation of the equipments brought to the site. (Ref. IRC paper 98-1997 on utilities).

Where permission has been granted for the road cutting, it should be made mandatory to see that the road is restored to its original condition by proper compaction and asphalting to the original standards as per IRC 98-1997.

4.2.7 IRC guidelines for road maintenance:

MORT&H (IV Revision) section 3000 provides details of symptoms,

causes and treatment of defects in bituminous surfaces and these require to be followed by all engineers of BBMP in the maintenance work of the roads in the city. Several suggestions are also made under MORT&H sections 3004 and 3005. These require to be studied properly before deciding on any particular treatment to be taken whether it is BM/BC/OGPS/MSS concrete roads. These have also been discussed elsewhere in the manual.

4.2.8 Co-ordination among service providers:

In order to achieve the desired coordination between BBMP and the various service providers- BWSSB, BESCOM, KPTCL, BSNL, KSRTC, BDA, BMRTL, cable operators etc; the existing protocol and the memorandum of understanding between BBMP and BESCOM has to be enlarged and made applicable for all other service providers. The road opening and restoration protocol (ROR protocol) existing between BBMP and BWSSB has also to be widened to cover issues concerning domestic connections sought by the citizens for seeking water supply and sewerage connections.

Before taking up road improvement program preferably after POW & Budget is approved providing for strengthening of road surface meeting of service providers may be held & their program covering 5years be obtained & they may be apprised that & except for repairs no openings shall be permitted including DBC.

It is necessary for all the cable laying authorities like BWSSB, BESCOM, BSNL and other private cable operators to look into the critical culverts and storm water drains where these agencies have taken their pipes and cables across to ensure that they do not foul with the flow of storm water and ensure that if needed be, such pipes and cables are rerouted in consultation with BBMP. Cables, manholes be laid at least 50m away from cross drainages & they may be permitted in a single level to allow free flow, then only investment made by BBMP on roads will last to the designed life.

4.3. Administrative actions needed:

4.3.1 Environmental cell:

An "environmental cell" has to be opened with competent and qualified officials conversant with environmental legislation to carry out environmental impact assessment of mega constructional activities. It is also necessary to insist on an appropriate environment management plan.

When a land fill site is identified, the impact of disposal of waste at that site has to be studied scientifically by the environmental cell.

4.3.2 Road arboriculture:

Ornamental and flowering species of trees have to be planted on road sides and shrubs on medians in the city. In addition wherever there are vacant places under the control of BBMP or Govt, tree planting could be resorted to. The shrubs help in reducing the headlight glare during nights. Trees and shrubs help in providing an attractive landscape and generate revenue also. However trees should not be planted in the median & shrubs to be planted. Trees can be planted in side walk as for away from the kerb & spacing of planting to be as per guidelines of IRC & in between street lights to prevent branches obstructing the light. The environment also gets improved with the reduction of fumes and sound waves from vehicles.

Species of trees have to be selected keeping in view of their life span, their timber and fruits yield, their shade giving capacity and their strength to resist wind velocity. It is not desirable to plant wide crowned trees on road sides as they obstruct day light and it would be unsafe to drive during nights. The branches of the trees should not interfere with traffic up to a height of 4.5 m from the road surface and should not obstruct street lights and telephone wires.

4.3.3. Regulation of office hours in wards:

It is necessary for the ward engineers to be available at their ward offices during certain fixed hours of the day so that the citizens could meet them. It is preferable if the corporator of the ward is also available during these hours. This has to be regulated.

4.3.4. Tender processing:

The authority to invite and evaluate tenders has to be fixed as per a certain principle. Guidelines could be taken from the existing government rules. The standard tender document approved by government has to be followed. It is also necessary to fix a certain time limit for handling the tenders at different stages - in evaluations, in getting approval.

Issuing work orders etc: calling short term tenders and delaying in entrustment of the work for months and years should be avoided. Transparency act should be strictly followed at all stages.

Except in emergencies, period of tendering to be as per KTPP ACT and regular tenders have to be invited. Technical and Financial evaluation of tenders has to be completed within one week each. The tender accepting authority should take about one

week to recommend it to the works committee. The works committeemay take about 2 weeks to submit its recommendation for consideration of the council. About one month should be sufficient for decision of the council. If it requires approval of the government, about one month should be sufficient to pursue and get approval.

This would help in avoiding "short term tenders" and the undesirable single tender acceptance. This would also help in getting more and better contractors and in ensuring that the funds earmarked for that year in the budget is properly spent. There would be no spill over work or spill over grant.

Before recommending any tender, it is essential to verify the experience certificate, availability of field laboratory, deployment of essential staff and capacity of assuring quality work by the tenderers. If the tenderer is incapable of providing sufficient funds, has insufficient machinery or lack of experience, does not have sufficient number of technical and other staff, the work naturally suffers and such a situation should be avoided.

4.3.5 Awarding under piece work system:

In case of emergency, awarding works under piece work system upto a maximum of two works per contractor at a time subject to a maximum of Rs.10 lakhs could be considered. It should however be ensured that these works are also subjected to quality control. There should be an open policy in awarding piece work so that all contractors get equal opportunity. The works completed by each contractor should be evaluated for its quality and timely completion and these should provide guidance for future awards of the works.

4.3.6 Cartel formation:

In order to break the monopoly and cartel-formation among the contractors, it is advisable to slice asphalt works into larger packages (of about Rs.5 crores value) and invite prequalification bids based on appropriate criteria to ensure that such contractors : posses the required machinery, equipment and the experience needed including financial strength. Tenders could then be called for from among pre-qualified contractors.

4.3.7 Enhanced power delegation :

The financial powers delegated to the various authorities in the BBMP have been , revised as per G.O No. UDD/116/AAD/2002 dated: 24.1.03.

However, these have not been linked to the tender premiums above the estimated cost that could be approved by these authorities. It is therefore suggested that the following limits be fixed to avoid misuse and wrong interpretations.

SI. no	Authority	Total cost of tender	Tender premium above estimated cost
1	Commissioner BBMP	Rs. 60 lakhs	Upto 15%
2 ,	Works committee of BBMP	Rs. 100 lakhs	15 to 20%
3	Council of BBMP	Rs. 200 lakhs	20 to 25%
4	State Govt	No limit	(Above 25%)

4.3.8. Programme of works:

The programme of works proposed to be taken up may be published in the website of BBMP and suggestions and comments invited from the public including residents association. Only after considering the suggestions received within a fixed time schedule, the lists could be taken up for execution.

For emergency works, a certain amount of the grant could be placed at the disposal of each executive engineer of BBMP who should be given a set of guidelines for taking up such works. On no account, works should be taken up without valid reasons and without satisfying the criteria fixed for the purpose.

4.3.9. Master file of sanctioned estimates:

Once an estimate is sanctioned, it should be signed by the concerned officers in each page and a copy is filed with the engineer in chief and CE/EE. A CD may also be kept with it. This is necessary to prevent any modification of the figures in the estimates after they are sanctioned.

It is also necessary to mention in the sanctioned estimate the details of the starting and ending point changes of the road under consideration. This should invariably be verified while approving the concerned bills.

4.3.10. Letter of intent to be stopped:

The practice of issuing a letter long before issuing the work order has to be stopped, as this practice has not stood the legal scrutiny. Only work orders issued after the due process would be valid. It is important to fix a certain time limit for completion of the works after the work order is issued. If the contractor does notcomplete the works within stipulated time limit, there should be a provision to penalize him. Extension of time may however be accorded by the competent authorities if, there are valid reasons not attributable to the contractor, otherwise levy of fine as per agreement/tender clauses shall be enforced.

When a contract is rescinded after following the prescribed procedure, the contractor should be informed of the action taken and the extra cost involved in carrying out the remaining portion of the work has to be recovered from him as per the terms of the contract, payments due to him in other works shall also be withheld.

4.3.11. Streamlining office procedures:

The existing single file system has to be modified and copies have to be maintained at different levels as in government offices. This helps in reconstructing in case of loss of file.

The next step in improving the office procedure is in introducing the "level jumping" system as in Government. If for any reason, a particular intermediate level officer is not available, the file may pass on to the next higher level officer so that time is not lost in processing it.

An effort is also required to examine the number of levels in the office through which a file has to move. This is required to consider possibility to reduce the number of stages through which the file has to move.

Effort is also necessary to consider whether it would be possible to reduce the existing statutory time limit prescribed for various committees and the council to expedite the sanctions at different levels.

4.3.12. Establishment of "vigilance cell":

In order to check irregularities and keep sustained pressure on the staff and a regular check on the quality of works, a vigilance cell with a selected band of engineer-officers with impeccable track record may be set up so that it works directly under the control of the Commissioner BBMP.

The cell may conduct surprise inspections to check the quality of all works and materials, conduct random scrutiny of bills and the measurements recorded there in and scrutinize at random sanctioned estimates and the modifications made there on. In addition to these, the cell has to deal with all complaints received on any works referred to the cell and any other specific works entrusted by the Commissioner.

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4.3.13. Inspection by senior officers:

Inspecting officers should invariably issue inspection notes immediately after the inspection. Any claims arising out of such instructions not accompanied with an inspection note should not be passed. As an alternative the junior officers receiving instructions should put up draft inspection notes for confirmation of the inspecting officer.

In addition, periodical inspection of subordinate offices should be conducted by all higher officers to scrutinize records, documents, registers and correspondence. It is necessary to draw up a programme and prescribe the documents, registers and records to be inspected during such inspections.

4.3.14. Staffing in BBMP:

Other than under exceptional circumstances, the staff in BBMP should not be disturbed in less than a minimum of 2 years. This is necessary to ensure that the staff could work without fear or favour and follow the norms, rules and regulations and maintain good quality in the execution of works. Even when transfers have to be effected, a counseling system has to be introduced.

In view of the experience over a long period, it is advisable to limit deputation of officers from the government or any other organizations for short periods unless it becomes unavoidable. It is therefore preferable to develop expertise in house and accommodate only BBMP employees in all posts so that complete control and loyalty is available for the BBMP.

» Whenever new projects are taken up for construction, proportionate establishment has to be planned for. If the project needs a new division, it should be temporarily established in order to provide effective project management.

Depending on the work load in each unit, the existing staff has to be redistributed so that there is uniformity in the work load of each engineer. If found necessary, the staff strength may have to be increased as it is observed that the strength has not been revised proportionate to the budgeted expenditure for a long time. It is advisable to engage a human resource expert and get a work study done to assess the ground realities.

4.3.15 Equipments supply to subordinate offices:

Basic and essential tools, machinery and equipments are at present not available in sufficient quantities and hence the equipments requested for by the chief engineers have to be supplied. Some of the equipments required are listed below

Tools:

- Spades Pans
  Pick axes
  Sickles
  Crowbars
  Showels
- Chistles Cutting
  players Ladders
  mumties
  Hand cart with solid rubber tyres Tar
  sprinklers
- Tar buckets
  Tar boilers
  Brushes - wire/coir/hair brushes
  Hammers
  Ropes (12mm/ 6mm)
  Tar thermometers(digital)
  Depth gauges
  Camber boards
  Spring balances

G.I. buckets Straight edges
Caution boards Equipments:

- Lorries
- Mini vibratory rollers
- Core cutting machines -D.G sets
- Hand mixers
- Leveling instruments
- Drawing board/drafter

Reference:

- MORT & H specifications
- Current S.R. Book

Man power:

Gangmen Work
inspectors

4.3.16 Responsibility of engineer in charge:

The executive engineer who is the designated engineer in charge should alone be charged with the responsibility of signing agreements, tender documents and handle all correspondences with the contracting agencies. All other authorities should refrain from direct correspondences.

4.3.17 Diary of Engineers:

Every Engineer need to maintain a diary wherein entry of works done, instructions received, meetings attended & job to be done need to be maintained & copy submitted to the next higher authority.

4.3.18 Field book for major projects:

Engineers incharge of major projects need to maintain a Field book indicating works executed in that particular project each day. In respect of Bituminous work a diary shall be maintained indicating nature of work, date time, laying temperature, rolling temp including the vehicle number (Tipper) deployed for transportation of mix.

4.3.19 Awareness campaign:

Construction activity, disposal of construction debris, encroachment of road side drains, unscientific disposal of garbage etc; are causing the choking of drains. A close interaction is therefore necessary with the public to educate them and enlist their cooperation. Hence, a massive campaign has to be undertaken on a regular basis. The residents associations, non governmental agencies and the elected representatives have to be involved in this exercise. All the available media- TV, Radio, Print media etc; have to be utilized in addition to arranging seminars, bringing out brochures and leaflets, film shows etc;

The ward committee may include representation from the residents of the area. These committees may interact with the BBMP not only in the above activities, but even in taking up developmental works in the particular ward. The website should also be used for the above purposes. These committees may also be requested to keep a watch on the quality of works being executed in the wards.

4.3.20 Audit of BBMP accounts:

In view of a large number of financial irregularities observed by the expert committee constituted as per the orders of the Hon'ble high court, it is advisable to see that the accounts of the BBMP are audited by the accountant general on an annual basis. The necessary modifications required in the statutes may have to be got done through the state government.

4.3.21 Training needed:

In order to improve the performance of the engineer of the BBMP, it is necessary to provide proper and adequate training at regular intervals to the staff- both engineering and the accounts.

The training has to include the following fields:

i. Preparation of estimates as per IRC norms
ii. Preparation of tender documents duly following transparency act and governmental procedures
iii. Evaluation of tenders
iv. Quality control procedures
v. Contract management
vi. Repairs and maintenance of road works
vii. Documentation during execution of works
viii. Maintenance of road history register
ix. Processing contractor's bills in electronic form

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SAMPLE OF A TYPICAL ROAD HISTORY REGISTER

TYPICAL HISTORY OF ROAD

NAME OF THE ROAD:
KILOMETRES: 1/0 TO 20/0

YEAR	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	REMARK
1990-91																					YEAR OF COMPLETIO N
1991-92																					20mm 15mm
1992-93																					
1993-94																					
1994-95																					OVERLAY
1995-96																					EARTHEN DRAIN
1996-97																					
1997-98																					
1998-99																					
1999-2000																					
2000-01																					
2001-02																					
2002-03																					
RENEWALS / STRENGTHENING																					
1995																					
1996																					
1997										y											
1998																					
1999																					
2000			•																		
2001																					
2002																					
2003																					
2004																					
2005																					
2006																					
2007																					
2008																					

TRAFFIC DAILY

CHAPTER - 5

PREVENTIVE MAINTENANCE

Certain routine actions taken at regular intervals go in a long way to preserve the road system. These help in arresting further damages and provide comfort and safety for the road users. Some of the routine works are, clearing road side drains, sealing cracks wherever found, preventing stagnation of water on the road surface, repairing footpath surfaces and road edges, rehabilitation of dug up trenches in the road, providing missing guard rails, repairs to sign boards, removal of encroachments etc.

5.1. Drainage system;

5.1.1. Removal of water from the road surface is an extremely important task to ensure the longetivity of road surface and safety of the road system. If drainage is insufficient, earthen and water bound macadam roads are damaged by softening of the surface, unprotected top surfaces would be washed out, side slopes would erode, gullies may form and sub grade soil may be softened with the result that bearing capacity is reduced.

5.1.2. In addition to draining effectively the surface water from the carriage way and shoulders as soon as possible, water from the adjoining areas should not be allowed to enter the roadway. Water from the road surface has *to* be removed by providing camber or cross slope to the surface. A cross fall of 3 % is recommended. As far as possible, the road surface has to be made impervious in order to avoid softening of the sub grade.

5.1.3. Raised shoulders, silt deposition or debris stacked on the surface should be avoided in order to achieve satisfactory drainage. Timely action is necessary in this direction as durability and serviceability of any pavements mainly depends on the efficiency of the drainage system, the shoulders may be trimmed to 2.5% or as directed by the engineer.

5.1.4. It is thus necessary, to desilt the existing shoulder drains and longitudinal drains, to clear the blockage at the mouth of the kerb stone, provide shoulder drains and kerb openings at about 10 metres intervals, correct the kerb openings wherever necessary to facilitate easy entry of storm water to reach road side longitudinal drain. It is important to see that water flowing out of private properties is not allowed to flow on the road, but lead through suitable duct drains at the edge of the properties on the road side longitudinal drain only. All the encroachment on the footpaths in the form of ramps, gardens etc, should be removed periodically. After clearing all tertiary drains, it should be ensured that the flows from these drains are lead to secondary drains and from there to the primary drains.

5.1.5. In order to see that these objectives are achieved, before every rainy season, hydraulic tests have to be conducted wherever the drains are covered for considerable lengths and the deposited muck cannot be removed. However, property owners should not be allowed to close the open drains unnecessarily. Whenever the storm water drains pass in steep slopes, suitable drops should be provided, wherever levels permit, recharge wells have to be constructed in drains carrying storm water so that ground water recharge takes place. The details are furnished separately elsewhere in the manual.

5.1.6. It is also important to see that culverts are constructed wherever found necessary so that water does not flow on the road surface for a considerable distance.

5.1.7. There are several stretches *of* roads with foot paths raised *above the road level.* Shoulder drains are therefore necessary to lead to the tertiary drains. These have to be constructed wherever they are absent. At places where they are already provided, they are choked due to collection of leaves, garbage, plastic waste and paper etc. these require to be cleared periodically especially before the rainy season. At valley points or saucer points of the carriage way, shoulder drains have to be provided at closer intervals of say 5m. The alignment of shoulder drain has to be in the direction of the flow of water. It is recommended that these drains be placed at 15 to 30 degrees to the centerline of the carriage way. They should slope towards tertiary drains.

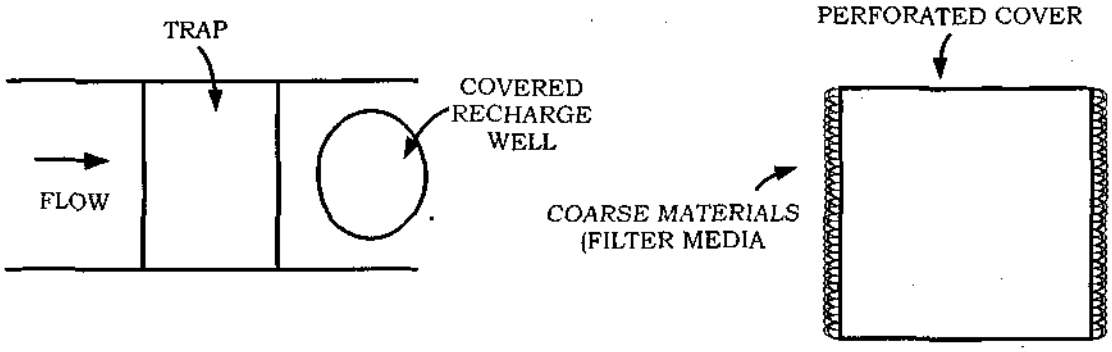
5.1.8. Tertiary drains require to be desilted at regular intervals. The desilted material has to carted away within 24 hours. Dumping of garbage or debris by the citizens into the drains should be strictly prohibited with stringent action against violators. Similarly, the BBMP staff should also be prevented from dumping the road sweepings in to the drains and burning them there. Other utility service providers like BWSSB, KPTCL, BESCOM, BSNL etc; who open shoulder drains and fail to restore continuity are responsible for stagnation of water. They should be suitably controlled in this regard.

5.1.9. Another problem area is near approaches to private properties, near buildings under construction and road crossings. Continuity of flow has to be ensured in these areas by removing obstructions and desilting. It is also necessary to remove the vegetation growth wherever found either in tertiary, secondary or primary drains.

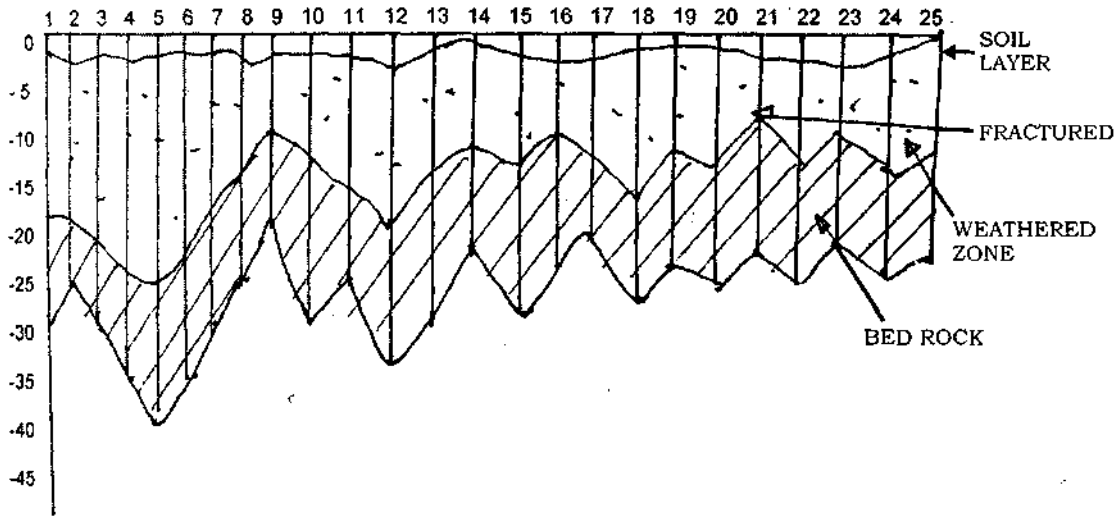
5.1.9.1 Recharge wells:

There has been a steep depletion in the groundwater level in Bangalore city in the recent years because of over exploitation and recharge is urgently needed.

It is necessary to identify the storm water drain suitable for recharge wells. The recharge well may be in the drain or off it. But the catchment area has to be clean and unpolluted. Rooftop rainwater and surface water flowing in the storm water drains can be filtered; silt removed and allowed to recharge the open wells. There should be a trap so that silt and leaves etc, are removed before water enters the well. The well itself should be covered with a perforated cover.



The typical ground section in Bangalore is indicated as below:-



Since roof can be the catchment area, it should be kept clean without allowing any junk there. The rain water falling on the roof could be filtered and stored in a sump tank. The excess water after harvesting could be allowed into a recharge well.

The recharge well could be of 0.6 to 0.9 mtr diameter and about 3 to 6 mtr deep depending on the percolation rate at the site. This supplements the ground water. On vacant sites, there could be a raised earthen bund of about 30 cms all-round and a recharge pit in the centre. After the construction starts each house should have its own arrangement for rain water harvesting.

5.1.9.2 Drops in drains.

Whenever there is a steep slope in the drain, a drop structure needs to be constructed. The purpose is to reduce velocity by allowing flatter upstream and downstream slopes. This would be necessary in view of the erodability of the drain bed at maximum discharge.

The design of the drop structure is based on the height of the drop, the normal depths upstream and downstream and the discharge. Normally drops are located nearer the culverts. A hydraulic jump in created by providing the required tail water level. The length of the downstream protection (apron) is dependent on the length of the hydraulic jump.

5.2. Road cuttings:

It should be impressed that road cutting is one of the major hurdles in maintaining the city roads. In addition to the riding surface, footpaths, drains etc, are also cut. It is necessary to properly monitor the restoration work. It is therefore recommended that a separate register be maintained at each ward in which details of each road cutting be recorded. Date of cutting, name of agency cutting, details of temporary and permanent restoration, whether the work has been executed satisfactorily etc; should be entered. These require to be reviewed regularly by senior officers.

Road cuttings permitted for repairs, installation or maintenance of utilities by the service providers like BWSSB, BESCOM, KPTCL, BSNL etc should be made good at least to the original condition and shape. In many cases, these are a constant source of annoyance and attract public criticism. The trenches normally sink and lead to poor riding quality and weaken the pavement structure.

5.2.1. Recommended practices:

Road cuttings should be of rectangular shape with vertical sides. The fill material should be carefully selected and should be compacted thoroughly layer by layer of thickness not exceeding 20 cms. Pavement should be built up under strict supervision. Bituminous layer thickness should be equal to or more than the existing layer thickness. The finished surface should match with the existing one. Since the repaired portion continues to trouble, sustained attention would be necessary, specification laid in IRC 98-1997 may be adhered to

The following additional guidelines are also recommended-

i. No permission for road cutting should be given during rainy season.
ii. No permission be given for open trenching wherever ducts are provided byBBMP iii. Proper diversion arrarigements and safety precautions like barricading
Agency name, and night signals should be taken, iv. All extra earth etc, left after the work is completed should be carted away immediately. If not, it should be done by BBMP, at the owner's cost with penalty.

5.2.2 Utility ducts:

The present trench system consumes more space and locations are not many times clear to the service providers. Roads are cut often and the backfilling which takes considerable time would not have been done properly. Road users are put to inconvenience for longer time and the condition of road also deteriorates with each road cutting. Each service provider cuts a different trench.

A common utility duct above, on or below the ground can carry more than two types of public utility lines. The locations of the ducts and thus, the networks are much easier to monitor. Utility networks occupy lesser space. Normally the ducts are constructed below ground.

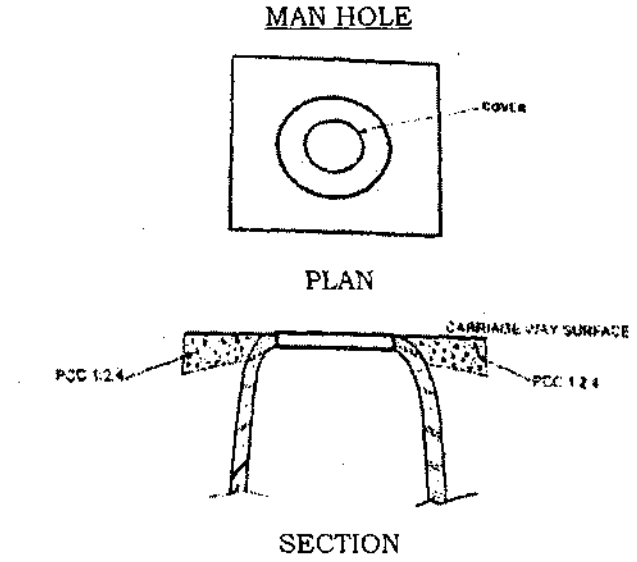
Access to networks is through access points where ducts are installed and excavations become a thing of the past. Road surfaces and pavements are not disturbed to get at utility networks and road works for maintenance of networks are greatly reduced resulting not only in economy, but increased efficiency also.

Annual rentals could be fixed for these services and all service providers could be asked to use these multipurpose ducts. The telecom and electricity poles become redundant and so, could be dismantled. New and evolving networks could also be accommodated in these ducts.

