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USE OF COLD MIX TECHNOLOGY IN CONSTRUCTION AND MAINTENANCE OF ROADS USING BITUMEN EMULSION

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LIST OF ABBREVIATIONS

IRC	Indian Roads Congress
AASHTO	American Assoication of State Highway and Transportation Officials
BIS	Bureau of Indian Standards
CMBM	Cold Mixed Bituminous Macadam
CMSDBC	Cold Mixed Semi Dense Bituminous Concrete
ASTM	American Society for Testing of Materials
WMM	Wet Mix Macadam
WBM	Water Bound Macadam
CRM	Crusher Run Macadam
SS	Slow Setting
MS	Medium Setting
RS	Rapid Setting

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USE OF COLD MIX TECHNOLOGY IN CONSTRUCTION AND MAINTENANCE OF ROADS USING BITUMEN EMULSION

1 INTRODUCTION

The Road Maintenance and Asset Management (H-6) Committee constituted a sub-group under the chairmanship of Dr. P.K. Jain with other members as Shri K. Sitaramanjaneyulu, Dr. N. K. S. Pundhir, Shri M. N. Nagabhushana, Shri Abhishek Mittal, Dr. M.C. Jain and Dr. I.K. Pateriya, for formulation of "Use of Cold Mix Technology in Construction and Maintenance of Roads Using Bitumen Emulsion". The draft document prepared by the sub-group was discussed by the Committee in series of meetings. The H-6 Committee approved the draft document in its meeting held on 4th May, 2013 for placing before Highways Specifications & Standards Committee (HSS) Committee. The HSS Committee approved the draft document in its meeting held on 19th July, 2013 for placing it before the Council. The Council in its meeting held at New Delhi on 11th and 12th August, 2013 approved the draft document on "Use of Cold Mix Technology in Construction and Maintenance of Roads Using Bitumen Emulsion" and authorised IRC to publish the same.

The Composition of H-6 Committee is as given below:

S.C. Sharma	--------	Convenor
Dr. S.S. Jain	--------	Co-convenor
K. Sitaramanjaneyulu	--------	Member Secretary

Members

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Co-opt Member

M. N. Nagabhushana

Ex-Officio Members

C. Kandasamy	Director General (Road Development) & Special Secretary, MoRT&H and President, IRC
Vishnu Shankar Prasad	Secretary General, IRC

Flexible (Bituminous) pavements constitute over 90 percent of the total road network including airfield pavements in India. Hot mixed bituminous materials and mixes are generally used for the construction of base course, binder course and wearing course of a flexible pavement. The paving bitumen (VG-10, VG-20, VG-30 and VG-40; as per IS:73), is used as a binder. It is either solid or semi solid at ambient temperature and converted into fluid state by either heating or by addition of petroleum solvent or by emulsifying bitumen in water. High amount of energy is consumed for heating of aggregates and bitumen for construction of roads using traditional hot mix technology. The following are some of the disadvantages of hot mix technologies:

- High level of noise and air pollution
- Emission of green house gases
- Compromise with the durability of bitumen due to aging during heating
- High energy consumption
- Unsafe for maintenance crew

Another form of bituminous binder is the cutback bitumen, which is brought into fluid state by adding petroleum solvent such as naphtha or kerosene oil. In the field, solvent evaporates as the curing of cut-back bitumen takes place. This technology has limited applications due to its inherent disadvantages and it is not environment friendly. The third type of bituminous binder, which is rapidly growing is the cationic bitumen emulsion. It available in fluid state at ambient temperature and it is prepared by microscopic dispersion of solid or semisolid bitumen in water using collordal null and chemical emulsifiers.

Emulsion was developed for the first time in the 1900s and its use in pavement applications started in the 1920s. The early use of bitumen emulsion was restricted to only spray applications and as dust palliatives. Over the years, with development of new types, grades, specifications, and availability of improved construction equipments and practices, emulsion based cold mix technology offered a wide range of solutions for construction and maintenance of roads.

In India, bitumen emulsion found its use only in the 1970s. The entire world used 12 million tonnes of emulsion during mid seventies, India consumed only 20,000 tonnes till 1996, out of the total bitumen consumption of about 2 million tones. However, there has now been a steady rise in the use of bitumen emulsion recently and significant growth in demand of emulsion has been observed after 2005. At the present time, practically all the road construction and maintenance requirements can be met with the use of bitumen emulsion as binder by way of warm and cold mix technologies. Judicious selection and appropriate use of these technologies can yield significant economies, environmental benefits and energy security as far as construction and maintenance of roads are concerned.

Lately, bitumen emulsion has also been used in half warm mixes, micro surfacing and in cold recycling; more especially in full depth reclamation works. Results obtained from field trials conducted by CRRI and oil companies on cold mixes and bitumen emulsion based applications under different traffic and climatic conditions have been found to be encouraging. Several factors that have lead to the increasing use of bitumen emulsion in road construction and maintenance are listed below:

- The energy scarcity and crisis.
- Bitumen emulsions do not require petroleum solvent to make it liquid.
- Bitumen emulsions can generally be used without additional heating.
- Concerns about reducing atmospheric pollution.
- The ability of certain types of bitumen emulsions to coat damp aggregate surface, which eventually reduces the fuel requirements for heating and drying aggregates.
- Availability of a variety of emulsion types which have led to development of new formulations and improved laboratory procedures in order to satisfy the design and construction requirements.
- The ability to use cold bituminous materials at remote sites.
- The applicability of emulsions for use in preventive maintenance so as to increase the service life of existing distressed pavements.
- Success stories of the use of warm and cold mix technologies in construction and maintenance of rural roads.
- Health of construction workers

The uses of emulsion in construction and maintenance applications covered in these guidelines are given below:

Surface Treatment Including Preventive and Corrective Maintenance	Maintenance Including Periodic Treatments		Other Applications
	Cold Mixes	Warm Mixes	
➢ Fog Seal ➢ Sand Seal ➢ Slurry Seal ➢ Microsurfacing ➢ Cape Seal ➢ Chip Seal	➢ Patching ➢ Pothole Repair ➢ Cold Recycling ➢ Bituminous Macadam ➢ Premix Carpet ➢ Mix Seal Surfacing ➢ Semi-Dense Bituminous Concrete	➢ Semi-Dense Mixes ➢ Dense Mixes	➢ Prime Coat ➢ Tack Coat ➢ Crack Sealing ➢ Soil Stabilization

Choice/Selection of Cold Mix Treatments for different Climate/Traffic conditions (warrants) is given in **Annex-I**.

Bitumen emulsion based mixes include:

a) Cold Mixes (CM)

These mixes are normally produced with unheated aggregates and bitumen emulsion.

b) Half Warm Asphalt Mixes (HWAM)

These mixes are produced by mixing bitumen emulsion, or foamed bitumen with warm aggregates (100±10°C), laid and compacted at a temperature between 80-90°C.

c) Warm Asphalt Mixes (WAM)

These guidelines apply to the bitumen emulsion based cold mixes, which are suitable for low to moderate traffic and are not recommended for heavily trafficked roads and areas where atmospheric temperature is high. However, bitumen emulsion based patching mixes for repairing potholes are recommended for all traffic and climatic conditions. For selection of cold mix treatments for different traffic and climatic conditions, reference may be made to **Annex I**.

2 CHEMISTRY OF BITUMEN EMULSION, PRODUCTION AND HANDLING

2.1 Introduction

Emulsion is a colloidal system, which finds vital place in our daily lives. Milk, Mayonnaise, Paints, Lotions, Cream and Rubber latex are some of the well known examples. An emulsion is a two phase system in which one constituent is dispersed into another. In each case, addition of certain chemicals with mechanical processing is required. It should be well understood that an emulsion system is very complex and many variables may come into play, when analyzing a particular type of emulsion system.

This chapter covers the basics of emulsion's chemistry pertaining to its composition, stability, and performance

2.2 Composition of Bitumen Emulsion

Bitumen emulsion is a two-phase system consisting of bitumen, water and one or more additives which assist in its formation, stabilization and in modifying its properties. The bitumen is dispersed throughout the water phase in the form of discrete globules, typically 0.1 to 50 μm in diameter, which are held in suspension by electro-static charge stabilized by an emulsifier. Depending on the composition of raw materials, which go into bitumen emulsion, these may include bitumen, water, emulsifier, acid or caustic, polymers, salts, solvents, additives, and emulsion stabilizers.

2.2.1 *Bitumen*

It is a viscous material derived from refining of crude petroleum. The composition of bitumen has a significant effect on process of emulsification, its physical properties and subsequent performance.

2.2.2 *Water*

Water and hydrocarbons are not soluble in each other. Depending on its source, water may contain varying amount of dissolved salts such as calcium or magnesium carbonate (found in "hard" water), or suspended particles of rust (iron oxide) or silt (very fine clay particles). Therefore, quality of water has significant effects on the stability and performance of emulsion. Water containing calcium amounting to more than 75 ppm is considered to be "hard water" while water containing calcium less than 75 ppm is considered to be "soft water". It is desirable to use only "soft water" for making emulsion of bitumen.

2.2.3 *Emulsifier*

Emulsifier is a chemical additive that is added to water prior to the production of an emulsion. Its function is to stabilize emulsion during its production, storage and transportation. The amount and type of emulsifier is also critical for determining the performance of emulsion, when it is applied in the field. A care in selection of emulsifier is thus absolutely necessary.

2.2.4 *Acid or caustic*

Acid or Alkali is added in combination of the emulsifier and water to "activate" the emulsifier.

2.2.5 *Polymers*

Polymers and rubber latex may be added to emulsion to improve physical properties of residue. Polymers can improve resistance towards wear and tear of the pavement. These may be added to the bitumen prior to emulsification in a solid form. Polymers and rubbers can also be added to the emulsifier solution in the form of latex (small polymer particles suspended in water phase), which can be in cationic or anionic form (similar to bitumen emulsion). The choice of polymer or latex type (i.e., natural or SBR latex, or solid SBS) would depend on the physical properties desired.

2.2.6 *Solvents*

Solvents such as the diesel, heavy or light gas oil, kerosene, naphtha, etc are added to bitumen emulsions to reduce the viscosity of binder. This is often done to allow proper mixing of aggregate with emulsion and to keep it workable. The highly volatile solvents, such as naphtha and light gas oil, are used in the case, where rapid curing or early return to full strength (due to relatively quick evaporation) is required. Medium cure cutback systems use kerosene, while slow cure systems typically use diesel and heavy gas oil.

2.2.7 *Additives*

Additives may also be used to enhance the performance of bitumen in emulsion. Additives blended with bitumen prior to the emulsification can provide improved properties of emulsion such as the uniform particle size, storage stability, curing, and adhesion to aggregate, all of which result in higher strength and resistance to water damage.

2.2.8 *Stabilizers*

Stabilizers are used, in case, where very high stability of emulsion is required (such as demanding mixing grade applications) or where improved quality and higher storage stability of emulsion are needed. Stabilizers are often not very effective as emulsifiers by themselves, but are used in conjunction with emulsifiers to enhance their performance.

2.2.9 *Structure of bitumen emulsion*

Bitumen emulsions consist of very fine spherical droplets of bitumen suspended in water. Bitumen emulsion particles are small enough that they experience Brownian movement. One gram of bitumen emulsion (a volume roughly equal to a sugar cube) can contain over one billion bitumen droplets. These one billion droplets of bitumen in emulsion have a total surface area of approximately 1 square meter. The typical structure of cationic bitumen emulsion is shown in **Fig. 2.1**.