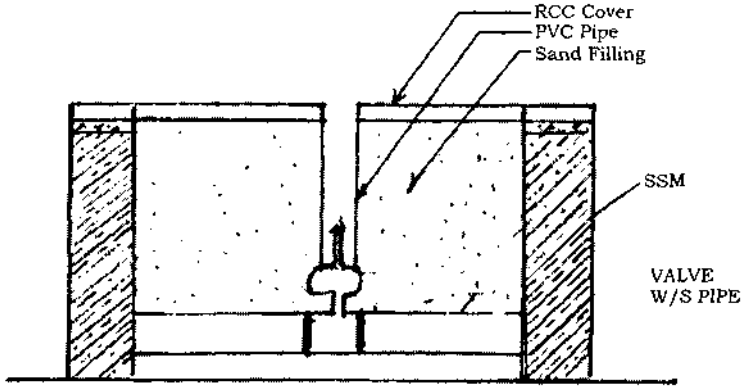
5.2.3. Man Holes

The man holes which are existing or likely to be provided in the carriageway shall be covered with IPB or M40 concrete all round to square shape (drawing) to prevent damage as the man holes are constructed in bricks & RCC Cover & susceptible for failure due to movements of heavy vehicles.

Design for Man Hole



5.2.4 Water line valves are provided for distribution of water, the valves are encased in SS Masonry with BS slab / Precast Slab Covers with opening to operate the valves. These BS Slabs/ Precast Slabs generally break due to movements of over loaded vehicles and restoration takes time, unconvincing traffic. As a preventive measure, it is suggested to fill the chambers with sand and AC Pipe for operating the valves followed by RCC precast cover, thus preventing failure of the cover as the load is transmitted to the filled material (sand).



5.3. Handling different situations:

5.3.1. Blockage or breach:

If a road is blocked or breached, the road has to be closed for traffic immediately by barricading (with empty drums with sand/loose earth etc or by any other means) duly fixing sign boards. Possible deviation arrangement should be made and traffic should be restored at earliest by repairing the damage immediately.

It is necessary to restrict the repair activity to a small stretch of road at a time and half its width wherever possible so that the other half can be used for traffic. Repairs to edges of carriage way, shoulders, clearing the drains etc, should be taken up in one installment and each lane of the carriageway may be taken up by turns later.

5.3.2. Repairs to CD works:

When repairs to an existing cross drainage work has to be taken up, traffic can be passed over a part width of the structure as far as possible. If this is not possible, temporary diversion arrangement has to be made.

5.3.3. Surface defects:

Excessive or deficient bitumen used for the road surfacing leading to surface defects like fatty surface or hungry surface may be treated with either sand blinding or burning of excess binder and slurry seal or fog seal respectively. The cause for fatty surface may be the presence of excess binder in the premix or loss of cover aggregates. Bleeding which occurs due to excessive bitumen content can also be treated by spreading 6mm size chips heated to 60 degrees and rolled. Hungry surface results if the bitumen used is insufficient and this is indicated by the presence of fine cracks in the surface or if there is loss of aggregates. If the surface is either slippery or if there is alternate lean and heavy lines of bitumen, resurfacing becomes necessary.

5.3.4. Cracks:

Cracks may lead to a worse situation as these allow the ingress of water into the road structure and results in potholes etc. The crack pattern generally indicates the causes.

5.3.4.1. Hairline cracks: Hairline cracks result if the bitumen used is not sufficient or if the compaction is improperly done. Hairline cracks are fine cracks in the bituminous pavement. This can be treated by light application of bitumen emulsion by a sprayer at a rate of 0.5 to 1.5 litre per sq mtr and if needed be with grit of 3mm size coated with about 2 % emulsion by weight.

5.3.4.2. Alligator cracks: If the pavement is weak or subgrade is unstable, then the cracks would be interconnected forming small blocks. These are called alligator cracks.

These occur due to repetitive application of vehicular loads. These are hexagons joined together. Treatment is done by mixture of fine aggregate, portland cement, bitumen emulsion and additional water to be spread to a thickness of 1.5 mm. the binder used is 1.5 kg per sq mtr with chippings.

5.3.4.3. Longitudinal cracks: Poor drainage or shoulder settlement leads to

longitudinal cracks along the road. Shrinkage of bituminous layer occurs with age and this results in cracks perpendicular to the axis of the road forming large blocks. This can be treated with a layer of MSS or SDBC.

5.3.4.4. Reflection cracks: If there are joints and cracks in the pavements layer below the surface, sympathetic cracks also called reflection cracks develop.

5.3.5. Depressions, Rutting:

Poor compaction of embankments or poor material or poor drainage results in settlement of the road. Faulty laying of surface course and instability in the mix might result in corrugations. In addition to this, if the pavement layers are not properly compacted, it might result in longitudinal depression in wheel tracks which is also called Rutting. All these deformations need careful assessment to decide whether it is necessary to remove and relay the surface layer with fresh materials or it would be sufficient to fill them with premix materials alone. Rutting is a permanent deformation along the maximum travelled wheel path. Generally this condition is treated by providing corrective course of bituminous mix namely MSS or SDBC or BC.

Depressions and reverse camber in the pavement results in stagnation of water on the road surface which would percolate into subgrade and subbase and also result in pot holes by churning action of wheel movement. The depressions have to be filled by a levelling course of bituminous mix and camber and the surfac'e brought to 1 in 40.

5.3.6. Potholes:

The occurrence of potholes is the most common phenomenon observed especially after rains. This is the result of

I) Ingress of water into the pavement through cracks
ii) Lack of bond between the surfacing and the base course/ earlier course
iii) Use of insufficient bitumen in the surfacing.

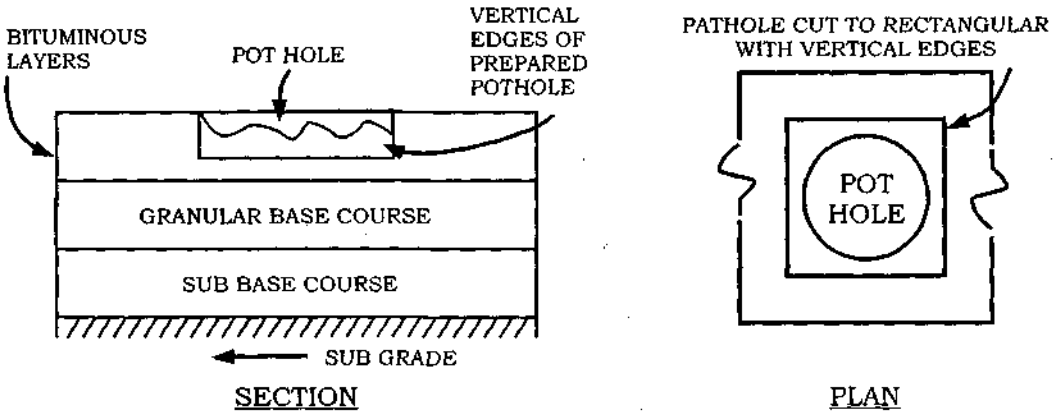
Patching of these potholes has to be executed with abundant precaution to make it successful.

Potholes often lead to avoidable accidents, slowing down of vehicles, aggravation if left untreated immediately.

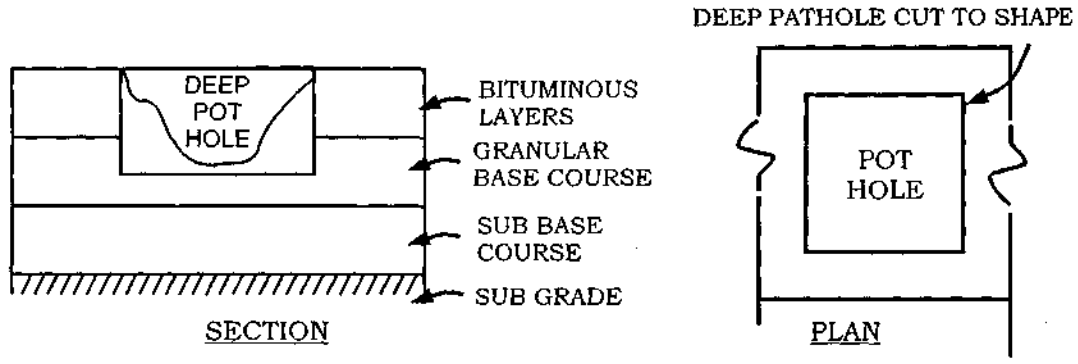
The pot holes should be cut as nearly as possible to the shape of a rectangle, the sides being vertical. All loose materials have to be cleaned out. A blower or atleast wire or coir brushes should be used. If there are deep pot holes as a result of improper drainage or existence of soft pockets in the subgrade, these should be dug out down to the solid subgrade and made good with well graded aggregates. In water bound macadam roads, potholes should be filled with aggregates and screenings as specified for WBM and compacted with heavy hand rammers. In asphalt roads, the bottom and sides of the pot holes duly trimmed to a rectangular shape should be sprinkled with hot bitumen and filled with premixed chips. A sprayer should be used for the purpose or atleast a painting brush has to used. The metal should be compacted in layers of 25mm at a time, the hand rammer being dipped in water often so that the coated metal may not stick to it. The finished surface sometimes is kept at about 6mm higher then the original surface to allow for subsequent settlement under the roller. After repairs, the surface should be slightly dusted with sand before opening it to traffic so that the coated material is not carried away by the wheels. It is necessary to use emulsion during monsoon and ready mix in high density corridors.

Potholes and ruts should be repaired immediately as otherwise, further damage would be fast and large areas may be disintegrated in a short time.

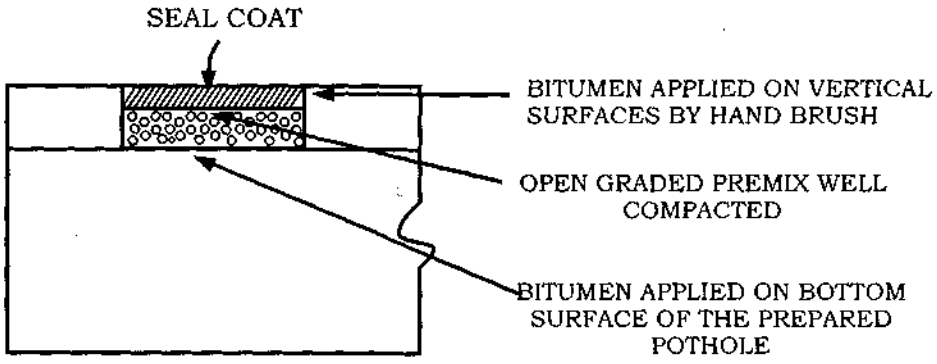
5.3.6.1. Diagramatic representation on various aspects of Potholes.



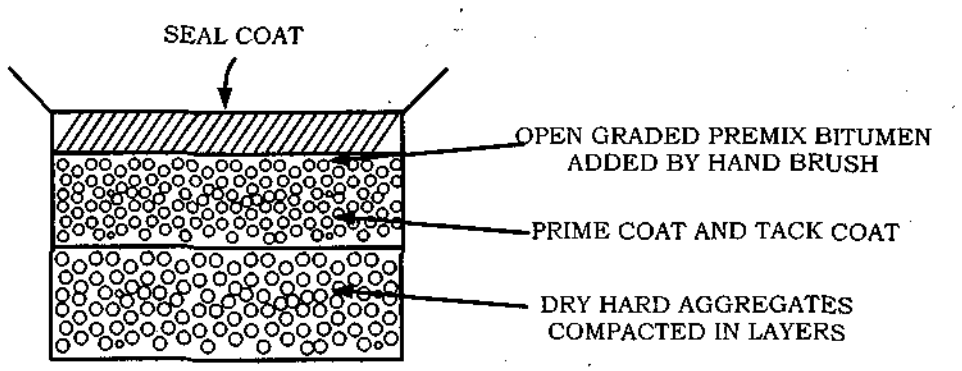
POT HOLE OF SHALLOW DEPTH



DEEP POT HOLE



PATCHING POTHOLE OF SHALLOW DEPTH



PATCHING DEEP POT HOLE

5.3.7. Pedestrian facilities;

It is necessary to reduce pedestrian conflicts with vehicular traffic. Conditions where pedestrians are forced to walk in unsafe circumstances should be avoided. Footpaths should be provided on both sides of the road above the level of the carriageway separated by kerbs. The minimum width of the footpath should be 1.5m. In shopping areas, this width should be atleast 2.5 m. Guidelines in IRC 103-1988 shall be adhered to.

To prevent indiscriminate crossing and spilling over to the carriage way, pedestrian guard rail are provided (IRC 103-1988). These guard rails are required in hazardous locations on straight reaches, at junctions, near schools, bus stops and railway stations, subways and flyovers etc.

Foot overbridges have to be provided near intersections and across a straight portion of any approach arm. Subways would normally depend on the intersection geometry and angles of intersection. It is normally a straight tunnel across the carriage way. Access to subways should be straight and in the direction of major pedestrian movement.

5.3.7.1. Footpaths - Encroachment etc.:

Most of the stretches in the city have raised side walks (foot paths). Where these are non existent, earthen shoulders exist at a higher level then the carriage way and this is responsible for stagnation of water with consequential pot hole formation and pavement failure.

An uneven foot path whether paved or not, results in danger to the pedestrians. Periodical and regular checks are necessary to maintain foot paths at a uniform level. Dumping of debris, loose stones, storage of construction materials etc, force the pedestrians on the carriage way itself which is totally undesirable from the point of view of avoiding accidents. The inter locking paver blocks would also settle because of the frequent disturbances by utility agencies. This requires to be redone using proper compaction with a layer of sand.

The problem of dumping construction materials on the foot paths and in the drain should be properly checked as it is impossible to totally avoid it. It should however be ensured that drains are not blocked under any circumstances. It should be the responsibility of the house owner who stacks the materials to provide pipes temporarily in

the drains before dumping materials on them. The maximum width occupied beyond the individual site area should not exceed about 20 percent of the road width if the road has parking facilities and it should not exceed 1 Opercent if parking is prohibited on the road. These should become a part of the conditions imposed on the house owner when plans are approved. In order to ensurethis, there should be regular inspections in all wards.

Absence of footpaths lead to a similar problem depending on the traffic intensity. It is desirable to provide some space (preferably about 1.5 mtr wide) for the pedestrians in all roads. Tree pruning, removal of overhangings, absurd signages etc. have to be removed to make the foot paths more useful and also to increase the sight distance for the drivers with better illumination.

Appurtenances like medians, kerbs etc, have to be brought to alignment wherever they are disturbed by traffic etc, or by various utility agencies. Regular painting of the medians and kerbs etc, would also be necessary especially before monsoon season.

5.3.7.2. SideJValks (Pavement Materials):

The Different types of pavement adopted for sidewalks (foorpath) are 1. BS Slab
2. Sadarahalli / Sira Stone Slab
3. Inter locking Paved Block
4.Chequred Tiles
5. Cement concrete / fibre concrete precast slab
6. Cement concrete M 20 over lean concrete
7. Cement concrete M20 in one layer with quarry dust & 120 micron sheets

Each of these pavement material have been tried for sidewalks, however the engineer incharge should select right material considering pedestrian intensity location & economy. Due to presence of multiple utility lines, *it* is desirable to avoid in - situ concrete which may require to be opened up for utility repairs 8s the restoration could be difficult & patchy. The advantage of other pavement material like BS Slab, Precast Slabs, Chequered tiles is that they can be removed and relaid without damage / loss when utility lines are required to be repaired / restored.

The Expert Committee constituted by Hon'ble High Court of Karnataka has made observation on usage of Sadarahlli / Sira stone as side walk pavement in view of prohibitive cost.

5.3.7.3. Road hump s and Rumblers;

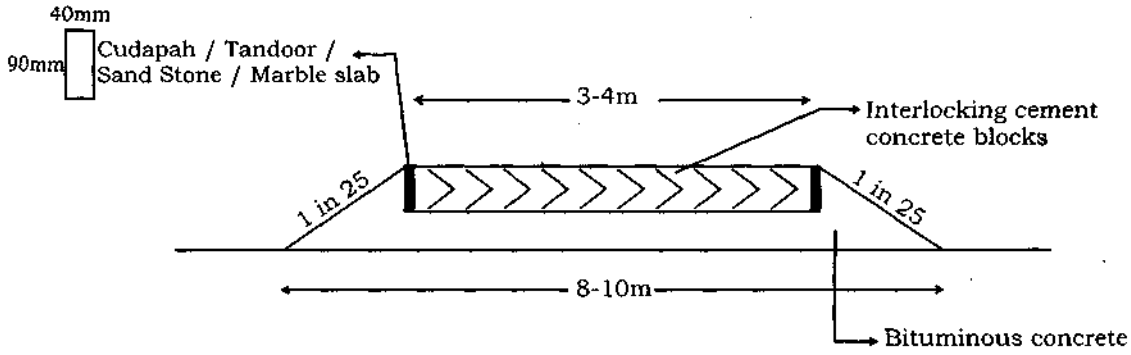
It is necessary to provide certain guidelines for construction and maintenance of road humps in order to prevent accidents. The shape of the hump should be parabolic, its central height being limited to 10 to 12 cms. The width could be about 3.5 mtrs. The hump should be painted with V shape and illuminated to make it visible for the commuters. Its location should not be more than 5 mtrs away from the junction orintersection. A sign board at 20 to 30 mtrs and another at 10 mtrs away from the hump should be placed to warn the commuters. The signboards and the humps should be glazed with reflective materials to make them visible at night. Solar cat's eyes could be installed before the road humps. Generally, humps should be on the feeder roads and not on arterial roads.

As an alternative, "rumble strips" may also be constructed on the main roads. There could be 5 to 10 strips together. Each strip could be one foot wide and the gap between strips could also be one foot.

5.3.7.4. Raised pedestrian crossing:

Raised pedestrian cross walks serve as traffic calming measures by extending the side walk (foot path) across the road and bringing motor vehicles to the pedestrian level. This allows the pedestrians to cross at nearly a constant grade and makes the pedestrians more visible to the approaching drivers. They have a trapezoidal shape in cross section to slow drivers at pedestrian crossing where the slowing will be most effective.

The width could be about 4-5m. These should not be used on sharp curves or steep grades. These should be located near Hospitals, schools, offices where large number of pedestrians are likely to cross the road. It is important to take care of the potential drainage problems. It would be desirable to adopt special colours and special paving materials for the raised cross walks.



High Rised Pedestrian Crossing

It is however necessary to take extra precautions at locations where culverts are constructed using precast slabs. If these have to serve as raised pedestrian crossings, slopes have to be easy on both sides of the slab and proper marking is also necessary.

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CHAPTER 6

BITUMINOUS PAVEMENTS

When the surface of low cost roads such as gravel or WBM roads are treated with some bituminous materials such as bitumen or asphalt they are called bituminous roads. Locally they are also referred to as black topped roads. One specific advantage with such roads is the possibility of stage development depending on the traffic demand.

6.1. Binders:

6.1.1. Road tar:

Road tar, which was being used till about 1955 as a binder is now replaced by bitumen because of its greater availability. Bitumen is a residual material obtained in the process of distillation of petroleum crude at refineries. It is a thermo-viscous material and possesses characteristics of adhesion with road aggregates and is durable.

6.1.2. Bitumen:

Bitumen is a semi solid at atmospheric temperature and has to be brought to a certain viscosity for use in road construction. This is achieved either by heating to elevated temperature, by fluxing with suitable petroleum distillates to obtain cut back bitumen or by dispersing in water to obtain bitumen emulsions.

Paving bitumens 30/40, 60/70, 80/100 are used for premix carpet, Built up spray grout, penetration macadam, bituminous macadam, asphaltic concrete etc. For surface dressing, bitumen 80/100 is mainly used. For mastic, a more viscous grade bitumen like 30/40 is required.

6.1.3. Asphalt:

Asphalt is a substance containing a high percentage of bitumen and some inert minerals. When crude petroleum is fractionally distilled the product is called bitumen while the naturally distilled product is asphalt. Asphalt, may be either cake asphalt or rock asphalt.

6.1.4. Coal tar:

Coal tar is a residual by product obtained by destructive distillation of coal for manufacture of coal gas. To modify this, a fraction of the distillate is mixed to it and this product is called cut back.

6.2.1. Bitumen emulsion:

Bitumen emulsion consists of asphalt dispersed in water in the presence of some emulsifying agent added at the rate of one percent. This can be applied at normal temperature without heating and it is useful for damp surfaces. When emulsion is spread over the road, water evaporates and the bitumen particles reunite. Its colour changes from brown to black.

There are three types of emulsified asphalts based on the rate of breaking of the emulsion.

6.2.1.1 .Rapid setting
6.2.1.2.Medium setting
6.2.1.3.Slow setting

6.2.2. Prime coat:

Prime coat is the first coat of bitumen emulsion applied on untreated compacted surface of gravel or WBM/WMM bases before placing bituminous wearing surface. This promotes adhesion between the base and the wearing surface, binds any loose aggregates in the base and plugs the capillary voids. (Refer to IRC 16-2008)

6.2.3. Tack coat:

Tack coat is a coat of bituminous binder applied on previously treated surfaces giving the new wearing surface a better adhesion. (Refer to IRC 16-2008)

6.3. Types of bituminous surfaces

The various types of bituminous surfaces are now dealt with-

6.3.1. Physical requirements of aggregates
6.3.2. Surface dressing
6.3.3. Other base courses
6.3.4. Built up spray grout
6.3.5. Semi dense bituminous concrete
6.3.6. Close graded premix surfacing / mixed seal surfacing
6.3.7 Bituminous concrete
6.3.8. Standards of surface evenness
6.3.9. Field tests for bituminous works
6.3.10. Other control measures

6.3.1. Physical requirements of the aggregates:

6.3.1.1 .The essential requirements for the aggregates used are-i. Abrasion value: max 40% ii. Aggregate impact value: max 30% iii. Flakiness and Elongation index(combined): max 30%

Aggregates with bricks, kankar, laterite etc which get softened in presence of water shall be tested for impact value under hot conditions in accordance with IS 5640. Flakiness index and elongation index shall be enforced only in case of crushed broken stone and crushed slag.

The screenings used to fill the voids have to satisfy the gradation given below. When gravel is used, the liquid limit should be less than 20 and the plasticity index less than 6. Percent passing 75 micron sieve should not be more than 10%.

6.3.2. Surface dressing:

A thin layer of bituminous material applied on the prepared surface gives a better stability to a WBM or gravel road. Bitumen is sprinkled first and fine mineral aggregate is spread and rolled.

Such a surface dressing makes the pavement dust free, prevents infiltration of rain water thus protecting the base course.

In the old areas where either WBM or gravel surfaces exist, the surface has to be brought to the required gradients and camber first. Then it is cleaned of all dust without disturbing the aggregates, if any. If there is no aggregates or if the aggregates are porous, a prime coat has to be applied. About 2 kg of binder per square metre is now uniformly spread followed by a uniform layer of chippings. Starting from the edges and moving towards the centre longitudinally rolling is continued till all particles are firmly interlocked. If found necessary, a second layer is also laid and compacted. The final surface is checked for its cross profile and opened to traffic after about 24 hours.

The requirements for gradation of aggregates are as follows:-

i) For first coat (13.2 mm)-passing through 22.4 mm square mesh sieve and retained on 11.2 mm square mesh sieve.
ii) For second coat (11.2mm)- passing through 13.2 mm square mesh sieve and retained on 5.6 mm square mesh sieve. The material should be free from salt, alkali, vegetable matter, dust and adherent coatings. Its Los Angeles abrasion value should not exceed 35 %, aggregate impact value not exceeding 30%, water absorption not exceeding 1 % and the stripping value should not be more than 25 % (for more details, reference is invited to IRC 23).

6.3.3. Other base courses:

Although WBM is the usual base course, others in use are the bituminous macadam, built up spray grout and the bituminous penetration macadam.

Detailed procedure for construction of bituminous macadam is given in IRC 27-1967; built up spray grout work in IRC 47- 1972 and bituminous penetration macadam in IRC 20-1966.

6.3.4. Built up spray grout:

The grading requirements are given below: percentage by weight passing the sieve.

IS sieve mm	**Coarse aggregate(mm)**	**Key aggregate (mm)**
53	100	
26.5	40-75	
22.4		100
13.2	0-20	40-75
5.6		0-20
2.8	0-5	0-5

Coarse aggregate is spread uniformly at the rate of 0.5 cum per 10 sq m area over a tack coat and rolled (rolling from edges to centre), overlap at least 1/3. The heated binder is spread at the rate of 15kg/10sq.m area and the second layer of coarse aggregate spread immediately and rolled. Again binder is applied at 15kg/10sq.m area. Immediately after key aggregate is spread uniformly at 0.13 cum/10 sq.m area and rolled, brooming whenever required for uniformity. Then the final surface ahs to be provided without delay. If there is delay, a seal coat should be provided as an intermediate step.

The rate of spread of bitumen for bituminous works is detailed below:

1. For tack coat:
   Normal bituminous surface : 2 to 2.5 kg/10 sq.m
   Dry or hungry surface : 3.5 to 4 kg/10 sq.m

Note: there is no need for tack coat on freshly laid bituminous surfaces if overlaid on same day without opening to traffic.

2. Requirement of bitumen for BSUG:
   a. First :l5kg/10sqm
   b. Second : 15 kg/ l0sqm

3. Requirement of bitumen for surface dressing:

Single coat surface dressing : binder 18 kg/10m^2 of road
Seal coat of two coat surface dressing : binder 11kg/ 10m^2 of road

6.3.5. Semi-dense bituminous concrete:

The grading requirements are given below (percentage by weight passing the sieve)

Table 500-15 MORT&H Specifications Clause 508

Grading	1	2
Nominal aggregate size	13 mm	10 mm
Layer Thickness	35 - 40 mm	25 - 30 mm
IS Sieve[1] (mm)	Comulative % by weight of total aggregate passing	
45		
37.5		
26.5		
19	100	
13.2	90 -100	100
9.5	70-90	90 - 100
4.75	35- 51	35- 51
2.36	24-39	24 - 39

1.18	15 -30	15 - 30
0.6	-	-
0.3	9 - 19	9 - 19
0.15	-	-
0.075	3 - 8	3 - 8
Bitumen content % by Mass of total mix[2]	Min 4.5	Min 5.0
Bitumen grade (pen)	65	65

This work shall consist of construction in a single or multiple layers of semi dense bituminous concrete on a previously prepared bituminous bound surface. A single layer shall be 25 mm to 100 mm in thickness.

6.3.6. Close graded premix surfacing / mixed seal surfacing:

The grading requirements are given below (percentage by weight passing the sieve)

(Table 500-26 MORT&H Specifications clause 512

IS Sieve Designation (mm)	**Comulative percent by weight by total aggregate passing**	
	Type A	**Type B**
13.2 mm 11.2 mm 5.6 mm 2.8 mm 0.090 mm	100 52 - 88 14- 38 0 - 5	100 88 - 100 31 - 52 5-25 0- 5

6.3.7. Bituminous Concrete:

The grading requirements are give below (percentage by weight passing the sieve). Table

500-18 MORT&H Specifications clause 509

Grading	1	2
Nominal aggregate size	19 mm	13 mm
Layer Thickness	50 - 65 mm	30 - 45 mm
IS Sieve (mm)	Comulative % by weight of total aggregate passing	
45		

37.5		
26.5	100	
19	79 -100	100
13.2	59 - 79	79-100
9.5	52-72	70-88
4.75	35-55	53-71
2.36	28-44	42-58
1.18	20-34	34-48
0.6	15-27	26-38
0.3	10-20	18-28
0.15	5-13	12-20
0.075	2-8	4-10
Bitumen content % by Mass of total mix 2	5.0-6.0	5.0-7.0
Bitumen grade (pen)	65	65

Note: 1. The Combined aggregate grading shall not vary from the low limit on one sieve high limit on the adjacent sieve. 2. Determined by the Marshal method.