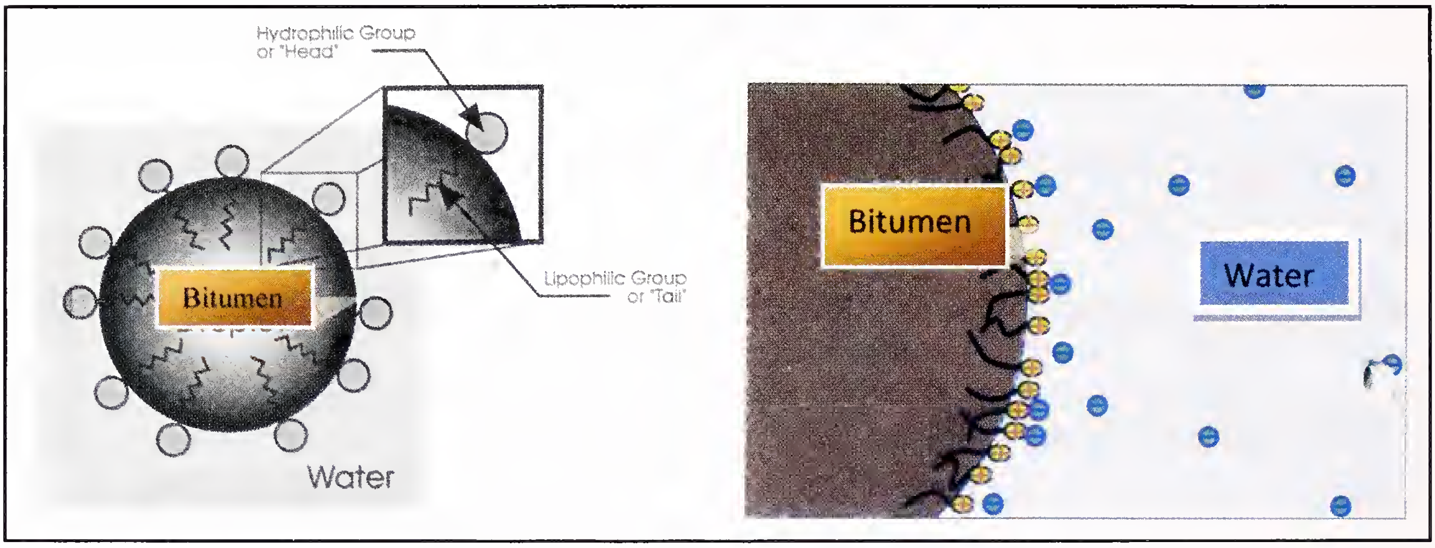
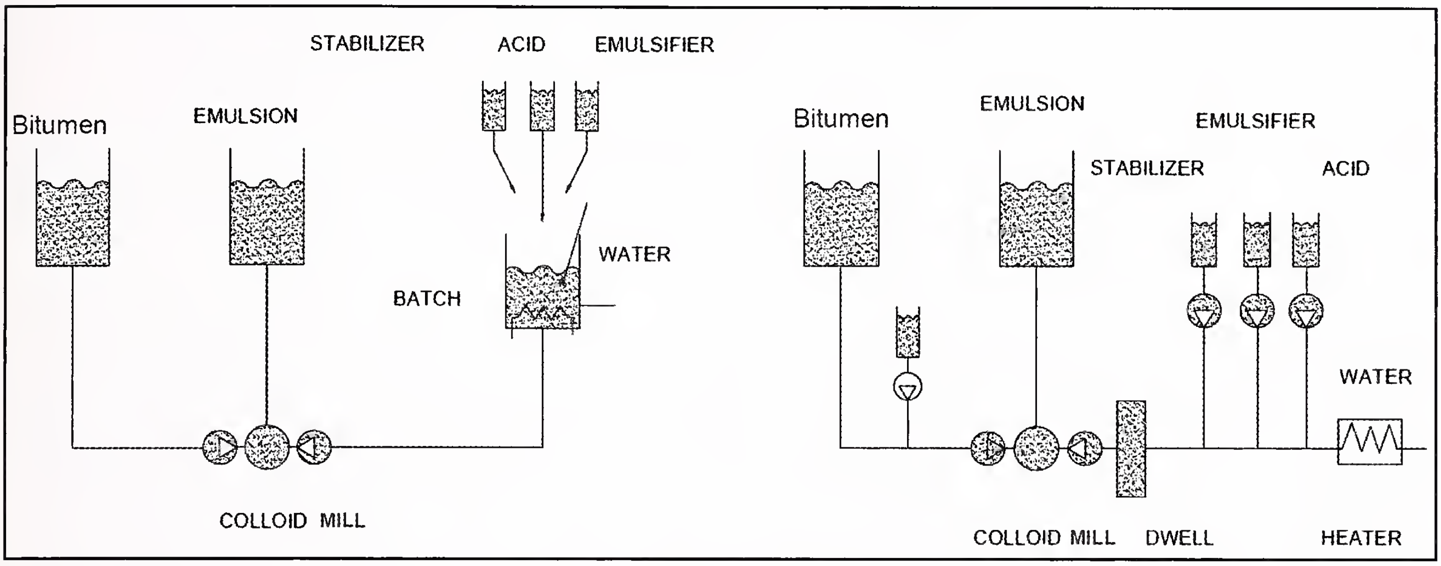


Fig. 2.1 Structure of Cationic Bitumen Emulsion

2.3 Production of Bitumen Emulsion

Most of the bitumen emulsions are manufactured by continuous process using a colloid mill, which consists of a high-speed rotor revolving at 1000 to 6000 revolutions/minute in a stator. Hot bitumen and emulsifier solutions are fed separately but simultaneously into the colloid mill. The temperature of two components is critical to the emulsification process. The viscosity of bitumen entering into colloid mill should not exceed 0.2 Pa-s (2 Poise). If a harder grade bitumen or modified bitumen is used, the emulsification process becomes more difficult. Higher temperature is needed to allow bitumen to be pumped into and disperse in the colloidal mill; dispersion of bitumen requires more power input to the mill, which further increases the production temperature. Pressurized mills are used for bitumen having high viscosity at normal emulsification temperature and to allow higher output with normal bitumen. Emulsions with temperature up to 130°C are produced under high pressure and emulsion output must be cooled down to below 100°C before being discharged into storage tanks. A batch process can also be used for production of emulsion wherein the type of mixer used is chosen to suit the consistency of end product. It may either be a high-speed propeller for low viscosity emulsion or a slow Z-blade mixer for paste-like industrial emulsion. Schematic diagrams of continuous and batch type emulsion manufacturing facilities are shown in **Figs. 2.2 and 2.3**. Bitumen emulsion can be prepared using a on-site mobile plant or off-site stationary plant. The mobile plant may save cost of transportation of water.



Figs. 2.2 & 2.3 Schematic Diagrams : Emulsion Production

2.4 Classification of Bitumen Emulsions

Bitumen emulsions are classified into four categories: anionic, cationic, clay and non-ionic. Cationic and anionic emulsions are widely used for construction and maintenance of roads. The term anionic and cationic emulsions refer to the electrical charges surrounding bitumen particles in emulsion. Emulsions are further classified on the basis of how quickly the bitumen droplets will coalesce. The terms RS, MS, SS and QS are relative terms only and have been used to simplify the classification. These terms expand to mean Rapid-Setting (RS), Medium-Setting (MS), Slow-Setting (SS) and Quick-Setting (QS).

IS 8887 prescribes specification for cationic bitumen emulsion. ASTM and AASHTO have also developed standards and specifications for various grades of bitumen emulsions. The various gradings of emulsions, as mentioned in IS, ASTM and AASHTO, are shown in **Table 2.1**.

Table 2.1 Classification of Bitumen Emulsion as per Different Standards

Asphalt Emulsion (ASTM D977, AASHTO M140)	Cationic Bitumen Emulsion (IS-8887)	Cationic Asphalt Emulsion (ASTM D 2397: AASHTO M208)
RS-1	RS-1	CRS-1
RS-2	RS-2	CRS-2
HFRS-2	-	-
MS-1	MS	-
MS-2	-	CMS-2
MS-2h	-	CMS-2h

HFMS-1	-	-
HFMS-2	-	-
HFMS-2h	-	-
HFMS-2S	-	-
SS-1	SS-1	CSS-1
SS-1h	SS-2	CSS-1h
QS-1h	-	CQS-1h

Note : 1) The numbers and letters relate to viscosity of the emulsion and hardness of base bitumen. The letter 'C' denotes to cationic. The addition of 'h' means that harder base bitumen has been used.

2) Only cationic emulsions are used in India.

Rapid Setting grade of bitumen emulsion (RS-1), specified in Indian Standard, is specially recommended for tack coat application, while Rapid Setting grade of emulsion RS-2 is recommended for surface dressing work. A Medium Setting grade of emulsion (MS) is used for mixes with high coarse aggregates (minimum of 80 percent) all of which are retained on 2.36 mm IS Sieve and practically none of which pass through 180 micron IS Sieve size. MS grade is also used for surface dressing and Penetration Macadam. Slow Setting grade (SS-1) is used for other applications such as fog seal, crack seal and prime coat, while Slow Setting grade SS-2 is used for plant mixes with graded and fine aggregates, a substantial quantity of which should pass 2.36 mm IS Sieve size, and a portion of which should pass 75 micron IS Sieve size.

The emulsion for micro-surfacing is required to meet IRC/ISSA specifications. A requirement of 3 percent of solid of rubber/polymer by weight of bitumen in the emulsion is always needed for compliance. The addition of rubber additive enhance the high temperature performance of bitumen and permits application of micro-surfacing in filling of ruts. Adding one letter (P, S or L) to the end of the grade (e. g. CRS – 2P) normally designates the modified emulsion. Specifications of cationic emulsion (ASTM D 2397, AASHTO M 208) permit solvent in some grades but restrict the amount. Some user agencies specify an additional cationic sand-mixing grade designed as CMS – 2S, which contains more solvent than other cationic grade, while IS:8887 does not permit addition of solvent/water.

2.5 Variables Affecting Quality of Bitumen Emulsion

There are many factors which affect the production, storage, use, and performance of a bitumen emulsion that it would be difficult to single out any one variable as being the most significant one. Nevertheless, certain variables having significant effect on quality and performance of emulsions include the following:

- Chemical properties of bitumen
- Consistency and quantity of bitumen
- Particle size of bitumen in the emulsion
- Quality and dose of emulsifier

- Manufacturing conditions such as temperature, pressure, and shear rate
- Ionic charge on the emulsion particles
- Sequence of addition of the ingredients
- Equipment used in manufacturing of emulsion
- Properties of chemical modifiers or polymers
- Quality of water particularly the hardness

These factors can be varied to suit the available aggregates or construction specifications. It is always advisable to consult the emulsion supplier with respect to a particular aggregate, as there are few rules, which apply under all conditions, while some rules are material (aggregate and emulsion) specific.

2.6 Properties of Bitumen Emulsions

The important properties of bitumen emulsions are given below:

- Stability
- Viscosity
- Breaking and curing
- Adhesion

2.6.1 *Stability of emulsion*

Emulsion having low bitumen content and low viscosity is prone to lower stability. The density of bitumen at ambient temperature is slightly greater than aqueous phase of emulsion and eventually bitumen particles in such emulsion tend to settle down resulting in a rich layer of lower bitumen content. The velocity of dispersed phase particles in the downward movement can be estimated by using Stoke's law.

$$v = \frac{2gr^2(\rho_1 - \rho_2)}{9\eta}$$

where,

g = gravitational force; r = radius of particle; ρ_1 = specific gravity of bitumen; ρ_2 = specific gravity of aqueous phase and η = viscosity of aqueous phase.

Therefore, the settlement can be reduced by equalizing the density of dispersed phase and dispersion medium and it can be achieved by adding buffer salts like calcium chloride in aqueous phase.

2.6.2 *Viscosity of emulsion*

The viscosity of emulsion at conditions during spraying is of prime importance. The viscosity of emulsion can be measured using orifice type viscometers such as Standard Tar Viscometer or Saybolt Furol Viscometer.

The viscosity of emulsion can be enhanced by the following methods.

- By increasing the concentration of dispersed phase (bitumen)
- By increasing the viscosity of continuous phase
- By reducing the range of particle size distribution.

The converse changes will, similarly, decrease the viscosity of emulsion. However, emulsion viscosity is almost independent of the viscosity of dispersed phase (bitumen).

2.6.3 *Breaking and curing*

2.6.3.1 Breaking

If the bitumen emulsion is to perform its ultimate function as a binder, the water must separate out from the bitumen phase and evaporate. This separation of water from bitumen is called "breaking". For surface treatments and seals, emulsions are formulated to break chemically upon contact with a foreign substance such as aggregate and pavement surface. When using anionic and cationic rapid-setting and medium setting emulsions, the breaking of the bitumen emulsion droplets on the aggregate develops through electrochemical factors. For slow-setting emulsions, the mechanism is through water evaporation. For dense mixes, more time is needed to allow for mixing and placement. Therefore, emulsions used for dense mixes are formulated for delayed breaking. A rapid-set emulsion will have a short breaking time (within one to five minutes after being applied), whereas a medium- or slow-set emulsion may take longer time.

2.6.3.2 Curing

Curing involves the development of cohesion. The end result is a continuous cohesive film that holds the aggregate in place with a strong adhesive bond. For this to happen, the water must completely evaporate, and the bitumen particles have to coalesce and bond to the aggregate. The water is removed by evaporation, by pressure (rolling), and by adsorption onto the aggregate surface. Water evaporation can be fairly rapid under favourable weather conditions, but high humidity, low temperatures, or rain soon after application can defer needed curing. When medium setting and slow setting grades of emulsion are used for paving mixes, the use of slightly damp aggregate facilitates the mixing and coating process. The development of strength in the slow setting types depends mainly on evaporation and absorption. Mixing grade emulsion usually contains some petroleum solvent to aid in the mixing and coating process. During curing process, some of solvent evaporates.

2.6.3.3 Factors affecting breaking and curing

The factors affecting the breaking and curing properties of cold mixes are given below:

- Water absorption – A rough texture as well as porous aggregate decreases the breaking and setting time by absorbing water
- Aggregate moisture content – The wet aggregate facilitates easy coating but it tends to slow the curing process due to increased time needed for the evaporation of water.