This work shall consist of construction in a single or multiple layers of bituminous concrete on a prepared bituminous bound surface. A single layer shall be 25 mm to 100 mm in thickness.

6.3.8. Standards of surface evenness:

The surface unevenness should be controlled during construction so that both longitudinal and cross profiles are simultaneously satisfied. The maximum number of undulations permitted in any stretch of 300 metres length is 30 and in the cross profile, it is 6 only. The details of the permitted tolerance of surface regularity of pavement courses are given as under:

Permitted tolerances of surface regularity for pavement courses

Sl. no.	**Type of construction**	**Max Permissible Undulations (mm)**	**Longitudinal profile with 3m straight edge**				**Cross profile Max. permitted variation from specified profile under camber template**
			Max no. of undulations permitted in 300m exceeding				
			18mm	**12mm**	**10mm**	**6mm**	
1	Earth sub grade	24	30				15

2	Sub base	15		30			12
3	WBM with 40m 90mm rolled	15		30			12
4	WBM with 20-50mm of 40-63 mm size BPM or BUSG	12			30		8
5	Surface dressing (2 coat)	12			20		8
6	Close graded premix carpet mix seal surfacing	10				30	6
7	Bituminous macadam	10				20	6
8	Semi dense carpet	10				20	6
9	Bituminous concrete	8				10	4

6.3.9. Field tests for bituminous works:

No bituminous work should be carried out when the atmospheric temperature is less than 16°C and when the base or the construction materials are damp. The thickness of the layer can be checked at frequent intervals after compaction by using pre decided depth blocks. Rolling should continue till the roller marks are eliminated. Rolling temperature should not fall below 80° C.

It is necessary to conduct tests at frequent intervals during the work to find out whether the prescribed quantity of asphalt is being used in the work. For this in addition to the sophisticated laboratory tests using a centrifugal machine which take a lot of time, a solubility test can be conducted (for field control) as follows:

About 1 kg of the mix is collected and weighed accurately. The sample is immersed in either carbondi sulphide or carbon tetra chloride liquids. Since the bitumen is completely soluble in these solvents except for negligible quantities of impurities like carbon, salts etc, the weight of aggregates without the bitumen can be obtained to arrive at the difference in weight, which represents the weight of bitumen used in the mix.

6.3.10. Other control measures:

The quantity of bitumen added should be weighed by a spring balance to find out whether the quantity calculated is going into the mix. The camber of the laid surface should be checked by means of camber board and spirit level. Triangular 6wedges may be

used for finding out depressions. Maximum allowable depression may be about 6mm. templates may also be prepared to check the cambers at different locations. The longitudinal alignment should be checked by a straight edge and triangular wedge.

Traffic on the fresh surface should not be normally allowed for a period of 24 hours

6.4. Treatment on existing surfaces:

It is important to create a good bond between the newly laid bituminous layer and the existing surface. Depending on the condition of the base either a prime coat, tack coat or seal coat is applied. If the existing surface is WBM, a prime coat is required. If there is already a bituminous surface or even a concrete surface, a tack coat is applied. The final coat over a pervious bitumen pavement is the seal coat which serves the purpose of making it water tight, to provide skid resistance and thus to increase the life span.

6.5. Bituminous penetration macadam:

This consists of courses of compacted crushed aggregates bonded by application of bituminous materials and key aggregates and finished with a seal coat. (IRC 20-1966)

The aggregates should be clean, strong, fairly cubical and should be free from disintegrated pieces, vegetable matter, dust and adherent coatings.

Grading requirement of coarse aggregates and key aggregates for Bituminous penetration macadam are as follows.

IS sieve designation	**Percent by weight passing**			
	For 50mm compacted thickness		**For 75mm compacted thickness**	
	Coarse aggregates	**Key aggregates**	**Coarse aggregates**	**Key aggregates**
65mm	-	-	100	-
45mm	100	-	58-82	-
26.5mm	37-72	-	-	100
22.4mm	-	100	5-27	50-75
13.2mm	2-20	50-75	-	-
11.2mm	-	-	-	5-25
5.6mm	-	5-25	-	-
2.8mm	0-5	0-5	0-5	0-5

For built up spray grout, the gradation requirement is slightly different given earlier.

IS sieve	Percent by weight passing	
	Coarse aggregates	Key aggregates
53mm	100	-
26.5mm	40-75	-
22.4mm	-	100
13.2mm	0-20	40-75
5.6mm	-	0-20
2.8mm	0-5	0-5

6.6. Bituminous Macadam:

The binder and aggregates are mixed earlier to placement keeping the bitumen content at about 3.5 percent. The maximum size of the aggregates depends on the thickness of the layer. One specific advantage of the bitumen bound macadam is that even medium quality aggregates could be used.

6.7. Premix carpet:

Using 10 to 12 mm size chippings along with sand and bitumen binder, the thickness of the surface layer is kept at about 20mm. Here; the chippings and bitumen are heated separately to the required temperatures and then mixed properly till a homogenous mix is obtained. Premix should be laid to a length of about 15 metres at a time and rolled. A premixed medium coarse sand (with bitumen) is applied over the carpet and rolled with a light roller.

6.8. Bituminous concrete:

This is usually preferred for heavier and mixed traffic conditions. Bituminous concrete could be in a single or multiple layers and is prepared as per specified job mix formula on a previously prepared bituminous base. The mix design for SDBC should be in accordance with clause 508.3 of MORTH specifications.

Semi dense bituminous concrete (SDBC) should satisfy the following requirements.

SDBC requirements:

Max stability KN at 60° Celsius	-8.2
Min flow(mm)	-2
Max flow(mm)	-4
Compaction levelfno of blows)	-75 blows on each face of the specimen
Percent air voids	-3-5
Strength of the coarse aggregates	- Max 35% Los Angeles abrasion value Max 27% aggregate impact value
Stripping of C. A	- Max retained coating 95%

If the proposed aggregate falls short of the requirements in the stripping test, and approved anti-stripping (adhesion) agent could be added to the binder. The long hydrophobic chain of the anti-stripping agent helps in reducing the affinity of aggregates for water by lowering the surface tension. This ensures bonding of bitumen to aggregates.

6.9. Mastic asphalt:

This is an intimate homogenous mixture of selected aggregates, filler and bitumen. It yields a plastic and voidless and hence impermeable surface. The mix design and construction operation should be in accordance with clause 515 of the MORTH specifications.

6.10. Recycling bituminous pavement:

On city roads frequent layers are added for renewal/ strengthninng periodically raising the road level every time, it is necessary to recycle the bituminous materials of the existing road surface. With this, the road level does not go on increasing endlessly and also the old materials are reused with minimum additions. This method is already being adopted in metropolitan cities- Delhi, Mumbai and Chennai.

The work consists of milling old pavement, stock piling of the removed materials, addition of new bitumen and untreated aggregates in the required proportions, mixing, spreading and compacting of the blended materials. The removed materials are tested for finding the optimum blend to meet the mix requirements.

The gradation requirement and bitumen content in the final mix should conform to the relevant clauses applicable to bituminous macadam, dense bituminous macadam or bituminous concrete. The mix design has to be done as per Marshall Method.

The old pavement materials have to be removed by ripping and crushing using scarifiers, grid rollers or rippers. The materials so removed should be hauled for crushing and then stock piled as if they are new materials. These materials are blended with new aggregates and bitumen in a hot mix plant. The binder temperature has to be between 150 to 163° C and the difference between the temperatures of binder and aggregates should not be more than 14° C. Then the mix is placed and compacted as usual.

The machinery required for the recycling work has been imported from foreign countries in Delhi, Mumbai, and Chennai. However, small milling machines having cutter width of 30 to 50 cms can remove materials which can be collected and recycled. Hot in situ recycling machines are now being made available in the country which may require some improvements.

The recycling process would solve the problem of endless increase in levels of roads leading to drainage complications and would also result in economy in construction in the long run.

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CHAPTER 7

CONCRETE PAVEMENTS

Cement concrete pavements give excellent riding surface and their maintenance is easy. However, their initial cost is high and the construction takes longer time of about 28 days. In addition, there will be a large number of longitudinal and transverse joints which would be a source of weakness.

The construction of a concrete pavement is through cement grout method or rolled concrete layer method for the base course. Over this, concrete slab is laid either by alternate bay method or by continuous bay method.

Concrete is placed with pavers with independent units to spread, compact and finish, texture and cure the freshly placed concrete-all in one pass of the machine. The paver is equipped with electronic controls. Fresh concrete is transported from the central batching and mixing plant by trucks or tippers using covers to protect the concrete from the weather. Care should be taken to avoid segregation or loss of cement slurry during transportation and unloading into the paver.

If construction is properly executed, the concrete pavement does not require any maintenance except at joints where oxidized joint filler and sealants have to be periodically replaced by new materials.

7.1. Maintenance of concrete roads:

Abnormal loading, excessive expansion, defective drainage or settlement due to ingress of water into the subgrade causes failure of the concrete roads. When the concrete slab is broken into small pieces which are incapable of distributing the load to the subgrade, the damaged portion has to be replaced. If however, the surface is crumbling due to the poor material or workmanship, the remedy may be in patching up with asphalt although this may look unsightly. Joints, cracks and potholes may be filled with heated bitumen and coarse sand after removing all dirt and dust.

When a concrete slab has been badly damaged because of its inability to withstand the heavy axle loads, a thin overlay of asphaltic concrete may be laid over it, the minimum thickness of this carpet being about 100 mm. sometimes when the slab is badly cracked and settled, it is broken into pieces, compacted thoroughly and grouted with bitumen.

7.2. Joining concrete and asphalt roads

Adhesion between concrete and asphalt is very poor and junction between concrete and asphalt surfaced roads demand appropriate precautions. The pavement slab should be roughened by cutting grooves or by providing stone transition layer. A transition slab may also be constructed at the end of the concrete pavement at a depth below the wearing surface and the flexible wearing course should be laid with care.

7.3. Geotextiles for pavements

Geotextiles are permeable synthetic fabrics which can separate, filter, reinforce, protect or drain the soil. Geo textile composites have also been introduced in the field and products like the geogrids and meshes have a wide range of applications and are currently being used for many civil engineering works including roads, airfields, railways and in irrigation works.

When placed beneath the aggregate layer, the geotextile prevents intermixing of aggregates and underlying subgrade soils. This in turn, increases the load bearing capacity of the base. The fabric also helps in filtration and drainage capacity when dealing with wet or saturated soils. When weak subgrade conditions exist, the geotextile provides the reinforcement function also. It may be recommended that the use geotextile may be resorted to when the CBR value of the subgrade is less than 3 or when the road is water logged.

A cracked pavement is structurally weak and it is generally overlaid with bituminous base or wearing course to make up for the deficiency. This naturally transmits the distress to the overlay since adequate and appropriate measures to treat the pavement are not taken before hand. One method to tackle the problem of "reflection cracking" is to seal cracks prior to overlay. Alternatively, a thicker overlay can be provided or even an additional levelling course may be laid.

Geosynthetics in the form of fibres, fabrics and grids have been found to be useful. The geosynthetic should be durable and resilient under loads. Before installing the geosynthetic and placing the overlay, it is necessary to apply uniformly a specified sealant or bitumen and then the geosynthetic should be spread without wrinkles or folds. The bituminous overlay course of hot mix bituminous concrete should then be laid immediately to a minimum thickness of 25mm when the existing surface is bituminous and 50 mm for cement concrete surface.

The use of geosynthetics in bituminous overlays on cracked pavements retards the propagation of cracks and hence the service life of overlays is enhanced.

Geosynthetics can be used in road structure for the following additional areas also.

i) Separation and reinforcement between subgrade and stone base in paved roads, ii) Separation between old and new asphaltic layers,
iii) Reinforcement of jointed flexible pavements, iv)
Restraining soil in pavements on expansive clays, v)
Improvement of CBR value of the soil.

7.4. White topping

Although a bituminous overlay on the existing black topped surfaces is the common practice in the country because of the amenability of this method for stage construction, some times cement concrete overlays are also provided. This is also called "white topping".

Many advantages are claimed for this. For instance, it has long life; no maintenance is needed; it provides good riding quality; provides hard surfaces; no penetration of water; good reflectivity and even economics.

However, several disadvantages are also attributed. Most important among them are i) troublesome repair if the concrete slab breaks ii) joints in pavement provide rough riding iii) skid prone smooth surface after sometime iv)long initial curing period postponing traffic for a long time.

Since adhesion between concrete and asphalt is very poor, junction between concrete and asphalt surface demand appropriate precautions.

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CHAPTER 8 ASSESSMENT OF

MAINTENANCE NEEDS

8.1. Pavement condition index study

A small segment of a pavement section of a convenient size is taken up for inspection in detail. The distress found in this segment is used to calculate the pavement condition index (PCI). It may be advisable to concentrate on a total area of about 400 sq.mtrs of road. If a small area of pavement is found to be worse than the majority of the pavement, it can be identified as a special unit. This special unit can be used to identify areas of localized deterioration. A weighted average is used to calculate the PCI so that this local deterioration is accounted for.

The type, severity and amount of each distress present in the selected stretch of the road are estimated using measuring techniques as accurately as possible.

8.1.1. Alligator cracks:

Alligator cracks are fine, longitudinal hairline cracks running parallel to each other with only a few interconnecting cracks could be considered as of low severity, if the cracks are not spalled. If there is a further development of these cracks where a network of cracks with light spalling has taken place, it could be considered as of moderate severity. If the spalled pieces are well defined and the network of cracks has progressed to such an extent where the pieces rock under traffic, the condition is severe. Alligator cracks could be measured in square meters of the surface area.

8.1.2. Distortions:

Corrugations, bumps, sags and shoving etc; result in abrupt, localized upward or downward displacements in the pavement surface and the riding quality is affected. If the speed of travel is considerably affected, the distortion may be considered severe.

8.1.3. Rutting:

Rutting is the surface depression in the wheeled path is caused by consolidation or lateral movement of the materials due to traffic loads. This leads to major structural failure of the pavement. There could be depressions in localized areas too. The depth of rut and the area affected could be measured.

8.1.1. Ravelling:

The wearing away of the pavement surface because of the loss of asphalt and dislodged aggregate particles indicates that either the binder has hardened too much or that the mixture is of poor quality. There could also be softening of the surface and dislodgement of the aggregates because of oil spillage or loss of surface seal coat.

After assessing all these and making any other significant observations in a particular stretch of the road, the pavement condition index is assessed as under:

100	85	70	55	40	25	0
EXCELLENT	VERY GOOD	FAIR	POOR	VERY POOR	FAILED	

8.2. Symptoms, causes and treatment of defects in bituminous surfaces

	Type of distress	**Symptoms**	**Probable causes**	**Possible type of treatment**
A	**Surface defects**			
1	Fatty surface	Collection of binder on the surface	Excessive binder in premix, spray or tack coat, loss of cover of aggregates, excessive heavy axle loads	Sand blindage, open graded premix, liquid seal coat, burning of excess binder, removal of affected area
2	Smooth surface	Slippery	Polishing of aggregates under traffic or excessive binder	Resurfacing with surface dressing or premix carpet
3	Streaking	Presence of alternate lean and heavy lines of bitumen	Non-uniform application of bitumen or at a low temperature	Application of a new surface
4	Hungry surface	Loss of aggregate or presence of fine cracks	Use of less bitumen or absorptive aggregates	Slurry seal or fog seal
B	**Cracks**			
1	Hair line crack	Short and fine cracks at close intervals on the surface	Insufficient bitumen, excessive filler or improper compaction	Sealing the cracks with 1 to 1.5 kg/ sqm dose of bituminous emulsion
2	Alligator cracks a) without any sinking	Interconnected cracks forming a series of small blocks	Weak pavement, unstable conditions of sub grade or lower layers excessive overloads or brittleness of binder	Sealing the cracks with 1 to 1.5 Kg/sqm dose of bituminous emulsion, topping it with 2 to 4 mm aggregate and rolling it. Alternatively slurry sealing or surface dressing
	^			

				depending on the crack width. Keeping the pavement under observation.
	b) with noticeable sinking and deformation			Removing the damaged surfaceto a depth depending on the damage and at least 50 to 80 mm all around the affected portion, shaping the pit to regular rectangle, sides trimmed to vertical. Making good the pavement after application of tack -coat to all 5 sides. Improve the drainage. If cracking is extensive the pavement may need strengthening. Treatment will depend on whether the pavement is structurally sound or otherwise. Look for drainage, stability of embankment slopes and side support of the shoulders etc. If pavement is sound the cracks should the cracks should be filled with low Viscosity binder and slurry sealed. Unsound pavement will need strengthening.
3	Longitudinal cracking	Cracks parallel to traffic direction	Poor drainage, shoulder settlement, weak joint between adjoining spreads of pavement layers or different frost heave	

4	Edge cracking	Crack near and parallel to pavement edge	Lack of support from shoulders, poor drainage, frost heave, or Inadequate pavement width	Improve the side support by strengthening the shoulders and improving the drainage. Add pave shoulders if width is insufficient
5	Shrinkage crack	Cracks in transverse direction or interconnected cracks forming a series of large blocks	Shrinkage of bituminous layer with age	Seal the cracks with low viscosity bitumen binder, slurry sealing. If the cracks are inter connected and blocks are formed, removing the damaged portion *as* above and making good the pavement
6	Reflection cracks	Sympathetic cracks over joints and cracks in the pavement underneath	Due to joints and cracks in the pavement layer underneath	Sealing the cracks with slurry-seal after cutting and widening the cracks, removing dust, damaged and loose particles. If blocks are formed investigate the pavement for structural soundness of the pavement cause.
C	**Deformation**			
1	Slippage	Formation of crescent-shaped cracks pointing in the thrust of wheels	Unusual thrust of wheels in a direction, lack or failure of bond between surface and lower pavement courses	Removal of the surface layer in the affected area and replacement with fresh material.
2	Rutting	Longitudinal depression in the wheel tracks	Heavy channelised traffic, inadequate compaction of pavement layers, poor stability of pavement material, or heavy bullock cart traffic	Filling the depressions with premix material.

3	Corrugations	Formation of regular undulations	Lack of stability in the mix, oscillations set up by vehicle springs, faulty laying of surface course	Scarification and relaying of surfacing, or cutting of high spots and filling of low spots.
4	Shoving	Localized building of pavement surface along with crescent shaped cracks	Unstable mix, lack of bond between layers or heavy start-stop type movements and those involving negotiation of curves and gradients	Removing the material to firm base and relaying a stable mix.
5	Shallow depression	Localized shallow depressions	Presence of inadequately compacted pockets	Filling with premix materials.
6	Settlement and upheaval	Large deformation of pavement	Poor compaction of fills, poor drainage, inadequate pavement or frost heaves	Where fill is weak the defective fill should be excavated and redone. Where inadequate pavement is the cause, the pavement should be strengthened.

D Disintegration

1	Stripping	Separation of bitumen from aggregate in the presence of moisture	Use of hydrophilic aggregate, inadequate mix composition continuous contact with water, poor bond between binder and aggregate, poor compaction etc	Spreading and compacting heated sand over the affected are in the case of surface dressing. Sealing the .surface with binder having anti-stripping agent.
2	Loss of aggregate	Rough surface with loss of aggregate in some portions	Ageing and hardening of binder, stripping poor bond between binder and aggregate insufficient binder, brittleness of binder etc	Application of liquid seal, fog seal or slurry seal depending on the extent of damage. Use anti-strippping agent in the binder.
3	Pothole	Appearance of bowl—shaped holes, usually after rain	Ingress of water into the pavement, lack of bond between the surfacing and WBM base, insufficient bitumen content, etc.	Filling pot holes with pre-mix material or penetration patching.
3	Corrugations	Formation of regular undulations	Lack of stability in the mix, oscillations set up by vehicle springs, faulty laying of surface course	Scarification and relaying of surfacing, or cutting of high spots and filling of low spots.

4	Shoving	Localized building of pavement surface along with crescent shaped cracks	Unstable mix, lack of bond between layers or heavy start-stop type movements and those involving negotiation of curves and gradients	Removing the material to firm base and relaying a stable mix.
5	Shallow depression	Localized shallow depressions	Presence of inadequately compacted pockets	Filling with premix materials.
6	Settlement and upheaval	Large deformation of pavement	Poor compaction of fills, poor drainage, inadequate pavement or frost heaves	Where fill is weak the defective fill should be excavated and redone. Where inadequate pavement is the cause, the pavement should be strengthened.
D	**Disintegration**			
1	Stripping	Separation of bitumen from aggregate in the presence of moisture	Use of hydrophilic aggregate, inadequate mix composition continuous contact with water, poor bond between binder and aggregate, poor compaction etc	Spreading and compacting heated sand over the affected are in the case of surface dressing. Sealing the .surface with binder having anti-stripping agent.
2	Loss of aggregate	Rough surface with loss of aggregate in some portions	Ageing and hardening of binder, stripping poor bond between binder and aggregate insufficient binder, brittleness of binder etc	Application of liquid seal, fog seal or slurry seal depending on the extent of damage. Use anti-strippping agent in the binder.
3	Pothole	Appearance of bowl—shaped holes, usually after rain	Ingress of water into the pavement, lack of bond between the surfacing and WBM base, insufficient bitumen content, etc.	Filling pot holes with pre-mix material or penetration patching.

4	Ravelling	Failure of binder to hold the aggregate shown up by pock marks or eroded areas on the surface	Poor compaction, poor bond between binder and aggregate insufficient binder brittleness of binder etc	Application of cutback covered with coarse sand, or slurry seal or a premix renewal coat. Use binder with anti-stripping agent
5	Edge breaking	Irregular breaker of pavement edge	Water infiltration, poor lateral support from shoulders inadequate strength of pavement edge, etc.	Cutting the affected area to regular sections and rebuilding with simultaneous attention paid to the proper construction of shoulders

CHAPTER 9

CONSTRUCTION SUPERVISION

9.1. Granular sub base and Wet Mix Macadam (section 400 of MORTH specifications)

a. The quality requirements of crushed materials shall be ascertained based on laboratory test results.
b. The screening plant shall be checked for efficiency, location & sequence to produce the required gradation of the aggregate with necessary checks on the conveyor belts also shall be ensured.
c. The stockpile of materials shall not be too high to prevent separation of coarse and fine aggregates.
d. Free fall of aggregates from screens shall be avoided to prevent segregation.
e. Contamination of stockpile area shall be avoided.
f. Representative sampling of the materials shall be done at site
g. The job mix formula for the base and sub base works submitted by the contractor and approved by the engineer shall be displayed at plant control room/ laboratory. Various parameters based on the approved formula such as aggregate gradation strength requirements, PI value of fine aggregates, workability, moisture content and durability etc. shall be checked.
h. The wet mix shall be placed over properly prepared surface with due allowance for compaction true to the required lines and levels and then compacted. i. The thickness of the compacted layers shall be checked using auto levels before construction of the next layer and density checked, j. Coarse aggregates shall not be separated by graders to form windrows of material on the outside limits of the placement area. The same shall be removed, reblended and then reused in other areas, k. The underlying areas shall not be disturbed while ploughing and mixing. 1. There should be no excessive fines oh the surface, m. The side slopes of the placed layers beyond the hinge point shall be fully compacted, n. The shoulders shall be prepared /compacted before WMM layer is laid to confine the pavement materials, o. If necessary overbuild, compact and cut backs to the design grades and lines to achieve desired compaction and side slopes, p. Finished layers must be checked for proper grade and alignment, q. Adequacy of construction equipments like graders, pavers and rollers shall be ensured.

9.2. Hot mix plant and accessories:

i. Suitable steps shall be taken to control segregation of aggregate reaching the cold feed bins, conveyor belts, scales and screens. ii. Necessary adjustments in plant operational procedures to correct separation of aggregates shall be made. " iii. The aggregates in cold feed bins shall be of correct size and fully charged to ensure uniform flow through feeder gates. iv. Aggregate samples from bins shall be collected from bins periodically and tested for suitability.

v. Belts, bin gate scales and other measuring equipments shall be periodically calibrated and correct rate of feed ensured, vi. Plant controls like batching/ measurement devices shall be checked periodically, vii. Asphalt bucket measuring device, displacement mechanism of the device shall be checked for accuracy. Correlation between volume measurements and batched weight of asphalt requires shall be done periodically, viii. Screen deck shall be inspected and the functioning checked, ix. Aggregate weight bucket shall be correct and hang freely, x. Efficiency and functioning of mixing control pug mill shall be confined. xi. Aggregate hot bins, balance and gates shall be periodically checked for correct functioning, xii. The hot mix shall be covered by tarpaulins during transport to site to avoid temperature variations, xiii. The good operational conditions of the loading system shall be checked periodically.

9.3. Bituminous mix:

a. Job mix formula based on the trail mixes prepared by the contractor shall be approved by the engineer and any changes warranted during construction shall be brought to the notice of the engineer.
b. Suitable revision shall be made based on trials and approved by the engineer.
c. Job mix formula shall indicate the dry and wet mixing times required *to* achieve the required results.
d. Uniformity of bitumen distribution in the pugmill /drum mixer shall be checked by trail samples of mixed asphalt concrete from the plant.
e. Aggregates shall be stockpiled separately and to proper heights.
f. Sampling of aggregates, asphalts and asphaltic mix shall be carried out at regular intervals as specified.
g. The temperature measurement of bituminous concrete at plant discharge points shall be checked for conforming to the specifications.
h. The discharged asphaltic concrete mix shall confirm with approval job mix formula, i. Temperature gauges of asphaltic tank shall be monitored to ensure correct temperature as per the specifications and the heating facilities periodically tested, j. Use of anti stripping agent if specified for the job shall be applied in accordance with specification requirements, k. Aggregates shall be fairly dry and brought to the required temperature before mixing by proper monitoring of dryer scales of temperature. 1. Haul trucks shall be cleaned at regular intervals.

9.4. Prime coat and tack coat:

1. Only the approved type of bituminous primer/emulsion shall be used and necessary test results of the same shall be verified.
2. Priming shall not be carried out during fog, rain and heavy winds and temperature below 10 dc.
3. The surface to be primed shall be swept clean free of dust and with no ruts or depressions.
4. The nozzles should be kept clean and priming coat applied uniformly at the specified rate.

5. The primed surface shall be allowed for curing for 24 hours.
6. The rate of spread of bitumen shall be checked with the required tests.