- Weather conditions – Temperature, humidity, and wind velocity have a bearing on water evaporation and emulsifier migration. The breaking occurs more quickly at warmer temperatures but that is not always the case. Hot weather can also cause skin formation on chip seals. Chemical formulations are available for faster breaking.
- Mechanical factors – Roller pressure and, to a limited extent, slow moving traffic, forces the water to evaporate from the cold mix and helps to attain mix cohesion, cure and stability.
- Surface area – Greater aggregate surface area, particularly excessive fines, accelerates the breaking of emulsions and that is why sand equivalent test is important.
- Surface chemistry – Quantum of aggregate surface charge, in combination with the intensity of emulsifier charge, can affect setting rate, particularly for cationic emulsions. Calcium and magnesium ions on the aggregate surface can react with certain anionic emulsifiers and thereby can accelerate setting process.
- Emulsion and aggregate temperature – Breaking is retarded when temperatures of emulsion and aggregate are low.
- Type and amount of emulsifier – The surfactant used in the manufacture of emulsion determines the breaking characteristic of fine mixes.

The supplier of emulsion is the best source of information in order to control the above listed parameters.

2.6.4 *Adhesion properties*

The quality of bond between bitumen and aggregate or existing surface depends on a number of factors, as listed below:

- type and amount of emulsifier
- bitumen grade
- pH of the emulsifier solution
- particle size distribution of the emulsion
- aggregate properties

2.7 Precautions for Storing and Handling

The following aspects need due consideration during the storing and handling of bitumen emulsions:

- Store preferably between 10°C and 50°C.
- Should not be heated above 85°C, as at elevated temperatures water evaporate and thereby, changing the characteristics of emulsion, may lead to breaking.

- Do not allow freezing. Freezing below 4°C may cause breaking of emulsion leading to separation bitumen from water.
- Do not allow temperature of surface to exceed 85°C. Since it will cause premature breaking of the emulsion.
- Do not use jet of air to agitate emulsion, as this may cause emulsion to break.
- When heating bitumen emulsion, agitate it gently to eliminate or reduce skin formation.
- Protect pumps, valves, and lines from freezing in winter. Drain pumps and service according to the manufacture's recommendations.
- Blow out line and leave drain plugs open when they are not in service
- Use pumps with proper clearances for handling emulsion. Tightly fitted pumps can bind and seizep
- Warm the pump to about 65°C to facilitate start-up.
- When diluting bitumen emulsion, check the quality and compatibility of water with the emulsion by testing a small quantity in a test tube.
- If possible, use warm and soft water for dilution. Always add water slowly to the emulsion (not the emulsion to the water).
- Avoid repeated pumping and recalculating, as the viscosity may drop and air may become entrained, causing the emulsion to be unstable.
- Place inlet pipes and return lines at the bottom of tanks to prevent foaming.
- Pump from the bottom of tank to minimize contamination from skinning.
- Remember that emulsions with the same grade designation can be very different chemically and also in performance.
- Agitate emulsions gently that have been subjected to prolonged storage. This may be done by recirculation
- Avoid breathing fumes, vapors, and mist
- Obtain a copy of supplier's material safety data sheet (MSDS). Read MSDS carefully and follow it.
- Do not mix different classes, types, and grades of emulsions in tanks and distributors.
- Do not dilute rapid-setting grades of bitumen emulsion with water. Medium and slow setting grades may however be diluted, but always add soft water slowly to the bitumen emulsion.
- Do not load bitumen emulsion into storage tanks, tank cars, tank transports, or distributors containing remains of incompatible materials.

3 SPECIFICATION AND TESTING

3.1 Specification

Emulsions as per IS 8887are classified into five types such as RS-1, RS-2 MS, SS-1 and SS-2 depending upon their setting characteristics and use. The recommended uses and specifications for different types of bitumen emulsions are given in **Tables 3.1 to 3.3**.

Table 3.1 Recommended uses for Different Types of Emulsion

Type	Recommended Uses
RS-1	A quick setting emulsion used for tack coat
RS-2	A quick setting emulsion used for surface treatment, surface dressing, Penetration Macadam, Penetration Grouting
MS	A medium setting emulsion used for plant or road mixes with coarse aggregate for premix carpet
SS-1	A slow setting emulsion used for priming
SS-2	A slow setting emulsion used for plant mixes with graded fine aggregate in SDBC, MSS, BM, DBM and BC. This emulsion is also used for slurry seal treatment and tack coat
Modified	Modified emulsion is used for microsurfacing

Table 3.2 Specifications of Cationic Bitumen Emulsion

S.No	Properties of Bitumen Emulsion	Grade of Emulsion (Softer Grade)					Test Method
		RS-1	RS-2	MS	SS-1	SS-2	
i)	Residue on 600 micron IS sieve (% mass), Max.	0.05	0.05	0.05	0.05	0.05	IS:8887
ii)	Viscosity by Say bolt Furol Viscometer, Seconds at 25°C at 50°C	 - 20-100	 - 100-300	 - 30-300	 20-100 -	 30-150 -	IS:3117
iii)	Coagulation of emulsion at low temperature	Nil	Nil	Nil	Nil	Nil	IS:8887
iv)	Storage stability after 24 hr, %, max.	2.0	1.0	1.0	2.0	2.0	IS:8887
v)	Particle charge	+ve	+ve	+ve	-	+ve	IS:8887
vi)	Coating ability and water resistance a) Coating, dry aggregates b) Coating after spraying water c) Coating, wet aggregates d) Coating after spraying water	 - - - -	 - - - -	 Good Fair Fair Fair	 - - - -	 - - - -	IS:8887
vii)	Stability to mixing with cement, % coagulation	-	-	-	-	2	IS:8887
viii)	Miscibility with water (coagulation)	No Coagulation	No Coagulation	No Coagulation	Immiscible	No Coagulation	IS:8887
ix)	Tests on Residue: a) Residue by evaporation, %, min. b) Penetration, 25°C/100 gm/5 sec. c) Ductility at 27°C, cm., min. d) Solubility In Trichloroethylene, %, min.	 60 80-150 50 98	 67 80-150 50 98	 65 60-150 50 98	 - - - 98	 60 60-120 50 98	 IS:8887 IS:1203 IS:1208 IS:1216

Table 3.3 Properties of Modified Bitumen Emulsion for Microsurfacing (IRC:SP-81)

S. No.	Properties	Requirement	Method of Test
1)	Residue on 600 micron IS sieve (% mass), maximum	0.05	IS:8887
2)	Viscosity by Say bolt Furol Viscometer, at 25°C, seconds	20 – 100	IS:8887
3)	Coagulation of emulsion at low temperature	Nil	IS:8887
4)	Storage stability after 24 h (168 h), %, maximum	2 (4)	IS:8887
5)	Particle charge,	+ ve	IS:8887
6)	Tests on Residue :		
	a) Residue by evaporation, % minimum	60	IS:8887
	b) Penetration, 25°C / 100 gm / 5 sec.	40 - 100	IS:1203
	c) Ductility at 27°C, cm, minimum	50	IS:1208
	d) Softening Point, °C, minimum	57	IS:1205
	e) Elastic Recovery*, %, minimum	50	IS:15462
	f) Solubility In Trichloroethylene, %, minimum	97	IS:1216

* In case elastic recovery is tested for Torsional Elastic Recovery, the minimum value shall be 20%.

3.2 Testing

The testing of emulsion is essential before its packaging, storage and release for transportation to ensure the quality of product against the applicable requirements. Tests such as Penetration, Ductility and Solubility in Trichloroethylene are also applicable on residue of bitumen emulsion as it has to perform the function of binder after breaking and evaporation of water. These specifications describe the importance and significance of various test methods applicable to bitumen emulsion to ensure the quality and application for intended use. Proper sampling should be ensured as detailed in IS:8887-2004 before testing the bitumen emulsion.

3.2.1 *Residue on 600 micron IS sieve*

An emulsion is characterized by the uniform distribution with respect to size of particles of bitumen droplets in aqueous phase. This dispersion should not contain foreign particles of any type whatsoever, which are likely to clog the nozzles and filters of spraying equipments. Therefore, sieve test is considered as an important test to ascertain the quality of bitumen emulsion. In this test, previously weighed 4 liters representative sample is filtered through 600 micron sieve at specified temperature (25 or 50°C) after rinsing the sieve with distilled water except in case of inverted emulsion (SS-1 grade). After filtering the emulsion, sieve is repeatedly washed with distilled water until washings are clear and then dried in oven at 105 ± 5°C for 2 hours and the residue over sieve is determined by weighing. The complete details of the test method experiment have been provided in Annexure-B of IS:8887. The weight of retained residue on sieve should not be more than 0.05 percent by mass, as per the requirements indicated in IS:8887.

3.2.2 *Viscosity by saybolt furol viscometer*

Viscosity is defined as resistance to flow. The viscosity of emulsion is an important property and it must meet the requirements of IS:8887. The viscosity of bitumen emulsion is measured at 25 or 50°C by using Saybolt Furol Viscometer depending on the grade of bitumen emulsion as per the test method given in IS:3117. The results are reported in Say bolt Furol seconds (**Fig. 3.1**).

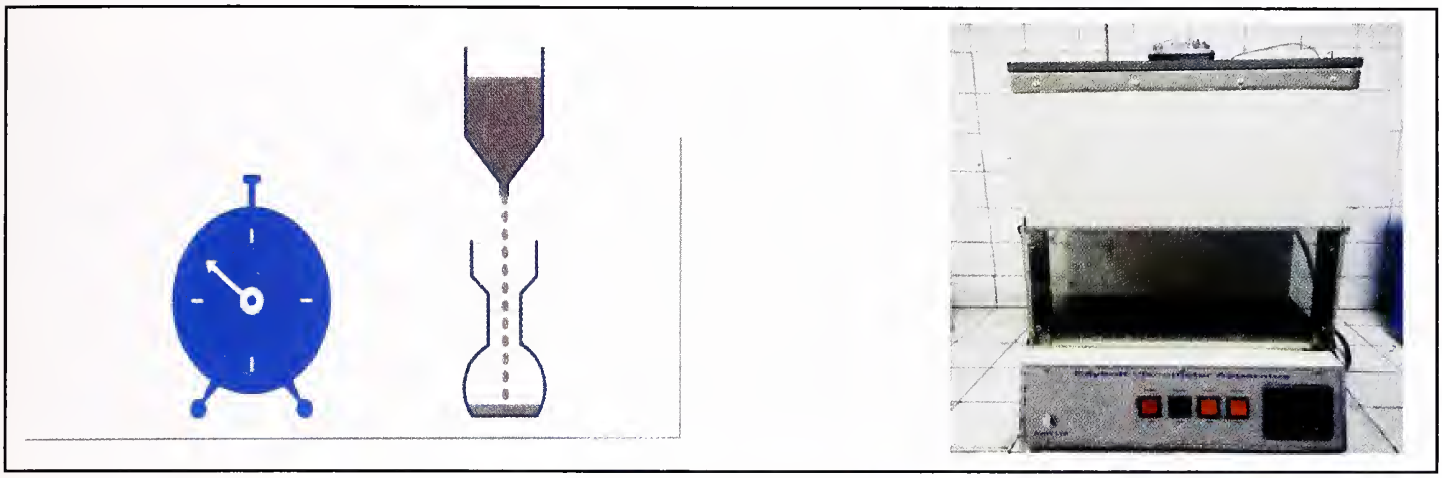


Fig. 3.1 Saybolt Furol Viscosity Measurement

3.2.3 *Coagulation at low temperature*

Coagulation test at low temperature is performed to ensure the homogeneity and stability of bitumen emulsion, if exposed or stored at sub-zero temperature. In this test, 20 ml of previously sieved homogenous bitumen emulsion is transferred in to a boiling tube. The temperature of this boiling tube is brought to 30°C by plunging the tube into water bath previously set at 30°C with gentle stirring by a glass rod. Once the temperature of bitumen emulsion is constant at 30°C, the tube is plunged into ice bath or refrigerator previously set to 0°C with slow stirring by road. Once the temperature of emulsion reaches 0°C, the tube is transferred into refrigerator for 30 minutes previously set at -3 to -4°C. Finally, the tube is removed from refrigerator and brought to room temperature without any disturbance. The emulsion is filtered through 600 micron IS sieve and sieve is washed with distilled water and checked for residual bitumen (coagulation), if any. As per the test method, there should not be any deposit or coagulation on the sieve. If emulsion is expected to expose below -4°C during storage and transportation, the coagulation is checked after applying 3 freeze and thaw cycles. The complete details of test are described in Annex-C of IS:8887.