9.5. Bituminous paving works:

a. The suitability of the underlying base course shall be fit for asphaltic works.
b. Bituminous pavement works shall not be taken up during rainy or foggy weather and at temperature below 10 dc.
c. Trail run should be carried out to ascertain the workability of the mix.
d. The tack coat shall be applied over the clean prepared surface with approved quality of bitumen at specified rates.
e. Availability of necessary equipment like pavers, rollers etc, man power tools and testing equipments shall be ascertained.
f. The paving work shall be planned in advance to enable smooth operation with minimum interruptions while laying.
g. The asphaltic mix temperature at various stages shall be monitored.
h. The type of asphaltic pavers shall comply with the specifications and its various components checked for smooth functioning. If the agreement provides for electronic sensor pavers the same shall be invariably put in use. I. Standby equipments like pavers and rollers shall be ensured to cope up with any breakdown during operations, j. The pavers, trucks and compactors shall be kept clean and properly maintained, k. Records like time of discharge, truck no, arrival time at site, temperature at site shall be maintained. 1. The asphalt mix shall be loaded into the paver at 150 dc and temperature at site shall be maintained, m. The paver automatic screed controls shall be checked for efficiency and the thickness of the layer controlled with thickness gauges. n. The correct temperatures and recommended compactors shall be used for different stages of compaction
o. The speed of the compactor shall be as per specifications (normally at 5km/hr)
p. The rolling pattern of the compactor shall be suitable and as per recommended practice, q. The rolling operations shall be before the mix temperature reaches below 100 dc. r. No traffic shall be allowed before the temperature of the mixture at mid depth of completed layer has cooled to the daytime maximum ambient temperature, s. The asphalting laying operation shall not be interrupted and longitudinal joints shall be preferably be hot plants, t. The finished surface shall be checked at regular intervals and the desired finished levels within tolerable limits are assured and immediate remedial measures shall be taken where defects are noticed, u. Representative samples of bituminous mix from trucks, inside the pavers and in place material with proper identification shall be collected for testing, v. To ensure the designed thickness and in place density core cutting of the finished layers shall be done as per specifications and proper map location of coring in each lane is with proper records are maintained.

9.6. Cement concrete works:

1. Only approved mix design for concrete shall be adopted.
2. Mix design shall be checked for batching proportions of fine and coarse aggregates, cement, water and admixes for each batch.

3. Representatives sampling and testing of freshly mixed concrete shall be done at site.
4. Sampling and casting of concrete specimens at site shall be supervised for number and frequency.
5. Slump tests shall be conducted and verified for compliance with specifications.
6. Work ability of concrete shall be ensured and any variation in water cement ratio shall be got approved by the engineer.

7. Proper batching slip for concrete shall be maintained.
8. The number test specimens as per specifications shall be prepared and the cast cube/ cylinder shall be properly cured in each curing tanks.
9. Any deficiency in slump or other characters of the concrete shall be informed to the engineer.
10. The forms works shall be checked for compliance with working drawings and supports for form works shall be checked before laying concrete.
11. No loss of water or fines through openings in formwork shall be allowed.
12. Proper compaction of concrete with correct type of vibrator as per specification shall be ensured.

9.6.1. Cement concrete works-Form works:

a. The frame work panels shall be smooth, clean and applied with form oil or other stripping agents.
b. Satisfactory amount of false work, temporary supports, shoring, braces, ties shall be ensured.
c. The form work structure should be firm and rigid with proper footing support.
d. The alignment and location of form work shall be checked along with the levels.
e. Satisfactory arrangements for providing cover for the reinforcement steel rods shall be provided.
f. There should be no gap, holes or other openings in between forms.
g. The correct number, location and type of construction joints shall be provided,
h. Prior approval of the form work and steel reinforcement by the competent engineer must be obtained before pouring the concrete.

9.6.2. Cement concrete works-Reinforcement:

1. The correct grade of steel reinforcement approved after testing for strength requirements shall only be used.
2. The number and spacing of main and secondary reinforcements shall be checked and shall be in conformance with the approved drawings and detailing as per approved schedule.
3. The size, unit weight, type, grades, location, spacing of steel shall be checked along with the mill certificates.
4. The main and secondary bars shall be securely tied with tie wires and the wires shall not protrude out of the concrete.
5. The reinforcement bars shall be free from rust, oil, grout and fracture.
6. The overlapping length of the reinforcements shall be in accordance with steel schedules and additional bars to be introduced where the lapping length is insufficient.
7. The number of main reinforcement bars, dowel bars and extra reinforcement if specified in the drawings shall be checked.
8. If welding of the steel reinforcement is found necessary prior approval of the engineer shall be obtained and correct type of welding for joints ensured. The

bars with welded joints shall be suitably staggered to meet the strength requirements.
9. Any steel reinforcement bars found not suitable for the work be marked by paint and removed from the work site.

9.7. Laying of cement concrete works:

a. The number lifts of stages of pouring wet concrete for columns, walls and other tall slender structural elements shall be planned in advance, besides checking the strength of form work and feasibility for vibrating the concrete.
b. The free fall of the concrete shall be controlled and any apparent segregation of aggregates shall not be allowed.
c. The concrete shall be poured from one end and advanced in the forward direction
d. The concrete shall be vibrated with suitable vibrators to ensure consistency.
e. Concrete shall be poured without interruptions to ensure homogeneity of structural concrete.
f. If construction joints are needed proper jointing arrangements shall be made (use of synthetic construction joints)
g. The poured concrete shall be protected from cold and extreme hot temperatures.
h. Proper records regarding type of vibrations, if any delay and interruption in pouring the concrete, or any unusual activities during concreting shall be maintained.

9.8. Completed concrete works:

1. Stripping of formwork shall be allowed after specified time limit and ensuring the strength of concrete(see clause 1058 of MORTH specification).
2. Adequate provisions for curing of concrete on a continuous basis shall be ensured.
3. The fresh concrete shall be covered, kept moist and continuously watered so that the concrete develops its required strength.
4. The stripped concrete shall be checked for honey combing, porous concrete, voids and inadequate cover and exposure of reinforcement not detrimental to the structural safety or architectural appearance shall be corrected.

9.9. Stone Masonry) MORTH clause 1400):

a. The correct type of masonry either Random masonry (coursed or uncoursed) and coursed masonry (1st Sort) as specified in drawings mustbe adopted.
b. The stones used for masonry work shall be hard, sound and free from cracks and weathering.
c. Stones with rounded surface, water absorption exceeding 5% shall not be used.
d. Bond stones of specified size at intervals of 1.5 to 1.8m shall be placed.
e. The cement and sand as per specified proportion shall b thoroughly mixed in a mixer on clean platform to get a uniform colour and water shall be added to workable conditions as specified.
f. Proper scaffolding arrangements shall be ensured.
g. Curing of the finished masonry shall be carried out for a minimum of 7days.
h. Proper dressing of stones to ensure minimum joint width is to be ensured.
I. Pointing of joints of approved type shall be carried out after removing the mortar in the joints and watering the surface properly.

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CHAPTER 10 QUALITY

MANAGEMENT

Construction management is an art. The management at top level should set guidelines for site staff at various levels and monitor quality during construction process. Seriousness of management in achieving quality is very important.

Achieving quality at any cost is not the correct concept, but it is desirable to achieve it at competitive costs. Quality management is an effective and comprehensive management process that helps in achieving goals of user's satisfaction and continuous improvement. There is an urgent need to introduce an effective quality management system in the construction sector also. As a first step, a quality manual and quality policy documents are to be brought out and implemented. Simultaneously action has to be initiated to impart training to all the personnel of the organization.

10.1. What is quality control?

The main objectives of quality control are:

1. To test the raw materials of construction.
2. To test the finished products like concrete, rolled earth fill, asphalt surfaces etc; and
3. To review construction practices with a view to see whether they conform to the accepted current practices.

Quality control is exercised in three stages:

i. Selection of materials.
ii. Processing of the materials and
iii. End product.

The means adopted are:

I. Sampling and testing.
ii. Inspection of construction technique and
iii. Compilation, analysis and interpretation of test results.

Quality control should not only lead to improved quality and uniformity, but should lead to more economical utilization of materials and should lead to reduction in user costs.

The stages of control in a highway project could be identified as:

i. During earthwork
ii. During subbase courses
iii. During base courses.
iv. During bituminous surface courses and
v. During control for concrete pavements.

10.2. CBR requirements:

To evaluate the subgrade strength, an adhoc penetration test is generally conducted. California bearing ratio (CBR) is a measure of the shearing resistance of a soil to penetration under controlled density and moisture conditions. The strength of the soil is found by penetrating the soil specimen by the plunger of standard size. The soil is kept in a standard mould. The resistance offered is compared with the known standard resistance. The lower sub base and subbase are tested for CBR values.

10.3. Pavement deflection tests-BBD technique:

Measurement of pavement surface deflection by Benkelman Beam method through rebound deflection measurement under static loading is a widely accepted procedure (IRC 81 - 1997). This provides a guide for strengthening *of* flexible road pavements. In this test static load is applied by the rear axle of a standard loaded truck.

There are other non destructive testing techniques such as impulsive deflection method which is also called falling weight deflectometer method and steady state deflection method or dynamic deflection method. In dynamic testing by surface wave propagation, vibrations are generated and their propagation in the pavement is monitored. While Benkelman Beam test provides the rebound deflection the dynamic method provides both the dynamic values as well as the deflector values of the pavement layers

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CHAPTER 11 QUALITY CONTROL IN

BITUMINOUS ROAD CONSTRUCTION

11.1. Types of Tests and frequency

Sr. No.	Type of tests	Acceptance Criteria	Frequency	IS/IRC code reference
1.	**Earthwork**			
a	Sub grade (cutting)			
	Field density	97% of MDD (Maximum dry density viz. modified proctor density). For sub grade and shoulders compaction level shall be preferably higher than stipulated in embankment	*One* test in 250 m^3	IS 2720(8)
	Field moisture	+ or- 1% to 2% of O.M.C	One test in 250 m^3	BIS 2720(2)
b	Embankment			
	Field density	97% of MDD (modified PD) for sub-grade and shoulders	One test in 250 m^3	BIS 2720(8)
	Field moisture	+ or - 1% to 2% of O.M.C 95% for embankment	One test in 250 m^3	BIS 2720(2)
	MDD (Maximum Dry Density in lab for approval of borrow area/quarries)	• Embankment up to 3mt, height not less than 15.2 KN/Cum. • Height exceeding 3m not less than 16.0 KN/ Cum. Sub grade earthen shoulders/verg es/back fill not less than 17.5 KN/Cu.m & Q value not less then 27 degree	For each source and at intervals when changes in material is noticed	MORT&H Table 300-1 C1.305
	Free swelling index	Not more than 50%		
	Sand content		One test in 250 m^3	BIS 2720(4)

	Plasticity index	Not more than 45	One test in 250 m^3	BIS 2720(4)
	Deleterious contest test	Not to be permitted. Peat, log, stump and perishable material, materials susceptible to combustion and frozen conditions	One test per source or when apparent change is noticed	BIS 2720(27) IRC SP:20-2002
	C.B.R	As stipulated	One test in 250 m^3	BIS 2720(16) & IS 2720(21)
2.	**Granular sub base**			
a	Aggregate gradation	As per table no. 400-l(MORTH), one of the three grading tender stipulation to indicate Grading I,II,III	One test in 200 m^3	MoRT&H Clause -400
b	Liquid limit	Not more than 25%	One test in 200 m^3	MoRT&H Clause - 400
c	Plasticity index	Not more than 6%	One test in 200 m^3 .	BIS 2720(5) MoRT&H Clause -400
d	Moisture content	Not more than 2 %	One test in 200 m^3	BIS 2720(8) MoRT&H Clause -400
e	Deleterious contents	Free from organic and deleterious contents"	As stipulated for each source	MoRT&H Clause - 400
f	C.B.R	As stipulated in tender 30%, 25 or 20%	As stipulated	BIS 2720(16) MoRT&H table 400-1 & BIS 2720(31)
3.	**WBM (water bound macadam)**			
a	Grading	As per table 400-7 of MoRT&H specification	One test for 100 m^3	MoRT&H Clause -404
b	Grading for screening	As per table 400-8 of MoRT&H specification	One test for 100 m^3	MoRT&H Clause -404
c	Los Angeles Abrasion	40% max	*One test for 100 m^3	2386 part (IV) MoRT&H Clause -404
* The value of elongation and flakiness index change very often with wearing of jaws of the stone crusher. A close watch shall be kept on variations in results and tests shall be taken more frequently than stipulated if large variations are noted				

d	F.I & Elongation indices	30% max	*One test for 100 m^3	2386 part (I)
e	Atterberg limit for binding material			
	L.L(for screening)	20% max	One in 200 m^3	BIS 2720(5)
	P.I (for screening)	6 max	One in 200 m^3	BIS 2720(5)
f	Water absorption	Maximum 2%	Initially one set of 3 representative specimen	BIS 2386(3)
g	Compaction	To be carried out as per Cl.404.3		MoRT &H
4.	**WBM (water bound macadam)**			
a	Grading	As per table 400-11 ofMORT&H	One in 200 m^3	MoRT &H
b	Los Angeles Abrasion Value	40% max	One in 200 m^3	BIS: 2386 (part 4)
c	Aggregate Impact value	30% max	One in 200 m^3	BIS: 2386 (part 4) On IS: 5640
d	Combined flakiness & elongation indices	30% max	One in 200 m^3	BIS: 2386 (part 1)
e	P.I (for screening)	30% max	One in 200 m^3	BIS: 22720 (5).
5.	**Prime coat/tack coat**			
a	Kinematic viscosity at 60° C and qty per 10 sq.m	i. for low porosity surface 30-60 ii. for medium porosity surface 70-140 iii. for high porosity surface 250-500	One test per lot or per 10T, whichever is more. Two samples per lot to be subjected to all or some tests as directed by^ the engineer at regular close intervals	BIS 217 BIS 414 BIS 8887 MoRT & H Cl. 502 IRC: SP: 20-2002

6-	**Seal coat/ surface dressing**			
a	Quality of binder	Bitumen emulsion	Two samples per lot	BIS 217, 454,8887
b	Aggregate Impact value	Max. 30%	One test per 50 m^3 of aggregates	BIS 2386 (4)
c	Stripping value	Max. 5%	Initially one set of 3 specimen for source subsequently as warranted	BIS 2386(4)
d	Water absorption of aggregates	Max. 2%	Initially one set of 3 specimen for source subsequently as warranted	BIS 2386(4)
e	Temperature of binder application	150° C- 163° C for aggregate and 155° -163 ° C for binder		
f	Rate of spread of materials	As per table 500-16 of MoRT & H	One test per 500 sq.m	MoRT&H
g	Rate of application in kg per sqm	i. 0.20 to 0.25 for normal bituminous surface ii. 0.25 to 0.30 for dry and hungry bituminous surface. iii.0.25 to 0.30 for granular surface treated with primer iv. Non bituminous surface	One test per lot or per 10 T, whichever is more	MoRT&H CI 503 IRC: SP:20-2002
		0.35 to 0.40 for granular base 0.30 to 0.35 for cement concrete		
7.	**Premix carpet/mix -seal surfacing**			
a	Quality of binder	Straight run bitumen grade 30/40	Two samples per lot as directed by engineer	BIS 217, 454,8857
b	Open graded 20mm thick	Aggregate 0.27 m^3 per 10 sq.m Binder 14.60 kg per sq.m	As directed by Engineer	MoRT & H C1.511 IRC SP: 20-2002

c	Close graded premix surfacing/ mixed seal surfacing 20mm thick	Aggregates gradation type A or type B as per table 500-26 of MoRT&H C1.512	As directed by engineer	MoRT&H C1.512 IRC SP: 20-2002
d	Aggregate impact value	30% max	One test per 200 m^3	BIS 2386 (4)
e	Flakiness index of aggregates	30% max	One test per 200 m^3	BIS 2386 (1)
f	Stripping value	5% max		BIS 2386 (4)
g	Water absorption	2% max		BIS 2386 (4)
h	Temperature of binder at application	150° C- 163° C	At regular close intervals	BIS 2386 (4)
i	Rate of spread of mixed material	As per MoRT&H Cl. 500	Regular control on materials and layer thickness	MoRT & H Cl.500
8.	**Dense graded bituminous macadam**			
a	Quality of binder and content	Cut back bitumen of 30/40 grade. Min 4% as per job mix formula	One test per lot or per 10T whichever is more	BIS 217, 454,8887 IRC SP: 20-2002
b	Coarse aggregate Grain size analysis	Passing 0.075 mm Max 5%	One test per 250 m^3 per source	MoRT&H Table 500-8 C1.507, IRC: SP: 20-2002
	Flakiness & Elongation index	Max 30%	One test per 250 m^3 per source	
	L.A Abrasion value	Max 35%	One test per 250 m^3 per source	
	Aggregate impact value	Max 27%	One test per 250 m^3 per source	
	Soundness In sodium sulphate	Max 12%	One test per 250 m^3 per source	

	In magnesium Sulphate	Max 18%		
	Water absorption	Max 2%	One test per 250 m^3 per source	
	Coating & stripping of bitumen	Minimum retained coating 95%	One test per 250 m^3 per source	
	Tensile strength retained	Min 80%	One test per 250 m^3 per source	
	Percentage of fractured faces	Min 75%	One test per 250 m^3 per source	
	Temperature of binder and aggregate for binder mixing and laying	150-163 °C		
	Density of compacted	Min 98% of lab density as per job mix formula	One test per 250 m^3 per source	
c	Tests on filler	Sieve analysis passing 0.6mm sieve 100% passing 0.3mm sieve 95-100% Passing 0.075 mm sieve 85-100%	One test per 250 m^3 per source	MoRT &H Table 500-9 C1.507 IRC: SP: 20-2002
	Plasticity index	Max 4	One test per 250 m^3 per source	
d	Aggregates grading	Grade 1 - *nominal* aggregate size 40mm layer thickness 80- 100mm	*One test per* 250 m^3 per source	MoRT&H Table 500-10 Cl. 507 IRC: SP: 20-2002
		Grade 2- Nominal	One test per 250 m^3 per source	
		Aggregate size 25mm	One test per 250 m^3 per source	
		Layer thickness 50-75mm		

e	Mix design (job mix formula)	Min stability @ 60 ° C 9.0 KN		MoRT &H Table 500-11 C1.507
		Min. flow 2mm		
		Max flow 4mm Percent air voids 3-6		
8a.	**Semi dense bituminous concrete**			
a	Quality of binder and content	Cut back bitumen of 80/100 grade. Min.4.5% as per job mix formula	One test per lot or per 10T whichever is more	BIS 217, 454, 8887 IRC SP: 20-2002
b	Coarse aggregate Grain size analysis (dust)	Passing 0.075mm Max 5%	One test per 250 m^3 per source	MoRT &H Table 500-8 CI. 507 IRC: SP: 20-2002
	Flakiness & Elongation index	Max 30%	One test per 250 m^3 per source	
	L.A Abrasion value	Max 35%	One test per 250 m^3 per source	
	Aggregate impact value	Max 27%	One test per 250 m^3 per source	
	Soundness -in sodium sulphate -in magnesium sulphate	Max 12% Max 18%	One test per 250 m^3 per source	
	Water absorption	Max 2%	One test per 250 m^3 per source	
	Coating & stripping of bitumen	Minimum retained coating 95%	One test per 250 m^3 per source	
	Tensile strength retained	Min 80%	One test per 250 m^3 per source	
	Percentage of fractured faces	Min 75%	One test per 250 m^3 per source	
	Temperature of binder and aggregate for mixing & laying	150-163 °C		

	Density of compacted	Min 98% of lab. Density as per job mix formula	One test per 250 m^3 per source	
c	Tests on filler	Sieve analysis passing 0.6mm sieve 100%. Passing 0.3mm sieve 95-100% Passing 0.075mm sieve 85-100%	One test per 250 m^3 per source	MoRT&H Table 500-9 CI. 507 IRC: SP: 20-2002
	Plasticity index	Max 4	One test per 250 m^3 per source	
d	Aggregates grading	Grade 1-nominal Aggregate size 13mm Layer thickness 35-40 mm	One test per 250 m^3 per source	MoRT&H Table 500- 10 CI. 507 IRC SP 20-2002
		Grade 2- nominal aggregate size 10mm Layer thickness 25-30mm	One test per 250 m^3 per source	
e	Mix design (job mix formula)	Min. stability @ 60° C 8.2 KN		MoRT&H Table 500- 10 C1.507
		Min. flow 2mm		
		Max. flow 4mm Percent air voids 3-5		
8b.	**Bituminous concrete**			
a	Quality of binder and content	Cut back bitumen of 80/100 grade. Min 5% as per job mix formula	One test per lot or per 10T whichever is more	BIS 217, 454, 8887 IRC SP: 20-2002
b	Coarse aggregate Grain size analysis (dust)	Passing 0.075 mm Max 5%	One test per 250 m^3 per source	MoRT&H Table 500-8 CI. 507 IRC SP 20-2002
	Flakiness & Elongation index	Max 30%	One test per 250 m^3 per source	
	L.A.Abrasion value	Max 30%	One test per 250 m^3 per source	
	Aggregate impact value	Max 24%	One test per 250 m^3 per source	
	Soundness -in sodium sulphate -in magnesium sulphate	Max 12% Max 18%	One test per 250 m^3 per source	
	Water absorption	Max 2%	One test per 250 m^3 per source	

	Coating & stripping of bitumen	Minimum retained coating 95%	One test per 250 m^3 per source	
	Tensile strength retained	Min 80%	One test per 250 m^3 per source	
	Percentage of fractured faces	Min 75%	One test per 250 m^3 per source	
	Temperature of binder and aggregate for mixing and laying	150-163°C		
	Density of compacted	Min 98%o of lab. Density as per job mix formula	One test per 250 m^3 per source	
c	Tests on filler	Sieve analysis passing 0.6mm sieve 100% Passing 0.3mm sieve 95-100% Passing 0.075mm sieve 85-100%	One test per 250 m^3 per source	MoRT &H Table 500-9 C1.507 IRC SP 20-2002
	Plasticity index	Max. 4	One test per 250 m^3 per source	
d	Aggregates grading	Grade 1- nominal aggregate size 19mm Layer thickness 50-65mm	One test per 250 m^3 per source	MoRT &H Table 500-9 C1.507 IRC SP 20-2002
		Grade 2- nominal aggregate size 13mm Layer thickness 30-45mm	One test per 250 m^3 per source	
	Mix design(job mix formula)	Min.stability@60°C 9.0 KN		MoRT &H Table 500-11 C1.507
		Min. flow 2mm		
		Max.flow 4mm Percent air voids 3-		
9.	**Dry Lean Concrete (DLC)**			
a	Aggregates coarse aggregate	Max. size 25mm	One test per source/plant size	MoRT &H C1.601 IS SP:20-2002
b	Water absorption	Max 2%	One test per source/plant size	
	Soundness	Max. loss 12% after 5 cycles (for sodium	One test per source/plant size	

		sulphate solution) & 18% (if magnesium sulphate sodium)		
	Fine aggregate	Natural sand, crushed stone sand or c ombination of two	One test per source/plant size	MoRT &H C1.601 IRC SP:20-2002
	Clay lumps	Max 4%	One test per source/plant size	
	Coal and lignite	Max 1%	One test per source/plant size	*
	Material passing IS sieve no. 75 micron	Max 4%	One test per source/plant size	
c	Cement content	Not less than 150 kg per cubic m		IRC SP 20-2002
d	Concrete strength	Not less than 10 mpa average at 7 days and any individual cube not less than 7.5 Mpa at 7 days.	2 tests per 150^3 test each 7 days and 28 days strength	IRC SP 20-2002
10.	**Cement concrete for pavement-Pavement Quality Concrete (PQC)**			
a	Cement	OPC 33 Gr.IS:269	One test per source /plant site	MoRT&H CI .602
		OPC 43 Gr. IS:8112	,	
		OPC 33 Gr. IS:12269		
b	Aggregates			
	Los Angeles Abrasion test	Max 35%	One test/day	
	Total chloride content	Max 0.06%	Once for approval of source of supply, subsequently only in case of doubt	
	Total sulphate content	Max 0.25%	Once for approval of source of supply, subsequently only in case of doubt	
	Coarse aggregate	Max size 25mm	One test/day	
	Water absorption	Max 2%		
	Soundness	Max. 12 % with sodium sulphate solution & 18% with magnesium sulphate	Before approving the aggregates and every month subsequently	

c	Concrete strength			
	Concrete cube strength @ 7 and 28 days	To be stipulated as per design of pavement	3 test/150m^3 test each 7, 14, and 28 days strength	
	Flexural strength at 28 days	One for every days work for each plant site	1 test/ 150m^3 test 28 days strength	
	Field core test	As stipulated in tender	As stipulated in tender	
d	C C paver blocks	As stipulated in tender	All stipulated test at the rate of one test for 5000 nos.	

Note:
The number of tests recommended herein may be reduced at the discretion of the Engineer if it is felt that consistency in quality of materials can still be maintained with the reduced number of tests, (vide MORTH IV revision clause 903.1)

11.2. PROCEDURE FOR FIELD CONTROL TESTS

11.2.1. Test for checking rate of spread of bitumen in surface dressing:

Light metal trays of 20cm X 20cm size and 3 cm depth are weighed and numbered. These are placed at intervals along the road in the path of the bitumen distributor between the wheel tracks. After the distributor has passed over, trays are removed and wrapped in weighed sheets of paper so that they can be handled, stocked and weighed as soon as convenient. The spacing and the number of trays can be varied to suit the particular conditions at the construction site, but at least five trays should normally be used. The tray test gives a measure of variation in rate of spread of bitumen along the road and a good approximation to the average rate of spread of bitumen.

The trays are weighed correct to first place of decimal. The maximum longitudinal distribution error in rate of spread of bitumen should be within +/- 10 percent of the specified fate of spread of bitumen.

Similarly transverse distribution of bitumen can be checked by placing a number of trays to collect bitumen sprayed over each 5cm width of spray bar. The variation in transverse distribution should be within +/- 20 percent from the mean. The extreme 15 cm width at either side of the sprayed area need not be taken into account.

11.2.2. Test for checking rate of spread of aggregates in surface dressing:

The rate of spread of aggregates by the aggregate spreader can be checked by measuring the area covered by each lorry/truck load of known capacity. This can also be checked by removing the spread aggregates from small areas of the road surface and weighing them. A 10 cm square metal frame is laid on the new surface dressing, and all the aggregates within the enclosed area are collected, washed in solvent to remove bitumen and weighed, and the rate of spread of aggregates is calculated. It is measured along the road at intervals of between 1 to 4 m. The variation in the rate of spread of aggregates should be within +/- 20 percent of the mean.

11.2.3. Test for determination of bitumen content in bituminous mix:

The test is intended for determination of bitumen content in the bituminous mix by cold solvent extraction method. The mineral aggregates recovered from the test can be used for checking their gradation.