3.2.4 *Storage stability*

Storage stability is an important property of bitumen emulsion and it reflects the tendency of bitumen globules settling down over a period of time. Storage stability of bitumen emulsion is determined after 24 h of storage, as per IS:8887. In this test, 500 ml homogenized and previously sieved bitumen emulsion is taken into graduated cylinder of 500 ml capacity and left undisturbed in the laboratory for 24 h at room temperature. The samples, 50 ± 0.1 g each, are taken from the top and bottom of the cylinder into previously weighed beakers of 600 ml capacity. Both the beakers are heated in an air oven at 163 ± 2.8°C for 2 h. The beakers are removed from the air oven and left over residues are stirred and further kept in air oven for 1 h at the same temperature, so as to remove water from the residues. Both the beakers are cooled and weighed to nearest 0.1 g. The difference in the weight of residues should not be more than 2 percent for RS-1, SS-1 and SS-2 grades, whereas it should not be more than 1 percent for RS-2 and MS grades of emulsion as per IS:8887. The complete details of test method are given in Annex-D of IS:8887.

3.2.5 *Particle charge*

The significance of this test is to differentiate between the anionic, cationic and inverted emulsions. In this test method, two steel plates, of size 25 mm X 75 mm, are immersed into emulsion placed at a distance of 25 mm, which are connected to 12 volt DC circuit through a switch, rheostat and a meter. In the test, 4mA current is passed between the electrodes for 30 minutes. At the end of experiment, the electrode plates are washed with distilled water and inspected for any bitumen deposition. In case of cationic bitumen emulsion, the particles of cationic bitumen emulsion get deposited on cathode during the experiment (**Fig. 3.2**). However, there is no deposition of bitumen particles on cathode in case of anionic and inverted bitumen emulsions. The complete detail of the test method has been provided in Annex-E of IS:8887specifications.

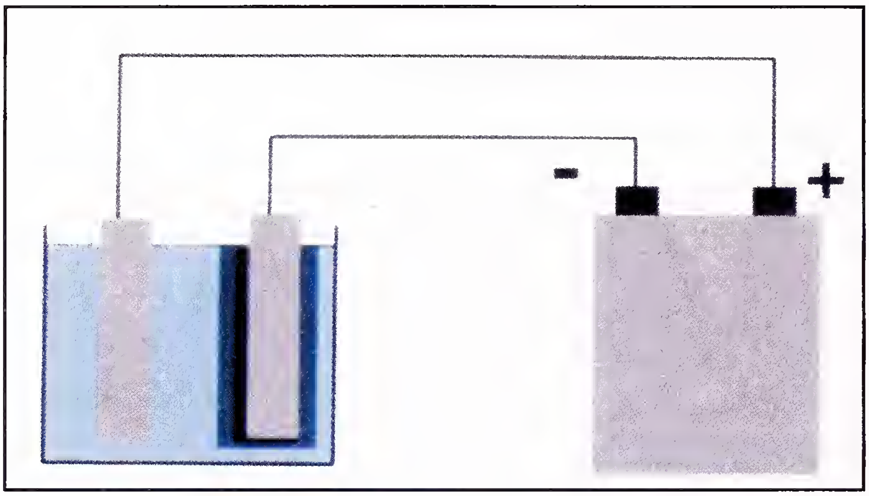


Fig. 3.2 Particle Charge Measurement

3.2.6 *Coating ability and water resistance*

The objective of this test is to determine the ability of bitumen emulsion to (i) coat the aggregates thoroughly, (ii) withstand mixing action while remaining as a film on aggregates, and (iii) resist the washing action of water after the completion of mixing. This test is developed to basically identify the medium setting cationic bitumen emulsion and to evaluate its suitability for mixing with coarse graded calcareous aggregates and is not applicable for rapid setting and slow setting bitumen emulsions. In this test, 460 gm of aggregate (passing through 19 mm IS sieve and retained on 4.75 mm IS sieve) is coated with calcium carbonate dust (4 g) and then mixed with bitumen emulsion (35 g) in a pan. About half of the mixture is then placed on absorbent paper for visual inspection of surface area of aggregate coated with bitumen emulsion. The leftover mixture in the pan is sprayed with water and rinsed with water until the rinse water runs clear. This material is placed on an absorbent paper and inspected for status of coating. 'Good' status means the aggregates are fully coated with bitumen except the pinhole and sharp edges of aggregate. 'Fair' status means the higher surface area is coated in comparison to the uncoated surface area whereas 'Poor' status means lower surface area is coated in comparison to the uncoated surface area.

The second test is repeated in the same manner as above with a difference that the aggregates are wet with water (9.3 ml) before mixing with bitumen emulsion and then are visually inspected for coating.

3.2.7 *Stability to mixing with cement*

This test indicates the ability of slow setting bitumen emulsion to mix with a high surface area material without breaking. In the field, slow setting grade of bitumen emulsion (SS-2) is often used with aggregates containing appreciable amount of fines and dust. In this test, bitumen emulsion sample (that has to be tested) is diluted with water so that it has bitumen content equivalent to 50 percent. This sample (100 g) is mixed with cement (50 g, already sieved with 150 micro sieve) with steel rod for 1 minute. At the end of mixing, 150 ml boiled water is added and mixed for 3 minutes. This mixture is finally washed over 1.4 mm sieve. The material retained on the sieve should not be more than 2 percent of bitumen present in the emulsion as per IS:8887 specifications. The complete details of test method are given in Annex-G of IS:8887.

3.2.8 *Miscibility with water*

The purpose of this test is to identify the types of bitumen emulsion i.e. bitumen in water or water in bitumen. Normally, cationic bitumen emulsions irrespective of the grades are miscible with water, whereas an inverted emulsion (SS-1 grade) is immiscible in water. In this test, 150 ml water, is mixed in 50 ml bitumen emulsion with constant stirring at room temperature. The mixture is allowed to keep for 2 h. As per IS:8887, there should not be any coagulation of bitumen after 2 h. The test method is detailed in Annex-H of IS:8887.

3.2.9 *Residue by evaporation*

Residue by evaporation provides a fair idea of bitumen content present in the bitumen emulsion. This test is conducted on all grades of cationic bitumen emulsions except for invert emulsion (SS-1 grade). In this test, 50 g sample is heated for 2 h in a two litre beaker at 163 ± 2.8°C in air oven. At the end of this period, the residue of beaker is stirred well and further heated for 1 h at 163 ± 2.8°C in air oven. The weight in percentages of the residue is determined after cooling the beaker at room temperature. The details of test method are given in Annex-J of IS:8887.

3.2.10 *Tests on residue*

Tests such as Penetration, Ductility and Solubility in Trichloroethylene are also applicable to the residue of bitumen emulsion as it has to perform the same function as bitumen after coagulation, followed by evaporation and drying of water. The penetration, ductility and solubility in trichloroethylene tests are conducted on residues as per the procedures given in IS:1203, IS:1208 and IS:1216 respectively.