A representative bituminous mix sample of about 500 gm by weight is accurately weighed and placed in the bowl of extraction apparatus and covered with commercial grade of benzene. The filter ring of the extractor is dried, weighed and then fitted around the edge of the bowl. The cover of the bowl is clamped tightly. A beaker is placed under the drain to collect the extract. The machine is revolved slowly and then gradually the speed is increased to a maximum of 3600 rpm. The speed is maintained till the solvent ceases to flow from the drain. The machine is allowed to stop, 200ml. of benzene is added and the above procedure is repeated. A number of 200ml. solvent additions (not less than three) are used till the extract is clear and not darker than a light straw colour. The filter ring from the bowl is removed, dried first in the air and then in oven at f 15°C to constant weight and weighed. The fine materials that might have passed through the filter paper recollected back from the extract preferably by centrifuging. The material is washed and dried to constant weight as before. The percentage of binder in the bituminous of binder in the bituminous mix sample is calculated as follows:

Percentage binder = $((W_1 - (W_2+W_3+W_4)) / W_1) \times 100$

W_1= weight of sample, gm
W_2= weight of sample after extraction, gm
W_3= weight of fine material recovered from the extract, gm
W_4=increase in weight of filter ring, gm

11.2.4. Test for determination of in-situ density of-Asphaltic concrete

The metallic tray of the field density unit is kept on a level spot of the bituminous surface and a hole; 10 cm in diameter, is cut up to the full thickness of the layer. All bituminous materials removed from the hole are carefully collected and weighed. The thickness of the layer is also recorded.

A known weight of dry standard sand passing 600 micron sieve and retained on 300 micron sieve, is taken in the sand-pouring cylinder. The cylinder is kept directly over the hole, and the shutter of the cylinder is released without any jerk and closed when the hole is filled with the sand. The quantity of the residual sand in the cylinder as well as the quantity filling the cone of the cylinder is separately weighed.

The in-situ density of the layer is calculated as follows:

In- situ density^ (A xD)/W- (W_1+W_2) gm per cc

Where-
A= weight of bituminous materials removed from the hole cut in the layer, gm
W= initial weight of sand taken in the cylinder, gm
W_1= weight of sand filling the cone of the cylinder, gm
W_2= weight of sand remaining in the cylinder, gm
D= bulk density of sand gm/cc

11.2.5. Procedure for checking surface regularity using a straight edge

The procedure to be followed for checking the surface regularity with a straight edge is as follows:

- The 3 meter straight-edge may be made of steel or seasoned hard wood. When made of wood, it may be 75 mm wide and 125 mm deep and its test face should preferably be shod with a metallic plate. The edge should be perfectly straight and free warps, rots or defects of any kind.
- Periodically, the straight-edge should be checked for its trueness with string or a metallic master straight-edge. The straight-edge should be rectified or replaced as soon as the same has lost its trueness.
- The depressions under the straight-edge are to be measured with a graduated wedge. The wedge should preferably be metallic but may alternatively be a seasoned hard wood. These should be graduated to read depressions up to 25 mm a least count of at least 3 mm
- For recording depressions in the longitudinal profile of the road surface, the straight-edge is placed longitudinally, parallel to the centre line of the road. Measurements along two parallel lines may normally be sufficient for a single-lane road and along three lines for a two-lane road. One additional line may be covered for each additional lane.
- The straight -edge has limitations as regards the measurements of undulations at vertical curves. Additional templates or straight - edges may be made for this purpose especially if the curve is sharp.
- The straight- edge may be placed at the starting point with the wedge inserted between it and the test surface, where the gap is maximum and the reading is taken. The wedge may then be slided forward by about 1.5m distance and the wedge reading is recorded. This process is continued. The straight edge need not always be moved forward to record the maximum depression existing at a location. Locations with depressions in excise of the specified magnitude should be marked on the surface.
- A team of three persons consisting of two workmen and a supervisor would be required for one straight-edge and two graduated wedges. The two workmen will operate the straight -edge, while the supervisor will record measurements with the wedges and do the markings on the road.

11.2.6. Tolerance in surface levels:

SL. No	Type of surface	Tolerance in level compared with longitudinal and cross profile
1	Sub grade	+ 20mm - 25mm
2	Sub base	+ 10mm - 20mm
3	Base ajMachine laid b) Manually laid	+ 10mm - 10mm + 15mm - 15mm
4	Wearing course a) Machine laid b)Manually laid	- 6mm + 6mm + 10mm - 10mm

11.2.7. Surface regularity of pavement courses:

The maximum allowable difference between the road surface and underside of a straight edge when placed parallel with or at right angles to the centre line of the road at points shall be:

For bituminous surface: 3mm For
GSB/base surface: 8 mm

The maximum permitted number of surface irregularities measured under a 3m long straight edge at the middle of each traffic lane along a line parallel to the centre line of the road shall be:

Maximum number of surface irregularities on bituminous roads and shoulders				
Irregularity	**4mm**		**7mm**	
Length, m	300	75	300	75
NH/SH	20	9	2	1

CHAPTER 12

TEST PROCEDURES

12. 1. Tests on soils

California Bearing Ratio (CBR) test:

The most widely used test for design of flexible pavements is the California Bearing Ratio test, abbreviated as the CBR test. It can be used for analysis of existing pavements layer by layer, in respect of their strength and load-carrying capacity. Also helps in identifying the causes of failure of road pavements and for devising measures to rectify these defects. The test has been standardized by the Indian Standards Institution (IS 2720: Part XVI). The test is basically a penetration test, in which the load required to cause a plunger of standard size to penetrate a specimen of soil at a standard rate is measured.

The test can either be conducted on remoulded specimens or undisturbed specimens in the laboratory or in-situ on the sub grade soil itself.

12.1.1. Determination of CBR values:

Apparatus:

i). Loading machine- With a capacity of at least 5000 kg and equipped with a movable head or base which enables the plunger to penetrate into the specimen at a deformation rate of 1.25mm/min. The machine shall be equipped with a load machine device that can read to suitable accuracy.

Note- In the machine priming ring can also be used.

ii). Penetration plunger- This hall conforms to 4.4 of IS: 9669 1980'"

iii). Dial gauges- Two dial gauges reading to 0.01 mm

iv). Sieves- 47.5mm IS: sieve and 19 mm IS sieve [see IS: 460(part 1) 1985"]

v). Miscellaneous apparatus- Other general apparatus such as a mixing bowl, straight edge, scales, soaking tank or pad, drying oven, filter paper, dishes and calibrated measuring jar.

Preparation of test specimen:

The test may be performed on:

a) Undisturbed specimens and

b) Remolded specimens which may be compacted either statically or dynamically

Note- The static method of compaction gives the required density but requires considerable pressure and there is a possibility of the actual density varying with depth though the mean density may be the one desired.

Remolded specimens:

The dry density for a remolding shall be either the field density or the value of the maximum dry density estimated by the compaction tests [see IS: 2720 (part 7)-1980", and IS 2720(part 8)-1983[vl]] or any other density at which the bearing ratio is desired. The water content used for compaction should be the optimum water content or the field moisture as the case may be.

Soil sample:

The material used in the remolded specimen shall pass a 19-mm IS sieve. Allowance for larger material shall be made by replacing it by an equal amount of material which passes a 19-mm IS sieve but is retained on 4.75-mm IS sieve.

Statically compacted specimens:

The mass of wet soil at the required moisture content to give the desired density when occupying the standard specimen volume in the mould shall be calculated. A batch of soil will be thoroughly mixed with water to give the required water content. The correct mass of the moist soil shall be placed in the mould and compaction obtained by presenting in the displacer disc, a filter paper is being placed between the disc and the soil.

Dynamically compacted specimen:

For dynamic compaction, a representative sample of the soil weighing approximately 4.5 kg or more for fine grained soils and 5.5 kg or more for granular soils shall be taken and mixed thoroughly with water. If the soil is to be compacted to the maximum dry density at the optimum water content determined in accordance with IS: 2720 (Part 7)™ or IS: 2720 (Part 8)-1983™ the exact mass of soil required shall be taken and the necessary quantity of water added so that the water content of the soil sample is equal to the determined optimum water content.

The mould with the extension collar attached shall be clamped to the base plate. The spacer disc shall be inserted over the base plate and a disc of coarse filter is paper placed on the top of the spacer disc. The soil water mixture shall be compacted into the mould in accordance with the method applicable to the 150mm diameter mould specified in IS: 2720(Part *7f* or IS: 2720 (Part 8)-1983". If other densities and water content are desired, they may be used and indicated in the report.

The extension collar shall then be removed by the compacted soil carefully trimmed even with the top of the mould by means of a straightedge. Any hole that may then develop on the surface of the compacted soil by the removal of coarse material shall be patched with smaller size material; the perforated base plate and the spacer disc shall be removed, then the mass of the mould and the compacted soil specimen is recorded. A disc of coarse filter paper shall be placed on the perforated base plate, the mould and the compacted soil shall be inverted and the perforated base plate clamped to the mould with the compacted soil in contact with the filter paper.

In both cases of compaction, if the sample is to be soaked, representative samples of the material at the beginning of compaction and another sample of the remaining material after compaction shall be taken for determination of water content. Each water content sample shall weigh not less than about 50 g.

If the sample is not to be soaked, a representative sample of material from one of the cut-pieces of the material after penetration shall be taken to determine the water content. In all cases, the water content shall be determined in accordance with IS:2720 (Part 2) 1973".

Procedures

Test for swelling:

A filter paper shall be placed on the compacted soil stem and perforated plate shall be placed on the compacted soil specimen in the mould. Weights to produce a surcharge equal to the weight of base material and pavement to the nearest 2.5 kg shall be placed on the compact soil specimen. The whole mould and weight shall be immersed in a tank of water to the top and bottom of the specimen. The tripod for the expansion measuring device shall be mounted on the edge of the mould and the initial dial gauge reading is recorded. This set up shall be kept undisturbed for 96 hours noting down the readings everyday against the time of reading. A constant water level shall be maintained in the tank through-out the period.

At the end of the soaking period, the change in dial gauge shall be noted, the tripod is removed and then the mould is taken out of the water tank.

The free water collected in the mould shall be removed and the specimen is allowed to drain downwards for 15 minutes. Care shall be taken not to disturb the surface of the specimen during the removal of the water. The weights, the perforated plate, and the top filter paper shall be removed and the mould with the soaked soil sample shall be weighed and the mass is recorded.

Note- The swelling test may be omitted if it is unnecessary and the penetration test specified may be carried out directly.

Penetration test:

The mould containing the specimen, with the base plate in position but the top face exposed shall be placed on the lower plate of the testing machine. Surcharge weight, sufficient to produce an intensity of loading equal to the weight of the base to produce an intensity of loading equal to the weight of the base material and pavement shall be placed on the specimen. If the specimen has been soaked previously, the surcharge shall be equal to that used during the soaking period. To prevent upheaval of soil, into the hole of the surcharge weights, 2.5 kg annular weight shall be placed on the soil surface prior to seating the penetration plunger after which the remainder of the surcharge weights shall be placed. The plunger shall be seated under a load of 4kg so that full contact is established between the surface of the specimen and the plunger. The load and deformation gauges shall then be set to zero (in other words, the initial load applied to the plunger shall be considered as zero when determining the load penetration relation). Load shall be applied to the plunger into the soil at the rate of 1.25mm per minute.

Reading of the load shall be taken to penetrations of 0.5,1.0,1.5,2.0,2.5,4.0,5.0, 7.5, 10.0 and 12.5 mm.(The maximum load and penetration shall be recorded if it occurs for a penetration of less than 12.5mm). The plunger shall be raised and the mould is detached from the loading equipment. About 20 to 50 g of soil shall be collected from the top 30mm layer of the specimen and the water content is determined according to IS: 2720 (part 2)- 1973[xii]. If the average water content of the whole specimen is desired, water content sample shall be taken from the entire depth of the specimen.

The undisturbed specimen for the test should be carefully examined after the test is completed for the presence of any oversize soil particles which are likely to affect the results if they happen to be located directly below the penetration plunger.

The penetration test may be repeated as a check test for the rear end of the sample.

Record of observations:

Specimen data: The specimen data shall be recorded on the data sheet. Apart from the soil identification, this includes the condition of the specimen at the time of testing, type of compaction adopted, the amount of soil fraction above 20mm that has been replaced, the water content and density determination before & after the mould has been subjected to soaking.

Penetration data: The readings for the determination of expansion ratio and the load penetration data shall be recorded in the data sheet.

Calculations:

Expansion ratio: The expansion ratio based on tests conducted as specified shall be calculated as follows:

Expansion ratio = d_t - d_s / h x 100

Where d_t = final dial gauge reading in mm d_s = initial dial gauge reading in mm h = initial height of the specimen in mm

The expansion ratio is used to qualitatively identify the potential expansiveness of the soil.

Load penetration curve:

The load penetration curve shall be plotted. This curve is usually convex upwards although the initial portion of the curve may be convex downwards due to surface irregularities. A correction shall then be applied by drawing a tangent to the point of greatest slope and then transposing the axis of the load so that zero penetration is obtained. The corrected load- penetration curve would then be consisting of the tangent from the new origin to the point of tangency on the resisted curve and then the curve itself.

California bearing ratio:

The CBR values are usually calculated for penetrations of 2.5 and 5mm. Corresponding to the penetration value at which the CBR values is desired, corrected load value shall be taken from the load penetration curve and then the CBR is calculated as follows:

California bearing ratio = Pt / Ps X 100

Where

Pt= corrected unit (or total) test load corresponding to the chosen penetration from the load penetration curve, and

P_s= unit (or total) standard load for the same depth of penetration as for P_t taken from the table

Generally, the CBR value at 2.5mm penetration will be greater than that at 5mm penetration and in such a case; the former shall be taken as the CBR value for design purposes. If the CBR value corresponding to the penetration of 5mm exceeds that for 2.5 mm, the test shall be repeated. If the identical results follow, the CBR corresponding to 5mm penetration shall be taken for design.

Penetration of results:

The results of the CBR test are presented as the CBR value and the expansion ratio

12.2. Test on aggregates

12.2. l._Aggregate crushing test:

The aggregate crushing value provides a relative measure of resistance to crushing under gradually applied compressive load.

Apparatus:

The apparatus for the standard test consists of a steel cylinder 15.2 cm diameter with a base plate and a plunger, compression testing machine, cylindrical measure of diameter 11.5 cm and height 18 cm, tamping rod and sieves.

Procedure:

Dry aggregates passing through 12.5 mm IS sieve and retained on 10 him sieve is filled in the cylindrical measure in three equal layers, each layer being tamped 25 times by
the tamper. The test sample is weighed (equal to W_1 g) and placed in the test cylinder in three equal layers, tamping each layer 25 times. The plunger is placed on the top of specimen and a load of 40 tons per minute is applied by the compressive machine. The crushed aggregate is removed and sieved on 2.36 mm IS sieve. The crushed material which passes this sieve is weighed equal to W_2 g. The aggregate crushing value is the percentage of the crushed material passing 2.36 mm sieve in terms of original weight of the specimen.

Aggregate crushing value = 100 x W_2/ W_1 12.2.2.

Abrasion test:

Due to the movement of traffic, the road stones used in the surface course are subjected to wearing action at the top. Abrasion tests are carried out to test the hardness property of stones and to decide whether they are suitable for the different road construction works.

The abrasion test on aggregates may be carried out by any one of the following methods:

1. Los Angeles abrasion test
2. Deval abrasion test
3. Dory abrasion test

Los Angeles Abrasion Test:

The principle of Los Angeles abrasion test is to find the percentage wear due to the relative rubbing action between the aggregate and steel balls used as abrasive charge.

Apparatus:

The Los Angeles machine consists of a hollow cylinder closed at both ends, having inside diameter 70 cm and length 50 cm and mounted so as to rotate about its horizontal axis. An opening is provided in the cylinder for the introduction o f the test sample. A removable steel shelf projecting radially 8.8 cm in to the cylinder and extending full length of it, is mounted on the interior surface of the cylinder rigidly, parallel to axis. Abrasive charge consists of the cast iron spheres of approximate diameter 4.8 cm and each of weight 390 to 445 g. The number of spheres to be used and their total weight has been specified based on grading of the aggregate sample.

Procedure:

The specified weight of aggregate specimen, (5 to 10 kg, depending on graduation) is placed in the machine along with the abrasive charge. The machine is rotated at a speed of 30 to 33 rpm for the specified number of revolutions (500 to 1000 depending on the grading of the specimen). The abraded aggregate is then sieved on 1.7 mm IS sieve, and the weight of powdered aggregate passing this sieve is found. The result of the abrasion test is expressed as the percentage wear or the percentage passing through 1.7 mm sieve. expressed in terms of the original weight of the sample.

The Los Angeles abrasion value of good aggregates acceptable for cement concrete, bituminous concrete and other high quality pavement materials should be less than 30 percent. Values up to 50 percent are allowed in base course like water bound and bituminous macadam.

This test is more dependable than other abrasion tests as rubbing and pounding action in the test simulate the field condition better.

12.2.3. Aggregate impact test:

Toughness is the property of a material to resist impact. The aggregate impact value indicates a relative measure of resistance of aggregates to impact.

Apparatus:

The apparatus consists of an impact testing machine, a cylindrical measure tamping rod, IS sieve balance and oven.

The machine consists of a metal base with a plane lower surface supported well on a firm floor, without rocking. A detachable cylindrical steel cup of internal diameter 10.2 cm and depth 5 cm is rigidly fastened centrally to the base plate. A metal hammer of weight between 13.5 and 14.0 kg having the lower end is cylindrical in shape, 10 cm in diameter and 5 cm long, with 2 mm chamber at the lower edge is capable of sliding freely between vertical guides, and fall concentric over the cup. There is an arrangement for raising the hammer and allowing it to fall freely between vertical guides from a height of 38 cm on the test sample in the cup, the height of fall being adjustable up to 0.5 cm. A key is provided for supporting the hammer while fastening or removing the cup.

A cylindrical metal measure having internal diameter 7.5 cm and depth 5 cm for measuring aggregates.

A straight metal tamping rod of circular cross section, 1 cm in diameter and 23 cm long, rounded at one end.

IS sieve of sizes 12.5 mm, 10 mm and 2.36 mm for sieving the aggregates.

Abalance of capacity not less than 500 g to weigh accurate up to 0.1 g

A thermostatically controlled drying oven capable of maintaining constant temperature between 100 °C and 110 °C

Procedure:

Aggregate specimen passing through 12.5 mm sieve and retained on 10 mm sieve is filled in the cylindrical measure in 3 layers by tamping each layer by 25 blows. The sample is transferred from the measure to the cup of the aggregate impact testing machine and compacted by tamping 25 times. The hammer is raised to a height of 38 cm above the) upper surface of the aggregate in the cup and is allowed to fall freely on the specimen. After subjecting the test specimen to 15 blows, the crushed aggregate is sieved on 2.36 mm sieve. The fraction passing the sieve is weighed accurate to 0.1 g. The fraction retained on the sieve is also weighed and if the total weight of the fractions passing and retained on the sieve is added, it should not be less than the original weight of the specimen by more than one gram; if the total weight is less than the original by over one gram, the result should be discarded and a fresh test should be made. The above testis repeated on fresh aggregate sample.

The aggregate impact value is expressed as the percentage of the fine formed in terms of the total weight of the sample.

Value	**Use**
Up to 30%	Wearing course
Up to 35%	Bituminous macadam
Up to 40%	Water bound macadam

12.2.4. Soundness test:

Soundness test is intended to study the resistance of aggregates to weathering action, by conducting accelerated weathering test cycles. The property of the stones to withstand the adverse action of weather may be called soundness.

In order to quicken the effects of weathering due to alternate wet-dry and /or freeze thaw cycles in the laboratory, the resistance to disintegration of aggregate is determined by using saturated solution of sodium sulphate or magnesium sulphate. Clean, dry aggregates specimen of specified size range is weighed and immersed in the saturated solution of sodium sulphate or magnesium sulphate for 16 to 18 hours. Then the specimen is dried in an oven at 105 - 110°C to a constant temperature, thus making one cycle of immersion and drying. No. of cycles haveto be predetermined. After completing the final cycle, the sample is dried and each fraction of the aggregate is examined visually to see if there is any evidence of excessive splitting, crumpling or disintegration of the grains. Sieve analysis is carried out to note the variation in gradation from the original.

The average loss in weight of aggregates to be used in pavement construction after 10 cycles should not exceed 12 % when tested with sodium sulphate and 18% when tested with magnesium sulphate.

12.2.5. Sieve analysis:

Object: To determine the particle size distribution of aggregates. Apparatus:

i). Sieves

ii). For coarse aggregates- 80, 63, 50, 40, 31.5, 25, 20, 16,12.5,10,6.3 and 4.75mm sieves lid and pan. iii). For fine aggregates-4.75 mm, 2.36mm, 1.18 mm, 6000micron, 300 micron, 150 micron lid &pan. iv).

Balance

Sampling:

The minimum weight of sample required for sieve analysis is as follows:

Max size of aggregate present in substantial proportions, mm	**Minimum weight of sample to be taken for sieving . kgs**
63	50
50	35
40 or 31.5	15
25	5
20 or **16**	2
12.5	1
10	0.5
6.3	0.2
4.75	0.2
2.36	0.1

Procedure:

a. Take not less than the minimum quantity of sample a indicated above and dry it either at room temperature or in an oven at 100° C -110° C. Weigh the samples accurate to 0.1
a. percent. Sieve the sample either by hand or by mechanical sieve shaker.
b.

Hand sieving:

The sample is placed on the sieve and shaking is done with varied motion i.e, backwards and forwards, left to right, etc, with frequent jarring, for not less than two minutes. Material shall not be forced through the sieve by hand pressure, but on sieves coarser than 20mm placing of particle is permitted, lumps of fine particles present may be broken by gentle pressure with fingers against the side of the sieve. Light brushing with a soft brush on the underside of the sieve may be used to clear the sieve openings.

Mechanical sieving:

1. The sieves are arranged one above the other, in the decreasing order of size with a pan at the bottom.

2. The sample is placed into the top most sieve and the lid is closed.
3. The set of sieves is fixed on the sieve shaker and sieved for not less than 10 minutes.
4. After sieving is completed, the material on each of the sieve and on the pan is weighed.
5. The. cumulative percentage by weight of total sample, passing through each of sieve is calculated.

12.3. Shape tests

12.3.1. Flakiness index:

Object: To determine the particle shape of aggregates by the percentage of flaky particles contained in it.

Apparatus: The apparatus consists of a standard thickness gauge, IS sieves of sizes 63,50,40,31,5,25,20,16,12.5,10 and 6.3mm and a balance to weigh the samples.

Procedure: The flakiness index of aggregates is the *percentage by* weight *of particles* whose least dimension (thickness) is less than three-fifths (0.6) of their mean dimension. The test is not applicable to sizes smaller than 6.3mm. The sample to be tested is sieved with the sieves mentioned above. A minimum of 200 pieces of each fraction to be tested are taken and weighed (W1 gms). In order to separate flaky materials, each fraction is then gauged for thickness on a thickness gauge or in bulk on sieves having elongated slots. The width of the slot used should be of the dimensions specified in column 3 of the table "A" for the appropriate size of materials. The amount of flaky materials passing the gauge is weighed to an accuracy of at least 0.1 percent of the test sample.

$$\text{Flakiness index} = \frac{(W_1+W_1+W_3+.....)}{(w_1+w_2+w_3+....)} \times 100 \text{ percent}$$

Where W_1; W_2, W_3 are weights of the fractions passing and retained on specified sieves.

w_1 w_2, w_3 are weights of materials passing each of the specified thickness gauge.

12.3.2. .Elongation index:

Object: To determine the particle shape by the percentage of elongated particles contained in it.

Apparatus: length gauge, sieves of the sizes specified in table "A" and a balance.

Procedure: The sample is sieved through the IS sieves specified in table "A". A minimum of 200 pieces of each fraction is taken and weighed. In order to separate elongated material, each fraction is then gauged individually for length in a length gauge. The gauge length used should be those specified in column 4 of the table for the appropriate material. The pieces of aggregates from each fraction tested which could not pass through the specified gauge length with its long side are elongated particles and are collected separately to find the total weight of aggregates retained on the length gauge from each fraction. The total amount of elongated material retained by the length gauge is weighed to an accuracy of atleast 0.1 percent of the weight of the tested sample.

The elongation index is the total weight of the material retained on the various length gauges expressed as a percentage of the total weight of the sample gauge.

Elongation index= $(x_1+x_2+x_3...)$ / $(w_1+w_2+w_3)$ x100 percent

where-

x_1, x_2, x_3 are the weight of material from each fraction retained on the specified gauge length.

w_1, w_2, w_3 are the weight of each fraction of aggregate passing and retained on specified sieves.

Elongation index of an aggregate is the percentage by weight of particles whose greatest dimension (length) is greater than one and four fifth times (1.8 times) their mean dimension. The elongation test is not applicable to smaller sizes than 6.3 mm.

Table "A"

SIZE OF AGGREGATES		(COL. 1 X COL.2 X 0.6) /2	
Passing through IS sieve (mm)	**Retained on IS sieve (mm)**	**Thickness gauge (0.6 times the mean sieve) mm**	**Length gauge (1.8 times the mean sieve) mm**
1	2	3	4
63.00	50.00	33.90	-
50.00	40.00	27.00	81.00
40.00	25.00	19.50	58.50
31.50	25.00	16.95	-
25.00	20.00	13.50	40.50
20.00	16.00	10.80	32.40
16.00	12.50	8.55	25.60
12.50	10.00	6.75	20.20
10.00	6.30	4.89	14.70

12.3.3. Bitumen adhesion test:

Apparatus: Thermostatically controlled drying ovens capable of maintaining constant temperature between 26° C and 12° C, balance of capacity of 1 kg and accuracy 0.1 g, mixing pan spatula, jars etc.

Bitumen and tar adhere well to all normal types of aggregates provided they are dry and free from dust. Largely the viscosity of the binder controls the process of initial binding.

Static immersion test is very commonly used as it is quite easy and simple.

The principle of this test is by immersing the aggregate fully coated with the binder, in water maintained at specified temperature and estimating the degree of stripping. The result is reported as the percentage of stone surface that is stripped off after the specified time periods.

Aggregates passing 19mm sieve and retained on 12.7 mm sieve is washed thoroughly with water rinsed in distilled water and dried in an oven at 120° C for two hours. For each test 500 g each of coated mixture is prepared. When bitumen is used as a binder, 3.5 % of the total weight is taken and so 482.5 g of aggregates is mixed with 17.5g of bitumen to get a total weight of 500g of the coated mixture. When tar is used as a binder, 4.25 percent of total weight is taken for mixing and therefore 478.75 g of aggregates is mixed with 21.25 g of tar to make 500 g mixture. When using cutback bitumen or tar, aggregates at 60 ° C and binder at 100° C are used. Mixing is carried out by hand in a suitable mixing pan using a spatula and mixing is continued for 5 minutes at approximately 60 turns per minute. The uncoated areas of aggregates which are found at the end may be touched up.

The sample is divided into two approximately equal parts after mixing and each is placed in a 500 cc glass jar allowed to stand at a room temperature for 3 hours. One of the two jars containing the mixture is then filled with distilled water boiled previously and brought to a room temperature of 25 °C. The other jar with mixture is filled with distilled water previously boiled and brought to a temperature at 40° C.

The jars are then covered and maintained at 25° C and 40 °C respectively until the test is completed. Observations are made at 1,3,24 and 48 hours after the water is added. In each case percentage of stone surface that remains coated after the above times are visually estimated. At least three opinions may be taken in estimating the percentage aggregates coated and average value is taken.

The result is reported as the percentage of stone surface that remains coated after the specified periods, the mean value of at least three visually estimated values, being rounded off to the nearest 5 percent.

IRC has specified that stripping value of aggregates should not exceed 25 % for use in bituminous surface dressing, penetration macadam, bituminous macadam and carpet constructions, when aggregates coated with bitumen is immersed in water bath at 40 °C for 24 hours.

12.4. Tests of bituminous materials

12.4.1. Penetration test:

Penetration test is the most commonly adopted test on bitumen to grade the material in terms of its hardness.

Apparatus:
It consists of items like container, water bath, Penetrometer, stopwatch etc

a. Container: A flat bottomed cylindrical metallic container 55mm in diameter and 35 mm or 57mm in height.
b. Needle: A straight, highly polished cylindrical hard steel needle with conical end, having the shape and dimensions. The needle is provided with a shank approximately 3.00mm in diameter into which it is immovably fixed.
c. Water-bath: A water bath is maintained at 25±1° C containing not less than 10 litres of water; sample is immersed to depth not less than 100 mm from the top and supported on a perforated shelf not less than 50 mm from the bottom of the bath.

d. Penetrometer: It is an apparatus which allows the needle assembly of gross weight lOOg to penetrate without appreciable friction for the desired duration of time. The dial is' accurately calibrated to give penetration value in units of one tenth of a mm.
e. Transfer tray: A small tray, which can keep the container fully immersed in water during the test.

Procedure:

The bitumen is softened to a pouring consistency, stirred thoroughly to make it homogenous and free from air bubbles and water. The sample material is then poured into the container to a depth at least 15mm more than the expected penetration. The sample containers are then placed in a temperature controlled water bath at a temperature of 25° C for aperiod of one hour.

The sample container is placed in the transfer tray with water from the water bath and placed under the needle of the Penetrometer. The weight of needle, shaft and additional weight are checked. The total weight of this assembly should be 100 g.

The needle assembly is lowered and the tip of the needle is made to just touch the top surface of the sample, using the adjusting screw, the needle assembly is clamped in this position. The contact of the tip of the needle is checked using the mirror placed on the rear of the needle. The initial reading of the Penetrometer dial is adjusted to zero or the initial reading is taken before releasing the needle. The needle is released exactly for the period of 5.0 sees by pressing the knob and the final reading is taken on the dial. At least three measurements are made on this sample by testing at distance of not less than 100 mm apart. . After each test needle is disengaged and cleaned with benzene and carefully dried.

The bitumen grade is specified in terms of penetration value. 80/100 grade bitumen means that the penetration value of the bitumen is in the range 80 to 100 at standard test conditions.

Results:

The difference between the initial and final penetration readings is taken as the penetration value. The depth of penetration is reported in one-tenth millimeter units. The mean value of three measurements is reported as penetration value.

12.4.2. Softening point:

Apparatus : consists of ring and ball.

a. Steel balls: They are two in number. Each has diameter of 9.5 mm diameter and weight 2.5+0.05 g

b. Brass rings : There are two rings of the following dimensions,

Depth	6.40mm
Inside diameter at top	17. 5mm
Inside diameter at bottom	15.9mm
Outside diameter	20.6mm

c. Support: The metallic support is used for placing pair of rings. The upper surface of water of the rings is adjusted to be 50mm below the surface of water or liquid contained in the bath. A distance of 25mm bottom of the rings and top surface of the bottom plate of support is provided. It has housing for a suitable thermometer.

d. Bath and stirrer: A heat resistant glass container of 85mm diameter and 120mm depth used. Bath liquid is water for material having softening point below 80° C and glycerin for materials having softening point above 80° C. Mechanical stirrer is used for ensuring uniform heat distribution at all times throughout the bath.

Procedure:

Sample material is heated to a temperature between 75° and 100° C above the approximate softening point until it is completely fluid and is poured in heated rings placed on metal plate. To avoid sticking of the bitumen to metal plate, coating is done to this with a solution of glycerin and dextrin. After cooling the rings in air for 30 minutes, the excess bitumen and rings are placed in the support as mentioned in (c) above.

At this time the temperature of distilled water is kept at 5° C. This temperature is maintained for 15 minutes after which the balls are placed in position. The temperature of water is raised to at uniform rate of 5° C per minute with a controlling heating unit, until the bitumen soften and touches the bottom plate by sinking of balls. At least two observations are made.

Results:

The temperature at the instant when each of the ball and sample touches the bottom plate of support is recorded as softening value- The mean of duplicate determination is noted.

12.4.3. Ductility test:

Procedure:

The bitumen sample is melted to a temperature of 75 °C to 100° C above the approximate softening point until it is fluid. It is strained through IS sieve 30, poured in the mould assembly and placed on a brass plate, after a solution of glycerin and dextrin is applied at all surfaces of the mould exposed to bitumen. Thirty to forty minutes after the sample is poured into the moulds, the plate assembly along with the sample is placed in water bath maintained at 27° C for 30 minutes. The sample and mould assembly are removed from water bath and excess bitumen material is cut off by levelling the surface using hot knife. After trimming the specimen, the mould assembly containing sample is replaced in water bath maintained at 27° C for 85 to 95 minutes. The sides of the mould are now removed and the clips are carefully hooked on the machine without causing any initial strain. Two or more specimens may be prepared in the moulds and clipped to the machine so as to conduct these tests simultaneously.

Results:

The distance stretched by the moving end of the specimen upto the point of breaking of thread measured in centimeters is recorded as ductility value. It is recommended by ISI that test results should not differ from mean value by more than the following.

Repeatability : 5 percent
Reproducibility : 10 percent

12.4.4. Viscosity test:

Apparatus:

Ten millimeter orifice viscometer is specified for testing road tar and is called tar viscometer 4.0 mm orifice is used to test cutback grades 0 and 1 and 10 mm orifice to test all other grades. The apparatus consists of main parts like cup, valve, water, bath, sleeves, stirrer, receiver and thermometer etc,

Procedure:

The tar cup is properly levelled and water in the bath is heated to the temperature specified for the test and is maintained throughout the test. Stirring is also continued. The sample material is heated at the temperature 20° C. Above the specified test temperature and the material is allowed to cool. During this, the material is continuously stirred. When material reaches slightly above test temperature, the same is poured in the tar cup, until the leveling peg on the valve rod is just immersed. In the graduated receiver (cylinder), 20ml of mineral oil or one percent by weight solution of soft soap is poured. The receiver is placed under the orifice. When the sample material reaches the specified testing temperature within +/- 0.1 °C and is maintained for 5 minutes, the valve is opened. The stop watch is started, when cylinder records 25ml. the time is recorded for flowup to a mark of 75ml (i:e 50ml of test sample to flow through the orifice)

The viscosity test on road tar is carried out using 10mm orifice and the standard test temperature for road tar grades RT1, RT2,RT3 and RT4 are 35,40,45 and 55 °C respectively. In case the viscosity test is being carried out to classify a given sample of road tar or to find its grade, then the test should be first conducted at the lowest temperature of testing road tar, i:e 35 °C, if the time taken for 50ml of the tar sample to flow through the 10mm orifice is more than 55 sec, or if the sample does not flow freely, test may be repeated at the next higher temperature, till the viscosity value falls in the specified range.

The viscosity test on cutback bitumen is carried out using 4.0 mm orifice for grades 0 and 1 (SC-0, MC-0, RC-0, SC-1, MC-1, RC-1 at 25 °C) the test for cutback grades 2 and 3 are carried out at 25° C using 10 mm orifice and those for grades 4 and 5 are carried out at 40° C using 10mm orifice.

Results:

The time in seconds for 50ml of the test sample to flow through the orifice is defined as the viscosity at a given test temperature. Therefore the temperature at which the test was conducted and the diameter of the orifice used should also be maintained. The viscosity values of repeat tests should not vary by more than 4.0 percent from the mean value.

12.4.5. Determination of optimum bitumen content:

Five graphs are plotted with values of bitumen content against the values of: Density G_b,

g/cm3

Marshall Stability, S kg Voids in total mix, V_v% Flow value, F (0.25 mm units) Voids filled with bitumen, VBF%

Let the bitumen contents corresponding to maximum density be Bl, corresponding to maximum stability be B2 and that corresponding to the specified voids content Vv (4.0 % in the case of dense AC mix) be B3. Then the optimum bitumen content for mix design is given by:

$$B_0 = (B_1 + B_2 + B_3) / 3$$

The value of flow and VFB are found from the graphs, corresponding to bitumen content Bo. All the design value of Marshall Stability, flow, voids and VFB are checked at the optimum bitumen content Bo; with the specified design requirements of the mix.

Design requirements of the mix:

As per MOST , the specimens are to be compacted with 75 blows on either face; the designed AC mix should attain the following requirements.

Marshall stability value kg (minimum)	= >9KN
Marshall flow value, 0.25 mm units	=2-4
Voids in total, V_v%	= 3 to 6
Voids in mineral aggregates filled with bitumen, VFB%	=65-75

The higher possible Marshall Stability values in the mix should be aimed at consistent with the other three requirements mentioned above. In case the mix designed does not fulfill any one or more of the design requirements, the gradation of the aggregates or filler content or bitumen content or combination of these are altered and the design tests are repeated till all the requirements are simultaneously fulfilled.

The Marshall Stability test method is very simple and rapid method for designing bituminous mixes. The stability values obtained in this test procedure indirectly represent the strength of a paving mix at a zero vertical stress level which is critical.

12.5. Tests on Bituminous paving mixes:

Bituminous mixes are used in the surface coarse of road and airfield, pavements; some types of bituminous mixes are also used in base and or binder coarse of flexible pavements.

The desirable properties of a good bituminous mix are stability, durability and flexibility, skid resistance and workability.

Stability is defined as resistance of the paving mix to deformation under load and thus it is a stress, which causes a specified strain depending upon anticipated field conditions. Stability is a function of friction and cohesion.

Durability is defined as the resistance of the mix against weathering and abrasive actions. Weathering causes hardening and this depends upon loss of volatiles and oxidation. Tensile strain is introduced in the surfacing course consisting of bituminous mix when wheel loads ply over it. Excessive strain causes cracking or plastic failure.

Flexibility is a property of the mix that measures the level bending strength.

Skid resistance is defined as the resistance of the finished pavement against skidding and is a function of surface texture and bitumen content.

Workability is the ease with which the mix can be laid and compacted.

Design of bituminous mixes:

The following steps may be followed for a rational design of a bituminous mix.

Selection of aggregates:

Aggregates which possess sufficient strength, hardness, toughness and soundness are chosen, keeping in view the availability and economic consideration. Crushed aggregates and sharp sands produce higher stability of the mix when compared with gravel and rounded sands.

Selection of aggregate grading:

The properties of bituminous mix including the density and stability are very much dependent on the aggregates and their grain size distribution. As maximum size of aggregates gives higher stability, usually the bigger size that can be adopted keeping in view of the compacted thickness of the layer is selected, provided all other factors are equal. In base course maximum aggregate size of 2.5 to 1.87 cm size are used in the mixes.

The gradation of final mix after blending of the aggregates and filler should be within the specified range.

12.5.1. Determination of specific gravity:

The specific gravity of the bituminous material is not usually determined, if already known. The specific gravity of the aggregates is represented as their bulk specific gravity, or apparent specific gravity. In bulk specific gravity the overall volume of the aggregates is taken. In apparent specific gravity the volume of capillaries which are filled by water on 24 hours soaking is excluded. When effective specific gravity is used, the specific gravity of the total or combined aggregate is determined and the average specific gravity Ga of blended aggregate mix is calculated from the following equation:

$$Ga = 100/ (W_1/G_1+W_2/G_2+W_3/G_3+W_4/G_4)$$

WHERE

W_1, W_2, W_3, W_4 are % by weight of aggregate 1,2,3,4 &
G_1, G_2, G_3, G_4 are specific gravities of the respective aggregates

12.5.2. Proportioning of aggregates:

First the design grading is decided based on the type of the construction work, thickness of the layer & the availability of aggregates. Then the available aggregates are proportioned either by analytical method, or graphical methods of proportioning viz: triangular chart method and Rothfutch's method.

Preparation of specimen:

The preparation *of* specimen depends on the stability test method employed. Hence the size of the specimen, compaction and other specifications should be followed as specified in the stability test method. The stability test methods which are in common use for design mix are Marshall, Hubbard-field and Hveem. Hence after deciding the test methods, the specimens are molded as per specification.

12.5.3..Marshall Stability test:

Bruce Marshall formulated Marshall method for designing bituminous mixes. Generally this stability test is applicable to hot-mix design of bitumen and aggregates with maximum size 25mm.

In this method, the resistance to plastic deformation of cylindrical specimen of bituminous mixture is measured when the same is loaded at the periphery at 5 cm per minute. This test procedure is used in designing and evaluating bituminous paving mixes. There are two major features of this method viz. i) density-voids analysis ii) stability flow tests

The stability of the mix is defined as a maximum load carried by a compacted specimen at a standard test temperature oL 60° C.The flow is measured as the deformation in units of 0.25 mm between no load and maximum load carried by the specimen during stability test.

Apparatus:

a. Mould assembly: Cylindrical moulds of 10 cm diameter and 7.5 cm. height are required. It further consists of a base plate and collar extension. They are designed to be interchangeable with either end of cylindrical mould.

b. Sample extractor: For extruding the compacted specimen from the mould, an extractor suitably fitted with a jack on compression machine.

c. Compaction pedestal and hammer: It consists of a wooden block capped with MS plate to hold the mould assembly in position during compaction. The compaction hammer consists of a flat circular tamping face 8.8 cm diameter and equipped with a 4.5 kg weight constructed to provide a free fall of 45.7 cm . Mould holder is provided consisting of spring tension device designed to hold compaction mould in place on the compaction pedestal.

d. Breaking heat: It consists of upper and lower cylindrical segments or test heads having an inside radius of curvature of 5 cm. The lower segment is mounted on a base having two vertical guide rods which facilitate insertion in the holes of upper test hand.

e. Loading machine: The loading machine is provided with a gear system to lift the base in upward direction. On the upper end of the machine, a pre-calibrated proving ring of 5 tons capacity is fixed. In between the base and the proving ring, the specimen contained in test head is placed. The loading machine produces a movement at the rate of 5 cm/min. Machine is capable of reversing its movement downwards also. This facilitates adequate space for placing test head system after one specimen has been tested.

f. Flow meter: One dial gauge is fixed to the guide rods of a testing machine which can serve the purpose. Least count of 0.025mm is adequate. The flow value refers to the total vertical upward movement from the initial position at zero loads to a value at a maximum load. The dial gauge or flow meter should be able to measure accurately the total vertical movement upward. Besides the above equipment, the following are also required: ovens on hot plates. Mixing apparatus, water bath & thermometers of range up to 200° C with sensitivity of 2.5° C.

Procedure:

In the Marshall method each compacted specimen is subjected to the following tests and analysis in the order listed below:

Bulk density determination
Stability and flow index Density
and voids analysis

At least six samples are prepared for each binder content and in five binder contents are selected.

Preparation of test specimens:

The coarse aggregates, fine aggregates and the filler material should be proportioned and mixed in such a way that final mix after blending has the gradation within the specified range. The specified graduation of mineral aggregates and bitumen binder as per IRC :29-1968 are given in table below.

The aggregates and filler are mixed together in the desired proportion as per the design requirements and fulfilling the specified graduation. The required quantity of the mix is taken so as to produce a compacted bituminous mix specimen of thickness 63.5 mm approximately.

Approximately 1200 g of aggregates and filler are taken and heated to a temperature of 175° C to 190 °C. The compaction mould assembly and rammer are cleaned and kept pre-heated to a temperature of 100° C to 145° C. The bitumen is heated to a temperature of 140°± 5°C and required quantity of first trial % of bitumen (say 3.5% by weight of total mineral aggregates) is added to the heated aggregate and thoroughly mixed using a mechanical mixer or by hand mixing with trowel. The mixing temperature for 80/110 grade bitumen may be around 154° C and that for 60/70 grade about 160° C. The mix is placed in a mould andcompacted by rammer, with 75 blows on either side. The compacting temperatures may be about 138° C for 80/100 grade bitumen and 145° C for 60/70 grade. The compacted specimen should have the thickness of 63.5 mm. The weight of the aggregates taken may be suitably altered to obtain a thickness of +/-63.5 mm. at least six specimens should be prepared at each trail bitumen content which may be varied at 0.5 percent increments up to about 7.5 to 8.0 percent.

Marshall Stability and flow values:

The specimens to be tested are kept immersed under water in a thermostatically controlled water bath maintained at 60° +/- 1 °C for 30 to 40 minutes. The specimens are taken out one by one, placed in the Marshall Tests head and the Marshall Stability value (maximum load carried in kg, before failure) and the flow value (the deformation the specimen undergoes during loading up to the maximum load in 0.25 units) are noted. The

corrected Marshall Stability value of each specimen is determined by applying the appropriate correction factor, if the average height of the specimen in not exactly 63.5mm.

12.5.4. Specific gravity of compacted specimens:

The specific gravity values of the different aggregates, filler and bitumen used are determined first. The theoretical specific gravity Gt of the mix is given by:

$$G_t = 1/(W_1/G_1+W_2/G_2+W_3/G_3+W_4/G_4)$$

Where,

W_1=percent by weight of coarse aggregates
W_2=percent by weight of fine aggregates W_3=percent by weight of filler W_4=percent by weight of bitumen in total mix

G_1, G_2, G_3, G_4 are bulk specific gravity values of the coarse aggregates, fine aggregates, filler and bitumen respectively.

12.5.5. Density and voids analysis:

After the compacted bituminous mix specimens have been cooled to room temperature, the weight, average thickness and diameter of the specimen are noted. The specimens are also weighed in air and then in water. The bulk density value Gb of the specimen is calculated from the weight and volume. The voids analysis are made as given below:

$$V_v\% = 100\ (G_t - G_b)/G_t$$

$$V_v\% = G_b \times W_4 / G_4$$

$$VMA\% = V_v + V_b$$

$$VFB,\% = 100 V_b / VMA$$

Where V_v = air voids in the mix, %
V_b = volume of bitumen VMA=voids in mineral aggregates, % VFB=voids filled with bitumen, %

CHAPTER 13

MISCELLANEOUS

13.1. SOME COMMON DEFICIENCIES OBSERVED IN CONSTRUCTION PROCEDURES AND REMEDIAL MEASURES SUGGESTED

Construction Activity	Commonly noticed defects	Remedial Measures
Earthwork and subgrade	- soil from borrow area containing deleterious materials	Confirm that the proposed borrow area is completely stripped of top soil and free from contamination
	- soil carried from borrow areas is either too wet or too dry	Check for the OMC requirement. If the soil is too wet, excavation shall be done after the material is dried by temporary cuts and drainage arrangement in the borrow area. If the material is too dry, the surface area of the borrow area may be watered in advance
	Borrow material not consistent with subgrade requirements	Check the various parameters like grain size, moisture content, plasticity and strength requirements periodically at the borrow area and allow the soil after conformation of the requirements.
▪	Thickness of fill materials, fill segregation and improper grading	Subgrade material shall be spread in layers of uniform thickness not exceeding 200mm compacted thickness. Material shall be placed in small dumps to avoid segregation of coarse materials. The spreading of dumped material shall be done by motor grader and shall be from outside limits of placement and working towards the inside carriageway.
	Deficiency noticed in soil compaction and density requirements	Use only approved compaction equipments (eg. 8 to 10 tonnes static weight vibratory roller) & ensure compaction requirements as per table 300-2 of the MoRTH specifications, check for OMC, MDD. The finished surface shall confirm to table 900-1 of MoRTH specifications.

II. shoulders	The finished shoulder is not uniformly compacted and in level with the adjoining pavement. Gullies formed during rains or water stagnating in pavement edge due to high shoulders. Pavement edges ■ undulating and shoulders width not uniform. Shoulders material spilled and dragged to pavement surface	Shoulders shall be constructed accordance with 407-4 of MoRTH specification. • The sequence of operation shall be such that the construction of paved shoulder is done in layers matching the thickness of adjoining pavement layer. Only after a layer of pavement and shoulder portion have been laid and compacted, the construction of next layer of pavement and shoulder shall be taken up. • Where the materials in the adjoining layers are different these shall be laid together and the pavement layers shall be compacted first. The corresponding layer *in* the paved shoulder portion shall be followed by compaction of the earth shoulder layer. The adjacent layers having same material shall be laid and compacted together. • Compaction requirement of earthen shoulder shall be as per table 300-2. In case of bituminous courses, work on shoulders shall be (earthen/hard/paved) and shall start only after the pavement course has been laid and compacted. • During all stages of shoulder earthen/hard/paved) construction, the required cross fall 3% shall be maintained to drain off surface water. Regardless of the method of laying, all shoulder construction material shall be placed directly on the shoulder. Any spilled material dragged on to the pavement surface shall be immediately removed, without damage to the pavement and the area so affected thoroughly
III. granular sub base and WMM	a)Variation in the gradation of the granular sub base, WMM materials at site	a) Frequent checks shall be made at the plant site, and the screening plant checked for efficiency. Segregation of the aggregates during stock pilling

	from the approved job mix formula	shall be avoided. Representative sampling of material at site shall be done to ensure consistency with the physical properties and strength requirements.
	b) 1) Occurrence of coarse aggregate on outer limits of placement areas.	b) 1) Coarse aggregate shall not be separated by the motor grader and if occurs the redistribution and blending of coarse aggregates with fines shall be made.
	2) Surface material broken down resulting in excessive fines in the underlying layers	2) The previously laid layers shall be checked for breakdown of surface materials into excess fines. The removal of excess fines by slightly blading with grader prior to placement of additional layer shall be made and surface compacted properly
	3) The disturbance of the finished layer of WMM resulting in segregation and rectification of disturbed portion with quarry fines before taking up next layer.	3) After completion the surface of any finished layer shall be well closed from the movement under compaction equipment or any compaction planes, ridges cracks and loose material. All loose segregated or otherwise defective areas shall be made good to the full thickness of the layer and recompacted.
	4) excessive surface irregularity of the finished WMW course	4) As per clause 400-6 of MORTH where the surface irregularity of WMW is excessive above permissible tolerance or where the courses otherwise defective due to subgrade soil getting mixed with the aggregates, the full thickness of the layer shall be scarified over the affected area reshaped with added premixed material or removed & replaced with fresh premix material as applicable & recompacted. The area treated in the aforesaid manner shall not be less than 5m long and 2m wide. In no case shall depression be filled up with unmixed & ungraded material or fines.
IV)Prime coat &tack coast	a) The surface to be primed is not properly cleaned free from ruts & depressions.	The surface to be primed shall be free from moisture. The surface shall be swept clean and free from dust, ruts and depressions. Proper sweeping with the brushes shall be done to ensure dust free surface.

	from the approved job mix formula	shall be avoided. Representative sampling of material at site shall be done to ensure consistency with the physical properties and strength requirements.
	b) 1) Occurrence of coarse aggregate on outer limits of placement areas.	b) 1) Coarse aggregate shall not be separated by the motor grader and if occurs the redistribution and blending of coarse aggregates with fines shall be made.
	2) Surface material broken down resulting in excessive fines in the underlying layers	2) The previously laid layers shall be checked for breakdown of surface materials into excess fines. The removal of excess fines by slightly blading with grader prior to placement of additional layer shall be made and surface compacted properly
	3) The disturbance of the finished layer of WMM resulting in segregation and rectification of disturbed portion with quarry fines before taking up next layer.	3) After completion the surface of any finished layer shall be well closed from the movement under compaction equipment or any compaction planes, ridges cracks and loose material. All loose segregated or otherwise defective areas shall be made good to the full thickness of the layer and recompacted.
	4) excessive surface irregularity of the finished WMW course	4) As per clause 400-6 of MORTH where the surface irregularity of WMW is excessive above permissible tolerance or where the courses otherwise defective due to subgrade soil getting mixed with the aggregates, the full thickness of the layer shall be scarified over the affected area reshaped with added premixed material or removed & replaced with fresh premix material as applicable & recompacted. The area treated in the aforesaid manner shall not be less than 5m long and 2m wide. In no case shall depression be filled up with unmixed & ungraded material or fines.
IV) Prime coat Mack coast	a) The surface to be primed is not properly cleaned free from ruts & depressions.	The surface to be primed shall be free from moisture. The surface shall be swept clean and free from dust, ruts and depressions. Proper sweeping with the brushes shall be done to ensure dust free surface.

	b) Prime/ tack coat not uniform	The bituminous primer shall be as per approved specifications. The nozzles of the bituminous spray bar shall be clean to release the primer at the specified pressure and flow. The rate of spraying and temperature shall be periodically checked.
V) Bituminous mixes . .	Surface not having uniform finish, open textures top surface observed after rolling. Hairline cracks observed during rolling. Ridges and bulging of BM surface at edges	Check the suitability of base course to receive the bituminous macadam. It should be dry and clean. The tack coat shall be applied properly before placing BM mix. The aggregate gradation shall be checked for compliance with specifications. Segregation of aggregate results in rough and open texture finish and shall be avoided. Confirm that the asphalt mix is not segregating when discharged into pavers, ensure that the paver is duly operating and after laying of the material designed bitumen content shall be ensured by bitumen extraction test. Proper temperature at the time of spraying and rolling shall be ensured for durable and uniform finish. The speed of the compacting roller shall be within 5 kmph. The shoulders shall be constructed in each layer matching the thickness of the pavement layer. Only after the earth shoulder portion has been laid and compacted upto WMM level the BM shall be placed. Otherwise, the BM edges may not get uniform compaction while rolling. The transverse and longitudinal joints in BM layer shall be properly merged by cutting the already laid layer with required slope and after shall be properly merged by cutting the already laid layer with required slope and afte removing the loose material in the mix. Care shall be taken while rolling to ensure smooth finish at the joints with proper merging of freshly laid mix.

13.2. Some additional steps suggested for information

Bus bays have to be, planned and constructed wherever space could be earmarked. This is in additional to improvements required in all bus stops and junctions of roads, (ref: IRC) This could be combined with the possible revenue generation by providing for advertisements and thus, the scheme could be made self financing.

There could be a number of foot over bridges with/without escalators, precast unit subways at important road junctions where pedestrians find it difficult to cross the roads. Even here, advertisement space could yield revenue. But care has to be taken to see that advertisements do not divert the attention of drivers.

This scheme could also be considered under pubic-private participation scheme. Electronic display boards could also be installed.

Multistoried parking facilities have to be planned at locations where it is difficult to find sufficient place to cater to the needs of vehicles especially at the central areas of the city. Similarly, truck terminals and bus terminals could be planned at the outskirts of the city with feeder bus service stations needed.

In addition to the above, certain traffic regulation schemes can also be considered. Road markings, signals, reflectors and overhead gantry displays, are some steps that could be considered. Exclusive dedicated bus lanes elevated or at grade, introduction of high capacity bus rapid transport system, camera installation, synchronized traffic signals, way side amenities at bus stops, intermodal transfer through electronic ticketing kiosks, toll plazas through private participation, parks and green zones, cycle trucks and other slow moving vehicle segregation, no vehicle zones and street contra flow of traffic during morning and evening peak hours etc, are some other areas which require consideration.

CHAPTER 14

TASK

The erstwhile BMP of 225 sqkm area (with 3500 km of roads) has increased to 800 sqkm (with another 6000 km of roads) which comprises of revenue layout, villages & a few unapproved layouts with lack of water supply / Under Ground Drainage, unpaved narrow roads, lack'of road side drainage, street lights. These are apart from well laid BDA layouts.

The task of upgrading the newly added areas is a challenging job & Engineers of BBMP are to put forth best efforts and augment their knowledge in achieving the target.

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Zone wise Road Details

v Length of Road in each category in kms

SI. No	Zone	Arterial Roads	Sub Arterial Roads	Asphalt Road	Metal Roads	Gravel Roads	Cement Concrete Roads	Total
1	East	100.00	62.00	1314.00	111.00	72.00	132.00	1791.00
2	West	68.00	42.00	881.00	24.00	0.00	168.00	1183.00
3	South	88.00	60.00	1423.00	121.00	58.00	131.00	1881.00
4	Dasarahalli	53.00	34.00	130.00	148.00	160.00	2.00	527.00
5	Byatryanapura	38.00	18.00	438.00	90.00	475.00	18.00	1077.00
6	Rajarajeshwari nagara	13.00	23.00	137.00	156.00	440.00	2.00	771.00
7	Mahadevapura	37.00	45.00	481.00	99.00	850.00	12.00	1524.00
8	Bommanahalli	40.00	44.00	525.00	108.00	925.00	10.00	1652.00
	Total	**437.00**	**328.00**	**5329.00**	**857.00**	**2980.00**	**475.00**	**10406.00**

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APPENDICES

APPENDIX - 1

OUTPUT OF MACHINES

Sr. No	Description of		Output of Machine	
	Machine	**Activity**	**Unit**	**Output**
1.	Dozer D-50-A 15	Spreading Cutting Clearing	cum/hour cum/hour cum/hour	200 100 150
2.	Dozer D-80-A 12	Spreading Cutting Clearing	cum/hour cum/hour cum/hour	300 150 250
3.	Motor Grader 3.35metre blade	Clearing Spreading GSB WMM	cum/hour cum/hour cum /hour cum/hour	200 200 50 50
4.	Hydraulic Excavator of 1 cum bucket	Soil Ordinary Soil Marshy Soil Unsuitable	cum/hour cum/hour cum/hour	60 60 60
5.	Front end loader 1 cum bucket capacity	Soil loading Aggregate loading	cum/hour cum/ hour	60 25
6.	Tipper-5 cum	Transportation of soil, GSB, WMM, Hotmix etc.	Capacity in cum	5.5
7.	Vibratory Roller 8 tonne	Earth/ Soil GSB WMM	cum/hour cum/hour cum/hour	100 60 60
8.	Smooth Wheeled Roller 8 tonne	Soil Compaction BM Compaction	cum/hour cum/hour	70 25
9.	Water Tanker	Water Transport	Capacity in KL	6
10.	Tractor	Pulling	Capacity in HP	50
11.	Rotavator	Scarifying	cum/hour	25
12.	Ripper	Scarifying	cum/hour	60
13.	Air Compressor	General Purpose	Capacity in cfm	170/ 250
14.	Wet Mix Plant 60 TPH	Wet Mix	cum/hour	25
15.	Mechanical Broom Hydraulic	Surface Cleaning	sqm/hour	1250

Sr. No	Description of		Output of Machine	
	Machine	Activity	Unit	Output
16.	Bitumen Pressure Distributor	Applying bitumen tack coat	sqm/hour	1750
17.	Emulsion Pressure Distributor	Applying bitumen tack coat	sqm/hour	1750
18.	Hotmix Plant - 120 TPH capacity	DBM / BM / SDC / Premix	cum/hour	40
19.	Hotmix Plant - 100 TPH capacity	DBM / B M / SDC / Premix	cum/hour	30
20.	Hotmix Plant - 60 to 90 TPH capacity	DBM / BM / SDC / Premix	cum/hour	25
21.	Hotmix Plant - 40 *to* 60 TPH capacity	DBM / BM / SDC / Premix	cum/hour	17
22.	Paver Finisher Hydrostatic with sensor control 100 TPH	Paving of DBM / BM/SDC/Premix	cum/hour	40
23.	Paver Finisher Mechanical 100 TPH	Paving of WMM Paving of DLC	cum/hour cum/hour	40 30
24.	Hydraulic chip Spreader	Surface Dressing	sqm/hour	1500
25.	Tandem Road Roller	Rolling of Asphalt Surface	cum/hour	30
26.	Pneumatic Road Roller	Rolling of Asphalt Surface	cum/hour	25
27.	Pot-Hole Repair Machine	Repair of patholes	cum/hour	4
28.	Bitumen Boiler Oil Fired	Bitumen Spraying	capacity in litre	1500
29.	GSB Plant 50 cum	Producing GSB	cum/ hour	40
30.	Mastic Cooker	Mastic Wearing Coat	capacity in tonne	1
31.	Batching and Mixing Plant a) 30 cum capacity b) 15-20 cum capacity	Concrete Mixing Concrete Mixing	cum /hour cum/hour	20 13
32.	Transit Mixer	Transportation of Concrete Mix to Site	cum/hour cum/hour Tonne/ km Tonne / km	4.5 3 4.5 3

Sr. No	Description of		Output of Machine	
	Machine	**Activity**	**Unit**	**Output**
33.	Concrete Pump of 45 & 30. cum capacity	Pumping of Concrete	cum/hour cum/hour	33 22
34.	Concrete Bucket	For Pouring Concrete	capacity in cum	1
35.	Kerb Casting Machine	Kerb Making	Rmtr /hour	80
36.	Concrete Mixer a) 0.4/0.28 cum b) 01 cum	Concrete Mixing Concrete Mixing	cum /hour cum /hour	2.5 7.5
37.	Piling Rig with Bantonite Pump	0.75m dia to 1.2m dia Boring Attachment	Rmtr /hour	2 to 3
38.	Concrete Paver Finisher with 40 HP Motor	Paving of Concrete Surface	cum-/ hour	20
39.	Generator a) 100 KVA b) 33 KVA	Generation of Electric Energy	KVA KVA	100 50
40.	Pneumatic Sinking Plant	Pneumatic Sinking of Wells	cum/hour	1.5 to 2.00
41.	Truck 5.5 cum per 10 tonnes	Material Transport	capacity/cum	4.5
42.	Road Marking Machine	Road Marking	Sqm/ hour	100
43.	Mobile Slurry Seal Equipment	Mixing and laying slurry seal	Sqm/ hour	2700

Source: National Highways S.R, Bangalore Circle

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APPENDIX - 2 LIST OF IRC

PUBLICATIONS FOR ROAD AND BRIDGE WORKS

S.No	Code/ Document No	Title of the Publication
I. IRC SPECIFICATIONS, STANDARDS, DESIGN CODES		
- 1	IRC:2-1968	Route Marker Sign for National Highways (First Revision)
2	IRC:3-1983	Dimensions & Weights of Road Design Vehicles (First Revision)
3	IRC:5-1998	Standard Specifications and Code of Practice for Road Bridges, Section I - General Features of Design (Seventh Revision)
4	IRC-.6-2000	Standard Specifications and Code of Practice for Road Bridges, Section II - Loads and Stresses (Fourth Revision)
5	IRC:7-1971	Recommended Practice for Numbering Bridges and Culverts (Fourth Revision)
6	IRC:8-1980	Type Designs for Highway Kilometre Stones (Second Revision)
7	IRC:9-1972	Traffic Census on Non-Urban Roads (First Revision)
8	IRC:10-1961	Recommended Practice for Borrowpits for Road Embankments Constructed by Manual Operation
9	IRC: 11-1962	Recommended Practice for the Design and Layout of Cycle Tracks
10	IRC: 12-1983	Recommended Practice for Location and Layout of Roadside Motor-Fuel Filling and Motor-Fuel Filling-cum-Service Station (Second Revision)
11	IRC: 14-2004	Recommended Practice for Open Graded Premix Carpets (Third Revision)
12	IRC: 15-2002	Standard Specifications and Code of Practice for Construction of Concrete Roads (Third Revision)
13	IRC: 16-2008	Standard Specifications and Code of Practice for Prime and Track Coat (Second Revision)
14	IRC:17-1965	Tentative Specification for Single Coat Bituminous Surface Dressing
15	IRC: 18-2000	Design Criteria for Prestressed Concrete Road Bridges (Post-Tensioned Concrete) (Third Revision)

16	IRC: 19-2005	Standard Specification and Code of Practice for Water Bound Macadam (Third Revision)
17	IRC:20-1966	Recommended Practice for Bituminous Penetration Macadam (Full Grout)
18	IRC:21-2000	Standard Specifications and Code of Practice for Road Bridges, Section III- Cement Concrete (Plain and Reinforced) (Third Revision)
19	IRC-.22-2008	Standard Specifications and Code of Practice for Road Bridges, Section VI- Composite Construction (Limit States Design) (Second Revision)
20	IRC:23-1966	Tentative Specification for Two Coat Bituminous Surface Dressing
21	IRC:24-2001	Standard Specifications and Code of Practice for Road Bridges, Section V - Steel Road Bridges (Second Revision)
22	IRC:25-1967	Type Designs for Boundary Stones
23	IRC-.26-1967	Type Design for 200-Metre Stones
24	IRC-.27-1967	Tentative Specification for Bituminous Macadam (Base & Binder Course)
25	IRC:28-1967	Tentative Specification for the Construction of Stabilised Soil Roads with Soft Aggregate in Areas of Moderate and High Rainfall
26	IRG:29-1988	Specification for Bituminous Concrete (Asphaltic Concrete) for Road pavement (First Revision)
27	IRC:30-1968	Standard Letters and Numerals of Different Heights for Use on Highway Signs
28	IRC:31-1969	Route Marker Signs for State Routes
29	IRC:32-1969	Standard for Vertical and Horizontal Clearances of Overhead Electric Power and Telecommunication Lines as Related to Roads
30	IRC:33-1969	Standard Procedure of Evaluation and Condition Surveys of Stabilised Soil Roads
31	IRC:34-1970	Recommendations for Road Construction in Waterlogged Areas
32	IRC:35-1997	Code of Practice for Road Markings (First Revision)
33	IRC:36-1970	Recommended Practice for Construction of Earth Embankments for Road Works
34	IRC:37-2001	Guidelines for the Design of Flexible Pavements (Second Revision)
35	IRC:38-1988	Guidelines for Design of Horizontal Curves for Highways and Design Tables (First Revision)

'36	IRC:39-1986	Standards for Road-Rail Level Crossings (First Revision)
37	IRC:40-2002	Standard Specifications and Code of Practice for Road Bridges, Section IV - Brick, Stone and Block Masonry (Second Revision)
38	IRC:41-1997	Guideline for Type Designs for Check Barriers (First Revision)
39	IRC:42-1972	Proforma for Record of Test Values of Locally Available Pavement Construction Materials
40	IRC:43-1972	Recommended Practice for Tools, Equipment and Appliances for Concrete Pavement Construction
41	IRC:44-2008	Guidelines for Cement Concrete Mix Design for Pavements (Second Revision)
42	IRC:45-1972	Recommendations for Estimating the Resistance of Soil Below the Maximum Scour Level in the Design of Well Foundations of Bridges
43	IRC:46-1972	A Policy on Roadside Advertisement (First Revision)
44	IRC:47-1972	Tentative Specification for Built-up Spray Grout
45	IRC:48-1972	Tentative Specification for Bituminous Surface Dressing Using Precoated Aggregates
46	IRC:49-1973	Recommended Practice for the Pulverization of Black Cotton Soils for Lime Stabilisation
47	IRC: 50-1973	Recommended Design Criteria for the Use of Cement Modified Soil in Road Construction
48	IRC:51-1992	Guidelines for the Use of Soil Lime Mixes in Road Construction (First Revision)
49	IRC:52-200L	Recommendations About the Alignment Survey and Geometric Design Hill of Roads (Second Revision)
50	IRC:53-1982	Road Accident Forms A-1 and 4 (First Revision)
51	IRC:54-1974	Lateral and Vertical Clearances at Underpasses for Vehicular Traffic
52	IRC-55-1974	Recommended Practice for Sand-Bitumen Base Courses
53	IRC:56-1974	Recommended Practice for Treatment of Embankment Slopes for Erosion Control
54	IRC:57-2006	Recommended Practice for Sealing of Joints in Concrete Pavements (First Revision)
55	IRC-58-2002	Guidelines for the Design of Plain Jointed Rigid Pavements for Highways (Second Revision) (With CD)

56	IRC:59-1976	Tentative Guidelines for the Design of Gap Graded Cement Concrete Mixes for Road Pavements
57	IRC:60-1976	Tentative Guidelines for the Use of Lime-Fly Ash Concrete as Pavement Base or Sub-Base
58	IRC:61-1976	Tentative Guidelines for the Construction of Cement Concrete Pavements in Hot Weather
59	IRC:62-1976	Guidelines for Control of Access of Highways
60	IRC.63-1976	Tentative Guidelines for the Use of Low Grade Aggregates and Soil Aggregates Mixtures in Road Pavement Construction
61	IRC: 64-1990	Guidelines for Capacity of Roads in Rural Areas (First Revision)
62	IRC-65-1976	Recommended Practice for Traffic Rotaries
63	IRC:66-1976	Recommended Practice for Sight Distance on Rural Highways
64	IRC:67-2001	Code of Practice for Road Signs (First Revision)
65	IRC:68-1976	Tentative Guidelines of Cement-Fly Ash Concrete for Rigid Pavement Construction
66	IRC:69-1977	Space Standards for Roads in Urban Areas
67	IRC:70-1977	Guidelines on Regulation and Control of Mixed Traffic in Urban Area
68	IRC-.71-1977	Recommended Practice for Preparation of Notations
69	IRC:72-1978	Recommended Practice for Use and Upkeep of Equipment, Tools and Appliances for Bituminous Pavement Construction
70	IRC:73-1980	Geometric Design Standards for Rural (Non-Urban) Highways
71	IRC:74-1979	Tentative Guidelines for Lean-Cement Concrete and Lean-Cement Fly Ash Concrete as a Pavement Base of Sub-Base
72	IRC:75-1979	Guidelines for the Design of High Embankments
73	IRC:76-1979	Tentative Guidelines for Structural Strength Evaluation of Rigid Airfield Pavements
74	IRC-.77-1979	Tentative Guidelines for Repair of Concrete Pavements Using Synthetic Resins
75	IRC:78-2000	Standard Specifications and Code of Practice for Road Bridges, Section VII-Foundations and Substructure (Second Revision
76	IRC:79-1981	Recommended Practice for Road Delineators

77	IRC:80-1981	Type Designs for Pick-up Bus Stops on Rural (i.e., Non-Urban) Highways
78	IRC:81-1997	Guidelines for Strengthening of Flexible Road Pavements Using Benkelman Beam Deflection Technique (First Revision)
79	IRC:82-1982	Code of Practice for Maintenance of Bituminous Surfaces of Highways
80	IRC-.83-1999 (Part-I)	Standard Specifications and Code of Practice for Road Bridges, Section IX - Bearings, Part I: Metallic Bearings (First Revision)
81	IRC:83-1987 (Part-II)	Standard Specifications and Code of Practice for Road Bridges, Section IX - Bearings, Part II : Elastomeric Bearings
82	IRC.-83-2002 (Part-Ill)	Standard Specifications and Code of Practice for Road Bridges, Section IX - Bearings, Part III : POT, POT-CUM-PTFE, PIN and Metallic Guide Bearings
83	IRC:84-1983	Code of Practice for Curing of Cement Concrete Pavements
84	IRC:85-1983	Recommended Practice for Accelerated Strength Testing 8s Evaluation of Concrete for Road and Airfield Constructions
85	IRC:86-1983	Geometric Design Standards for Urban Roads in Plains
86	IRC:87-1984	Guidelines for the Design and Erection of Falsework for Road Bridges
87	IRC:88-1984	Recommended Practice for Lime Flyash Stabilised Soil Base/Sub-Base in Pavement Construction
88	IRC:89-1997	Guidelines for the Design and Construction of River Training & Control Works for Road Bridges (First Revision)
89	IRC-.90-1985	Guidelines of Selection, Operation and Maintenance of Bituminous Hot Mix Plant
90	IRC:91-1985	Tentative Guidelines for Construction of Cement Concrete Pavements in Cold Weather
91	IRC:92-1985	Guidelines for the Design of Interchanges in Urban Areas
92	IRC:93-1985	Guidelines on Design and Installation of Road Traffic Signals
93	IRC:94-1986	Specification for Dense Bituminous Macadam
94	IRC:95-1987	Specification for Semi-Dense Bituminous Concrete
95	IRC:96-1987	Tentative Specification for Two-Coat Surface Dressing Using Cationic Bitumen Emulsion

96	IRC:97-1987	Tentative Specification for Two-Coat Surface Dressing Using Cationic Bitumen Emulsion
97	IRC:98-1997	Guidelines on Accommodation of Utility Services on Roads in Urban Areas (First Revision)
98	IRC:99-1988	Tentative Guidelines on the Provision of Speed Breakers for Control of Vehicular Speeds on Minor Roads
99	IRC: 100-1988	Tentative Specification for Single Coat Surface Dressing Using Cationic Bitumen Emulsion
100	IRC: 101-1988	Guidelines for Design of Continuously Reinforced Concrete Pavement with Elastic Joints
101	IRC: 102-1988	Traffic Studies for Planning Bypasses Around Towns
102	IRC: 103-1988	Guidelines for Pedestrian Facilities
103	IRC: 104-1988	Guidelines for Environmental Impact Assessment of Highway Projects
104	IRC: 105-1988	Tentative Specification for Bituminous Concrete (Asphaltic Concrete) for Airfield Pavements
105	IRC: 106-1990	Guidelines for Capacity of Urban Roads in Plain Areas
106	IRC: 107-1992	Tentative Specifications for Bitumen Mastic Wearing Courses
107	IRC: 108-1996	Guidelines for Traffic Prediction on Rural Highways
108	IRC: 109-1997	Guidelines for Wet Mix Macadam
109	IRC: 110-2005	Standard Specifications and Code of Practice for Design and Construction of Surface Dressing
II. IRC SPECIAL PUBLICATIONS		
110	IRC:SP:4-1966	Bridges Loading Round the World
111	IRC:SP: 11-1984	Handbook of Quality Control for Construction of Roads and Runways (Second Revision)
112	IRC:SP: 12-1973	Tentative Recommendations on the Provision of Parking Spaces for Urban Areas
113	IRC.-SP: 13-2004	Guidelines for the Design of Small Bridges and Culverts (First Revision)
114	IRC:SP:14-1973	A Manual for the Applications of the Critical Path Method to Highway Projects in India
115	IRC:SP:15-1996	Ribbon Development Along Highways and Its Prevention
116	IRC:SP: 16-2004	Guidelines for Surface Evenness of Highway Pavements (First Revision)
117	IRC:SP: 17-1977	Recommendations About Overlays on Cement Concrete Pavements

118	IRC:SP:18-1978	Manual for Highways Bridge Maintenance Inspection
119	IRC:SP: 19-2001	Manual for Survey, Investigation and Preparation of Road Projects (Second Revision)
120	IRC:SP:20-2002	Rural Roads Manual
121	IRC:SP:22-1980	Recommendation for the Sizes for each Type of Road Making Machinery to Cater to the General Demand of Road Works
122	IRC:SP:23-1983	Vertical Curves for Highways
123	IRC:SP:24-1984	Guidelines on the Choice and Planning of Appropriate Technology in Road Construction
124	IRC:SP:25-1984	Gopi and his Road Roller-Guidelines on Maintenance of Road Rollers
125	IRC:SP:26-1984	Report Containing Recommendations of IRC Regional Workshops on Rural Road Development (with Supplementary Notes)
126	IRC:SP:27-1984	Report Containing Recommendations of IRC Regional Workshops on Highway Safety
127	IRC:SP:28-1995	Road Transport and Energy (First Revision)
128	IRC:SP:29-1994	Directory of Indgenous Manufacturers of Road/ Bridge Construction Machinery & Important Bridge Components (First Revision)
129	IRC:SP:30-1993	Manual on Economic Evaluation of Highway Projects in India (First Revision)
130	IRC:SP:31-1992	New Traffic Signs
131	IRC:SP:32-1988	Road Safety for Children (5-12 Years old)
132	IRC:SP:33-1989	Guidelines on Supplemental Measures for Design, Detailing 8& Durability of Important Bridge Structures
133	IRC:SP:34-1989	General Guidelines About the Equipment for Bituminous Surface Dressing
134	IRC:SP:35-1990	Guidelines for Inspection and Maintenance of Bridges
135	IRC:SP:36-1991	Guidelines on Format for IRC Standards
136	IRC:SP:37-1991	Guidelines for Evaluation of Load Carrying Capacity of Bridges
137	IRC:SP:38-1992	Manual for Road Investment Decision Model (with CD)
138	IRC:SP:39-1992	Guidelines on Bulk Bitumen Transportation 8s Storage Equipment
139	IRC:SP:40-1993	Guidelines on Techniques for Strengthening and Rehabilitation of Bridges
140	IRC:SP:41-1994	Guidelines on Design of At-Grade Intersections in Rural 85 Urban Areas

141	IRC:SP:42-1994	Guidelines on Road Drainage
142	IRC:SP:43-1994	Guidelines on Low-Cost Traffic Management Technique for Urban Areas
143	IRC:SP:44-1996	Highways Safety Code
144	IRC:SP:45-1996	Time Series Data on Road Transport Passenger and Freight Movement (1951-1991)
145	IRC:SP:46-1997	Steel Fibre Reinforced Concrete for Pavements
146	IRC:SP:47-1998	Guidelines on Quality Systems for Road Bridges (Plain, Reinforced, Prestressed and Composite Concrete)
147	IRC:SP:48-1998	Hill Road Manual
148	IRC:SP:49-1998	Guidelines for the Use of Dry Lean *Concrete* as Sub-base for Rigid Pavement
149	IRC:SP:50-1999	Guidelines for Urban Drainage
150	IRC:SP:51-1999	Guidelines for Load Testing of Bridges
151	IRC:SP:52-1999	Bridge Inspector's Reference Manual
152	IRC:SP: 53-2002	Guidelines on Use of Polymer and Rubber Modified Bitumen in Road Construction (First Revision)
153	IRC:SP:54-2000	Project Preparation Manual of Bridges
154	IRC:SP:55-2001	Guidelines for Safety in Construction Zones
155	IRC:SP:56-2000	Guidelines for Steel Pedestrian Bridges
156	IRC:SP:57-2000	Guidelines for Quality Systems for Road Construction
157	IRC:SP:58-2001	Guidelines for Use Flyash in Road Embankments
158	IRC:SP:59-2002	Guidelines for Use of Geotextiles in Road Pavements and Associated Works
159	IRC:SP:60-2002	An Approach Document for Assessment of Remaining Life of Concrete Bridges
160	IRC:SP:61-2004	An Approach Document on Whole. Life Costing for Bridges in India
161	IRC:SP:62-2004	Guidelines for the Design and Construction of Cement Concrete Pavement for Rural Roads
162	IRC:SP:63-2004	Guidelines for the Use of Interlocking Concrete Block Pavement
163	IRC:SP:64-2005	Guidelines for the Analysis and Design of Cast-in-Place Voided Slab Superstructure
164	IRC:SP:65-2005	Guidelines for Design and Construction of Segmental Bridges
165	IRC:SP:66-2005	Guidelines for Design of Continuous Bridges

166	IRC:SP:67-2005	Guidelines for Use of External and Unbonded Prestressing Tendons in Bridge Structures
167	IRC:SP:68-2005	Guidelines for Construction of Roller Compacted Concrete Pavements
168	IRC:SP:69-2005	Guidelines & Specifications for Expansion Joints
169	IRC:SP:70-2005	Guidelines for the Use of High Performance Concrete in Bridges
170	IRC:SP:71-2006	Guidelines for Design and Construction of Pretensioned Girder of Bridges
171	IRC: SP: 72-2007	Guidelines for Design of Flexible Pavements for Low Volume Rural Roads
172	IRC:SP:73-2007	Manual of Standards & Specifications for Two Laning of State Highways on B.O.T. Basis
173	IRC:SP:74-2007	Guidelines for Repair and Rehabilitation of Steel Bridges
174	IRC:SP:75-2008	Guidelines for Retrofitting of Steel Bridges by Prestressing
175	IRC:SP:76-2008	Tentative Guidelines for Conventional, Thin and Ultra-Thin Whitetopping
176	IRC:SP:77-2008	Manual for Design Construction & Maintenance of Gravel Roads
177	IRC:SP:78-2008	Specifications for Mix Seal Surfacing (MSS) Close-Graded Premix Surfacing (CGPS)
178	IRC:SP:79-2008	Tentative Specifications for Stone Matrix Asphalt
179	IRC:SP:80-2008	Guidelines for Corrosion Prevention, Monitoring and Remedial Measures for Concrete Bridges Structures
180	IRC:SP:81-2008	Tentative Specifications for Slurry Seal and Microsurfacing
181	IRC:SP:82-2008	Guidelines for Design of Causeways and Submersible bridge
182	IRC:SP:83-2008	Guidelines for Maintenance, Repairs & Rehabilitation of Cement Concrete Pavements
III. MINISTRY OF SURFACE TRANSPORT PUBLICATIONS (Now Ministry of Shipping, Road Transport & Highways)		
183	MORT&H	Manual for Maintenance of Roads, 1983
184	MORT&H	Pocketbook for Bridge Engineers, 2000 (First Revision)
185	MORT&H	Pocketbook for Highways Engineers, 2002 (Second Revision)
186	MORT&H	Handbook on Road Construction Machinery, 1985

202	MORT&H	Addendum-5 to Technical Circulars & Directives on National Highways and Centrally Sponsored Road & Bridge Works Projects (Jan. 1995 to Dec. 1997)
203	MORT&H	Addendum-6 to Technical Circulars & Directives on National Highways and Centrally Sponsored Road & Bridge Works Projects (Jan. 2002 to Dec. 2004)
204	MORT&H	Model Concession Agreement for Small Road Projects
205	MORT&H	Report of the Committee on Norms for Maintenance of Roads in India,2001
206	MORT&H	Road Development Plan : Vision - 2021
207	MORT&H	Manual for Construction and Supervision of Bituminous Works, 2001
208	MORT&H	Guidelines for Maintenance Management of Primary, Secondary and Urban Roads
209	MORT&H	Manual of Specification and Standards for 4-Laning of National Highways through Public Private Partnership
210	MORT&H	Manual of Specification and Standards for Six Laning of National Highways through Public Private Partnership
IV. NATIONAL HIGHWAYS AUTHORITY OF INDIA (NHAI)		
211	NHAI	Works Manual
212	NHAI	Quality Assurance Manual
V. MINISTRY OF RURAL DEVELOPMENT (National Rural Roads Development Agency)		
213	MORD	Specifications for Rural Roads
214	MORD	Standard Data Book for Analysis of Rates for Rural Roads
VI. IRC SEMINAR PUBLICATIONS		
215	Seminar, 1986 (Preliminary Publication)	International Seminar on "Road Safety", Srinagar, September 17-18, 1986
216	Seminar, 1990 (Proceedings)	Seminar on "Modernisation of Holidays", New Delhi, 17-19 May, 1990
217	Seminar, 1991 (Proceedings)	International Seminar on "Expressways/High Speed Facilities in Developing Countries", Bangalore, 13-16, June,1991
218	Seminar, 1993 (Proceedings)	Seminar on "Modernisation of Highway Contraction Industry and Works Management", New Delhi, Sept. 20-21, 1993

-219	Seminar, 1995 (Proceedings)	Seminar on "Design, Construction and Maintenance of Hill Roads", Shimla, June 19-20, 1995
220	- Seminar, 1995 (Proceedings)	Seminar on "Private Sector Participation in Highway Development", New Delhi, Sept. 28-29. 1995
221	Seminar, 1996 (Proceedings)	Seminar on "Perspective Planning for Road Development in India", Oct.7-8, 1996
222	Seminar, 1999 (Proceedings)	International Seminar on "Highway Rehabilitation and Maintenance", New Delhi, Nov. 12-13, 1999
223	Seminar, 2000 (Proceedings)	Seminar on "Financing Implementation and Operation on Highways in 21st Century", New Delhi, Sept. 24-25, 2000
224	Seminar, 2001 (Technical Papers) (Vol.1)	International Seminar on "Sustainable Development in Road Transport", New Delhi, Nov. 8-10, 2001,Vol.1
225	Seminar, 2001 (Technical Papers) (Vol.11)	International Seminar on "Sustainable Development in Road Transport", New Delhi, Nov. 8-10, 2001,Vol.11
226	Seminar, 2001 (Proceedings)	International Seminar on "Sustainable Development in Road Transport", New Delhi, Nov. 8-10, 2001
227	Seminar, 2002 (Technical Papers)	Seminar on "Financial Management and Institutional Reforms in Highway Sector", Delhi, Nov. 18-19, 2002 •
228	Seminar, 2002 (Proceedings)	Seminar on "Financial Management and Institutional Reforms in Highway Sector", Nov. 18-19,2002
229	Seminar, 2003 (Technical Papers) (Vol.1)	Seminar on "Integrated Development of Rural and Arterial Road Network for Socio-Economic Growth", New Delhi, Dec. 5-6, 2003 Vol.-I
230	Seminar, 2003 (Technical Papers) (Vol.11)	Seminar on "Integrated Development of Rural and Arterial Road Network for Socio-Economic Growth", New Delhi, Dec. 5-6, 2003 Vol.-II
231	Seminar, 2003 (Proceedings)	Seminar on "Integrated Development of Rural and Arterial Road Network for Socio-Economic Growth", New Delhi, Dec. 5-6, 2003
232	Seminar, 2004 (Proceedings)	Seminar on "Design Construction and Maintenance of Cement Concrete Pavements", New Delhi, Oct. 8-10, 2004
233	Seminar, 2005 (Technical Papers)	Seminar on "High Speed Corridors", New Delhi Nov. 23-24, 2005
234	Seminar, 2005 (Proceedings)	Seminar on "High Speed Corridors", New Delhi Sept. 23-24, 2005
235	Seminar, 2006 (Technical Papers)	International Seminar on "Innovations in Construction and Maintenance of Flexible Pavement", Agra, Sept. 2-4, 2006, Vol.-I & Vol.-II

VII. HIGHWAYS RESEARCH BOARD PUBLICATIONS		
236	HRBSR. No.l, 2000	State of Art: Lime-Soil Stabilization
237	HRB SR. No.3, 1999	State of Art: Compaction of Earthwork and Subgrades
238	HRB SR. No. 10, 1989	State of Art: Behaviour of Concrete Under Sea-Water and in Marine Environment
239	HRBSR. No. 11, 1992	State of Art: Granular and Bound Bases and Sub-Bases
240	HRBSR. No. 12, 1994	State of Art: Application of Geotextiles in Highway Engineering
241	HRBSR. No. 13, 1994	State of Art: High Embankments on Soft Ground, Part A - Stage Construction
242	HRBSR. No. 14, 1994	State of Art: High Embankments on Soft Ground, Part B - Ground Improvement
243	HRBSR. No. 15, 1995	State of Art: Landslide Correction Techniques
244	HRB SR. No. 16, 1996	State of Art: Reinforced Soil Structures Applicable to Road Design & Construction
245	HRBSR. No. 17, 1996	State of Art: Non Destructive Testing Techniques of Concrete Bridges
246	HRBSR. No. 18, 1996	State of Art: Corrosion and Corrosion Protection of Prestressed Concrete Bridges in Marine Environment
247	HRBSR. No. 19, 2001	State of Art: Underwater Scanning and Repairing of Bridge Components
248	HRB SR. No.20, 2004	State of Art: Development of Bridge Bearings
VIII. OTHER PUBLICATIONS		
249	Paper Nos. 109 & 112, 1946	Standard Specifications & Code of Practice for Road Bridges, Sections I & II (with Explanatory Notes & Discussions)
250	Paper Nos.238, 1996	Considerations in the Design and Sinking of Well Foundations for Bridge Piers (B. Balwant Rao & C. Muthuswamy)
251	Paper Nos.257, 1967	Construction of a Ghat Road from Bodinayakanur to Bodimettu by E.C. Chandrasekharan
252	Paper Nos.278, 1969	The Use of Restrained-Neoprene bearings in Civil Engineering by J.W. Slottje & P.S. Gokhale
253	Paper Nos.317, 1997	Experience in the Improvement and Modernization of Raods in Tamil Nadu by E.C. Chandrasekharan
254	Paper on	Some Important papers on Design, Construction and Maintenance of Hill Roads, 1985
255	Paper for	Panel Discussion on Consultancy in the Highway Sector, 1993

256	Panel Discussion, 1994	Paper for Panel Discussion on Urban Transportation with Emphasis on Urban Network, 1994
257	Compendium	Compendium of Panel Discussions (upto 1994)
258	Compendium Vol. I & II	Compendium of Papers on Problems, Distress and Rehabilitation of Bridges Vol. I & II
IX. PERIODICALS		
Annual Subscription (Period January to December)		
259	Monthly	Indian Highways
260	Quarterly	Journal of the Indian Roads Congress
261	Bi - Annual	Highway Research Journal
262	Annual	Highway Research Record

APPENDIX - 3 LIST OF IS PUBLICATIONS

FOR ROAD AND BRIDGE WORKS

S.No	Specification No.	Title of the specification
	Bituminous material	
1	IS:73:1992	Specification for paving bitumen
2	IS:217:1988	Specification for cutback bitumen
3	IS:334:2002	Glossary of terms relating to bitumen and tar
4	IS:702:1988	Specification for industrial bitumen
5	IS: 1838:1983	Specification for preformed fillers for expansion joints in pavements and structures part 1 bitumen impregnated fibre
6	IS:2093:1974	Specification for distributors for hot tar and bitumen
7	IS:9381:1979	Method of testing tar and bituminous materials : FRAASS breaking point of bitumen
8	IS:10412:2003	Method of determination of wax content in bitumen
9	IS:15173:2002	Method of testing tar and bituminous materials: breaking point for cationic emulsion
10	IS:15174:2002	Method of testing tar and bituminous materials : breaking point for anionic emulsion.
11	IS: 15462:2004	Polymer and rubber modified bitumen-specification
	Aggregate	
1	IS:383:1970	Specification for coarse and fine aggregates from natural sources for concrete
2	IS:2386:part 1:1963	Method of test for aggregates for concrete-particle size and shape
3	IS:2386:part 3:1963	Method of test for aggregates for concrete-specific gravity, density, voids, absorption and bulking.
4 v	IS:2386:part4:1963	Method of test for aggregates for concrete-mechanical properties
5	IS:2386:part 5:1963	Method of test for aggregates for concrete-soundness
6	IS:2386:part 6:1963	Method of test for aggregates for concrete-measuring mortar making properties of fine aggregates
7	IS:2386:part7:1963	Method of test for aggregates for concrete-alkali aggregate reactivity

8	IS:2386:part 8:1963	Method of test for aggregates for concrete-petrographic examination
9	IS:2386:part 1:1963 ,	Method of sampling of aggregates for concrete
10	IS:5640:1970	Method of test for determining aggregate impact value
11	IS:6241:1971	Method of test for determination of stripping value
12	IS:7779:1979	Schedule for properties and availability of stones for construction purposes-Maharashtra state and their properties
13	IS: 10070:1982	Specification for machine for abrasion testing
14	IS: 10079:1982	Specification for cylindrical metal measures for use in tests of aggregates and concrete
15	BS: 812:1975	Method of test for determining-polished stone value
	SOIL	
1	IS: 1498:1970	Classification and identification of soils for general engineering purposes
2	IS:1888:1982	Methods of load test on soils
3	IS:2720:Part 1:1983	Methods of test for soils-preparation of dry soil samples for various tests
4	IS:2720:Part 2: 1983	Methods of test for soils-determination of water content
5	IS:2720:Part 3: Sec 2:1983	Method of test for soil- determination of specific gravity-part I-fine grained soils
6	IS:2720:Part 3: Sec 2:1983	Method of test for soil- determination of specific gravity-part II-medium and coarse grained soils
7	IS:2720:Part4:1985	Methods of test for soils-grain size analysis
8	IS:2720:Part 4:1985	Methods of test for soils-liquid and plastic limit
9	IS:2720:Part 1:1985	Methods of test for soils-liquid and plastic limit
10	IS:2720:Part 6:1972	Methods of test for soil-shrinkage factor
11	IS:2720:Part 7:1980	Methods of test for soil-determination of water content-dry density relation using light compaction
12	IS:2720:Part 8:1983	Methods of test for soil-determination of water content-dry density relation using heavy compaction
13	IS:2720:Part 9:1982	Methods of test for soil-determination of water content-dry density relationship by constant weight of soil method
14	IS:2720:Part 10:1991	Methods of test for soils-unconfined compressive strength

15	IS:2720:Part 11:1993	Methods of test for soils-determination of shear strength parameters-consolidated undrained triaxial compression without measurement of pore pressure
16	IS:2720:Part 12:1981	Methods of test for soils-determination of shear strength parameters-consolidated drained triaxial compression without measurement of pore pressure
'	IS:2720:Part 13:1986	Methods of test for soils-direct shear test
18	IS:2720:Part 1"5:1985	Methods of test for soils-consolidation properties
19	IS:2720:Part 16:1987 .	Methods of test for soils-laboratory CBR
20	IS:2720:Part 26:1987	Methods of test for soils- P H value
21	IS:2720:Part 27:1977	Methods of test for soils- soluble sulphates
22	IS:2720:Part 28:1991	Methods of test for soils-dry density by sand replacement
23	IS:2720:Part 29:1975	Method of test for soils- dry density by core cutter
24	IS:2720:Part 31:1990	Methods of test for soils- field CBR
25	IS:2720:Part 37:1976	Methods of test for soils-sand equivalent values
26	IS:2720:Part 39:1977	Methods of test for soils-direct shear for soils containing gravel.
27	IS:4332:Part 1:1967	Methods of test for stabilized soils-sampling and preparation of stabilized soils for testing
28	IS:4332:Part2:1967	Methods of test for stabilized soils- determination of moisture contents
29	IS:4332:Part 3:1967	Methods of test for stabilized soils-moisture content and dry density relation
30	IS:4332:Part 4:1968	Methods of test for stabilized soils-wetting and drying, freezing and thawing tests for compacted soil cement mixs
31	IS:4332:Part 5:1970	Methods of test for stabilized soils-unconfined compressive strength
32	IS:4332:Part 6:1972	Method of test for stabilized soils-flexural strength of soil-cement using simple beam with third point loading
33	IS:4332:Part 7:1973	Methods of test for stabilized soils- determination of cement content of cement stabilized soil.
34	IS:4332:Part 8:1969	Methods of test for stabilized soils- determination of cement content of lime stabilized soil.
35	IS:4332:Part 9:1970	Methods of test for stabilized soils- determination of bituminous stabilizer content in bitumen/tar stabilized soil

36	IS:4332:Part 9:1970	Methods of test for stabilized soils- test for soil/ bituminous mixtures
37	IS:9214:1979	Methods of determination of modulus of sub-grade reaction (k-value) of soils in field
38	IS:9259:1979	Specification for liquid limit apparatus for soils
39	IS: 10074:1982	Specification for compaction mold assembly for light and heavy compaction test
40	IS: 10379:1982	Code of practice for field control of moisture and compaction of embankment and sub-grade
41	IS:11229:1985	Specification for shear box for testing of soils
42	IS: 11550:1985	Code of practice for field instrumentation of swelling pressure in expansive soils
43	IS:11593:1986	Specification for shear box(large) for testing of soils
44	IS: 13468:1992	Specification for apparatus for determination of dry density of soils by core cutter method

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APPENDIX - 4

LIST OF IMPORTANT TESTS ON PAVEMENT LAYERS AND CONCRETE WORKS

I. Tests on borrow material for soils used in embankment and subgrade

a.	Borrow pit sampling using test pit/auguring	IS 2720 (part 4)
b.	Sieve analysis	IS 2720(part 5)
c.	Liquid limit and plastic limit	IS 2720(part 8)
d.	Moisture density relationship (Modified proctor)	
e.	California bearing ratio	IS 2720(part l6)

II. Tests on soil to be used in embankment/subgrade/shoulders

a.	Wet sieve analysis (gradation test)	IS 2720(part 4)
b.	Liquid limit and plastic limit	IS 2720(part 5)
c.	Deleterious materials	IS 1498
d.	Compaction test (Modified proctor) (moisture density relationship)	IS 2720(part 8)
e.	California bearing ratio CBR test	IS 2720(partl6)
f.	Chemical analysis	IS 2720(part8)

III. Tests on granular sub base material (GSB material) (clause 401-MORTH)

a.	California bearing ratio CBR test	IS2720 (part 16)
b.	Materials combinations	as per agreement clause
c.	Moisture content	IS 2720
d.	Soundness loss	IS 2386(part 5)
e.	Specific gravity and water absorption	IS 2720(part 4
f.	Gradation	IS 2386(part 1)
g-	Atterberg limits	IS 2720(part 5)
h.	Deleterious materials	IS 1498
I.	OMC & MDD (modified proctor	IS 2720(part 8)

IV. Tests on for bitumen

a.	Grade of bitumen/penetration test	IS 1203
b.	Ductility	IS 1208
c.	Flash or fire point test	IS 1209
d.	Loss on heating	Manufacture's certificate
e.	Softening point	IS 1205
f.	Solubility	Manufacture's ? certificate

V. Tests on aggregates for bituminous construction BM/MSS

a.	Aggregate impact value	IS2386 (part 4)
b.	Los Angeles or abrasion test	IS2386 (part 1)
c.	Flakiness and elongation index	IS 2720(part 4)
d.	Water absorption, specific gravity (coarse and fine)	IS 2720 (part 4)
e.	Stripping value	IS 6241
f.	Gradation	IS 2386 (part 1)
g-	soundness	IS 2386 (part 5)

VI Tests on Wet Mix Macadam

a.	Aggregate impact value	IS2386 (part 4)
b.	Los Angeles abrasion (either a or f)	IS2386(part 1)
c.	Flakiness and gradation indices	IS 2386(part 1)
d.	Water absorption, specific gravity (coarse and fine) For fine aggregates	IS 2720(part 4) IS 2386(part 3)
e.	Atterberg limits of portion of aggregates	IS 2720(part 5
f.	Gradation	IS 2386 (part 1)
&	soundness	IS 2386 (part 5)

VII. Tests on flne aggregates for bituminous construction

a. Passing 2.36mm sieve and retained on 75micron sieve - based on mix design
b. Deleterious materials- as directed by engineer

VIII. Tests on cement

a.	Normal consistency	IS 4031 (part 4&5)
b.	Fineness	IS 4031 (part 1
c.	Soundness	IS 4031 (part 1)
d.	Setting time-initial/final	IS 4031 (part 4 &5)
e.	Compressive strength(72 hrs, 168 hrs, 672 hrs)	IS 2720(partl6)

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APPENDIX - 5

(2) Manufacturing and rolling temperature (Ref: Pocket Book for Highway Engineers - MORT&H)

Bitumen penetraction (Grade of Bitumen)	Bitumen Mixing (°C)	Aggregate Mixing (°C)	Mixed Mixing (°C)	Rolling (°C)	Laying (°C)
35	160-170	160-175	170 Max.	100 Min.	130 Min.
65	150-165	150-170	165 Max.	**90** Min. 80	125 Min.
90	140-160	140-165	155 Max.	Min.	115 Min.

(3) Quantity of materials required for each item (a) Sub-Bases, Bases (Non Bituminous) and shoulders.

Sl. No	Item of wall	Materials per cum		
		Metal	Grit	
1.	GSB with close graded material (Plant mix method & mix in place method)	0.89 cum	0.38 cum	
2.	GSB with coarse graded material [grading - I]	1.02 cum	0.26 cum	
3.	(i) WBM - Grading II (a) Type A- Screening (b) Type B- Screening © Crushable type screening such as moorum or gravel	1.21 cum 1.21 cum 1.21 cum	0.16 cum (Type A- Screening) 0.24 cum (Type B- Screening)	0.08 cum (Gravel) 0.08 cum (Gravel) 0.373 cum (Gravel)
	(ii) Grading III (a) Type A- Screening (b) Type B- Screening	1.21 cum 1.21 cum	0.24 cum (Type B- Screening)	0.08 cum (Gravel) 0.373 cum (Gravel)
	(B) By Mechanical Means (i) Grading II (a) Using Type A- Screening (b) Using Type B- Screening (c) Using Crushable type Screening (Moorum & Gravel)	1.21 cum 1.21 cum 1.21 cum	0.16 cum (Type A- Screening) 0.24 cum (Type B- Screening)	0.08 cum (Gravel) 0.08 cum (Gravel) 0.373 cum (Gravel)

SI. No	Item of wall	Materials per cum		
		Metal	Grit	
	(ii) Grading III (a) Using Type A- Screening (b) Using Type B- Screening	1.21 cum 1.21 cum	0.24 cum (Type B- Screening)	0.08 cum (Gravel) 0.373 cum (Gravel)

b. Wet Mix Macadam

Method	Metal / cum	Grit / cum
Plant Mix Method	0.92 cum	0.40 cum
Crusher Run Macadam Base	1.32 cum	

c. Bases and Surface Courses(Bituminous)

SI. No.	Item of Wall	Bitumen Emulsion	Hot Bitumen
1.	Prime coat on WBM/WMM	0.60 **kg/** sqm	
2.	Tack coat on B.T. Surface	0.20 **to** 0.30 **kg/** sqm	0.30 to 0.40 kg/ sqm
3.	Tack coat on Granular base (WBM/WMM Surface treated with primer)	0.25 **to** 0.30 **kg/** sqm	0.35 to 0.45 kg/ sqm
4.	Tack coat on Cement Concrete surface	0.30 **to** 0.35 **kg/** sqm	0.40 to 0.50 kg/ sqm

Sources : IRC : 16 - 2008

d. Bituminous Layers

Sl. No	Type of Layers	Materials required per cum		Filler (Cement)
		Metal	Bitumen (G.60/70) VG - 30	
1.	Bituminous Macadam (BM) (a) grade - I (b) grade - II	1.418 cum 1.415 cum	68.04 kg (3.10%) 72.44 kg (3.30%)	—
2.	Dense Graded Bituminous Macadam (DBM) (I) Grading - I (ii) Grading - II	1.44 cum 1.44 cum	92.30 kg (4.00%) 103.84 kg (4.50%)	44.30 kg 44.07 kg
3.	Semi Dense Bituminous Concrete (SDBC) (i) Grading - I (35-40mm thick) (ii) Grading - II (25-30mm thick)	1.44 cum 1.432 cum	103.85 kg (4.50%) 115.38 kg (5.00%)	44.21 kg 44.21 kg
4.	Bituminous Concrete (BC) (I) Grading - II	1.454 cum	129.58 kg (5.50%)	44.52 kg
5.	Surface Dressing (i) using 19mm size metal (ii) using 13mm size metal	0.15 cum/ l0sqm 0.10 cum/ l0sqm	12 kg / lOsqm 10 kg / lOsqm	—
6.	Open graded Premix Surface (OGPS) (I) 20mm thick of 13.2mm to 5.60 mm aggregates	0.27 cum/ l0sqm	14.60 kg / lOsqm	—
7.	Close graded Premix Surface / MSS (I) using 11.20mm to 0.09 mm metal (Type A) (ii) using 13.20mm to 0.09 mm (Type B)	0.27 cum/ l0sqm 0.27 cum/ l0sqm	22 kg / lOsqm 19 kg / lOsqm	—
8.	Seal coat (a) Type A - 6.70 mm Stone Clipps (b) Type B - 6.70 mm size Stone Chipps	0.09 cum/ l0sqm 0.60 cum/ l0sqm	9.80 kg / lOsqm 6.80 kg / lOsqm	—

SI. No	Type of Layers	Materials required per cum		Filler Cement
		Metal	Bitumen (G.60/70) UG - 30	
9.	Mastic Asphalt (25mm Thick)	0.027 cum /sqm	5.83 kg / sqm	10.29 kg/ per sqm (Lime Filler
10.	Slurry Seal (i) 5mm thickness (ii) 3mm thickness (iii) 1.5mm thickness	0.00638cum /sqm 0.00374cum /sqm 0.0018cum /sqm	1.21 kg (R.S. Emulsion) per sqm 0.858 kg (R.S. Emulsion) per sqm 0.528kg (R.S. Emulsion) per sqm	0.22 kg/sqm 0.132 kg/sqm 0.0658 kg/sqm

Cement Concrete Pavements

SI. No	Description of Items	Material required mix cum			
		Cement	Sand	Metal	
1.	Dry Clean Concrete for sub base (25mm & 12.5 mm granite metal)	150 kg	0.45 cum	0.90 cum	—
2.	Cement Concrete pavement (with 43 grade cement @ 400 kg per cum)	400 kgs	0.45 cum	0.90 cum	Steel Dovel Bars 9.00 kg / Tie Bars 1.114kg
3.	Rolled Cement Concrete Base (Cement @200kg per cum)	200 kg	0.45 cum	0.90 cum	—

SOURCE : National Highways S.R. Bangalore Circle

APPENDIX - 6

I. Base and Surface Courses (Bituminous)

Clause 500 of MORT&H (IV th Revision)	Suggested Thickness (mm)
Bituminous Macadam (BM)	50 to 100
Bituminous Penetration Macadam	50 or 75
Built up spray grout	75
Dense Bituminous Macadam (DBM)	50 to 100
Semi Dense Bituminous Macadam (SDBM)	25 to 100
Bituminous Concrete (BC)	25 to 100
Open Graded Premix Surfacing (OGPS)	25 + Seal Coat
Close Graded Premix Surfacing / Mixed Seal Surfacing	20
Mastic Asphalt	25
Slurry Seal	1.5 to 5

II. Finished Quantity of mix (Compacted) in IKm of 7m width Carriage way

Mix	Qty in cum
BM (50 mm) (75mm)	350 525
DBM (50mm) (75mm)	350 525
BC (40mm) (50mm)	280-350
SDBC (25mm)	175
MSS (20mm)	140
WMM (250mm) WBM (200mm)	1750

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The rate of spread of bitumen for bituminous works is detailed below:

1. For track coat :
   Normal bituminous surface : 2 to 2.5 kg / 10 sq.m
   Dry or hungry surface : 3.5 to 4 kg / 10 sq.m
   Note : there is no need for tack coat on freshly laid bituminous surface overlaid on same day without opening to traffic.

2. Requirement of Bitumen for BSUG :
   a. First : 15 kg / l0sqm
   b. Second : 15 kg / l0sqm

3. Requirement of bitumen for surface dressing :
   Single coat surface dressing : binder 15 kg / m^2 of road
   Seal coat of two coat surface dressing : binder 15 kg / m^2 of road

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APPENDIX - 7

LIST OF PLATES

1. Steps involved in edge correction of roads
2. View of HMP site
3. Pot hole filling
4. Procedure for pot hole filling
5. Pot hole inspection, surface cleaning, erection of hot mix plant
6. Stone crusher, crusher plant
7. Various aspects of HMP plant
8. Temperature checks for the mix.
9. SDBC site
10. Temperature check, coarse aggregates laid for BUSG
11. Quality tests for bitumen
12. Bitumen extraction test
13. Laboratory tests being carried out
14. Monitoring of Quality checks
15. Quality control tests carried out
16. Gradation test, Bitumen extraction test
17. Marshall stability test.

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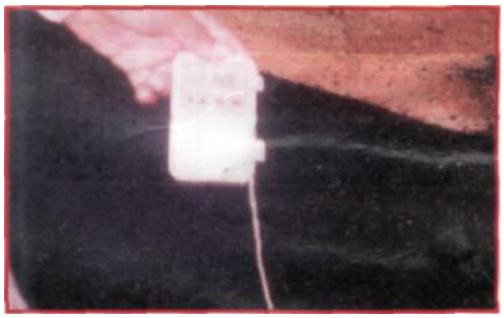
Control Room

Temperature checks for the mix

Temperature check of the SDBC mix before rolling

Completed SDBC

SDBC in progress



Temperature check

Temperature check for the mix

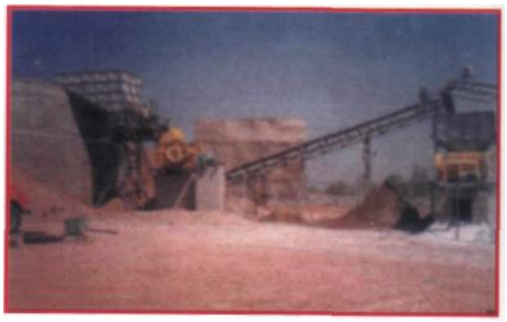
Coarse aggregates laid for BUSG

Suggestions on appropriate methodology for pot hole cutting

Surface cleaning using air compressor

Erection of Hot Mix Point

Stone Crusher



Crusher Plant

Aggregate Stacking

Four bins and Drum type HMP