3.2.11 *Distillation test*

Distillation test is performed on Slow Setting grade of Emulsion (SS-1) in place of 'Residue by Evaporation', as it contains higher concentration of organic distillates along with water in comparison to other grades of emulsion. The residue, obtained after distillation at 360°C, should not be less than 50 percent, as per IS:8887. The complete details of test method are given in IS:1213.

3.2.12 *Water content*

Water content is determined only in Slow grade of Setting grade of Emulsion (SS-1) by following Dean Stark test method given in IS:1211. The water content in SS-1 should not be more than 20 percent, as per IS:8887.

3.3 Sampling of Emulsion

The emulsion supplied by manufacture at site shall be collected from drums or tankers as per procedures describe in IS:8887 and IS:1201. In case of tanker, sample of emulsion shall be taken (**Fig. 3.3**) using a 3 kg container mounted on a woodier rode (75 cm length and 2 cm in dia). In case of drums, these have to be rolled to and fro 5-6 times at a distance of 4-5 meters. Sample (2 kg) from the drum will be taken using a pump or tilting drum at 60ºC angle. One sample for 10-20 tonne in case of tanker and 5-10 tonne in case of drums shall be taken at site for evaluation of quality at site.

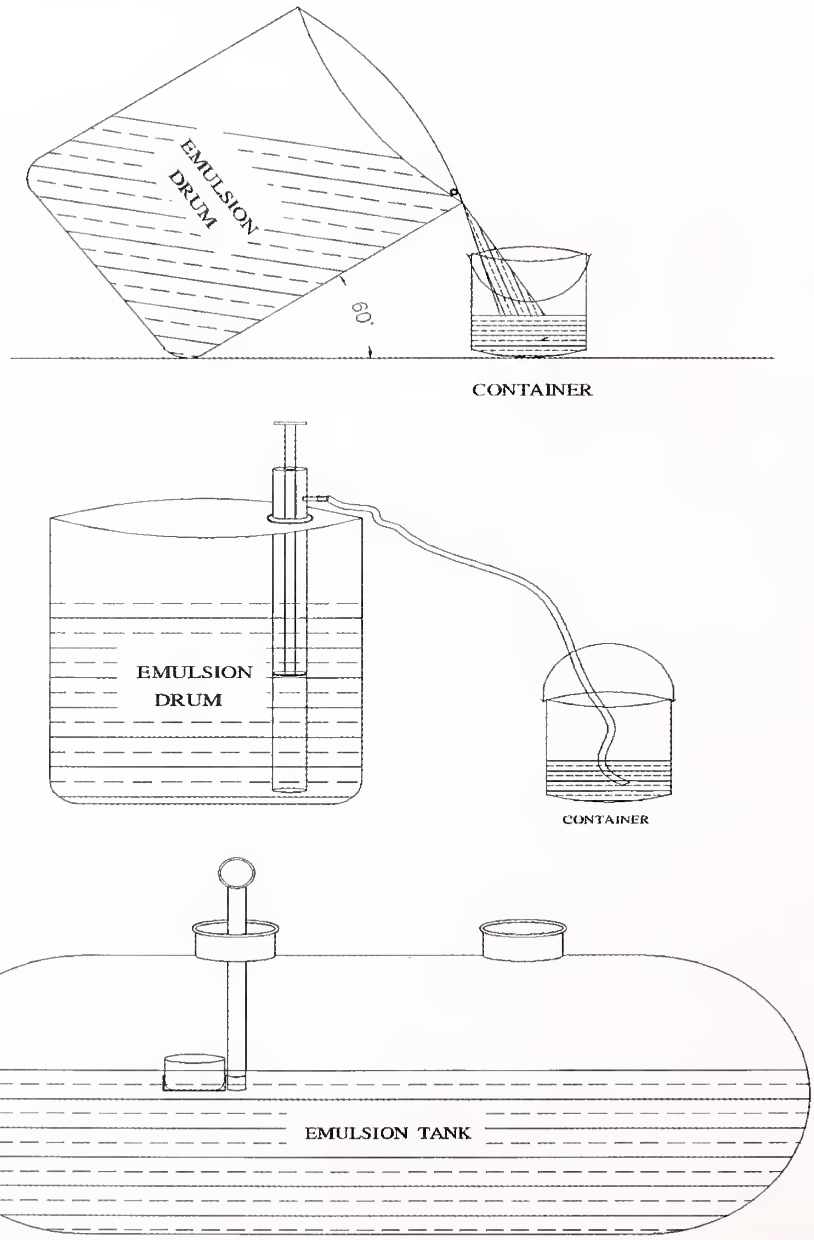


Fig. 3.3 Sampling of Emulsion

3.4 Quick Tests for Quality of Bitumen Emulsion at Site

Site Engineers are always concerned about the quality of bitumen emulsion received at site. The following tests should be carried out at site to ascertain the quality of bitumen emulsion supplied at site.

i) Residue on 600 micron IS sieve, as per test procedure described in section 3.2.1.

ii) Binder content as per test procedure described in section 3.2.9.

iii) Viscosity by flow type viscometer as per test procedure described in section 3.2.2.

4 SPECIFICATION AND TESTING OF AGGREGATES

4.1 Introduction

The understanding of aggregates mineralogy and its impact on the performance of emulsion based mixes is important. This section provide general information's on the composition of rocks, and their interaction with different types of emulsions, and some of the basic tests that are used to determine the suitability of aggregates for use in emulsion based cold mixes are given below.

4.2 Aggregate - Emulsion Interactions

For the purpose of predicting the performance of bitumen emulsion, rocks can be divided into two broad categories. The "oxide" rocks consisting of those with high ratios of silicon oxide (Silicate) or metal oxide content, and the "carbonate" rocks consisting of those with high ratios of Lime stone or Dolomite type minerals. Most of the igneous rocks and Slag fall into the oxide category, while most of the sedimentary rocks fall into the carbonate category. Metamorphic rocks can be in either category, depending on their properties and composition.

Based on the above information and the general principle that using emulsions and aggregate of opposite charges are beneficial, most of the aggregates used worldwide for paving are silicate-based (siliceous) and that is the reason why most of those areas specify cationic bitumen emulsions. Anionic emulsions can be used with Lime stone and Dolomite types of aggregates.

4.3 Testing

The following tests are considered important for deciding suitability of aggregates for cold mixes.

- Sand Equivalent Value Test
- Methylene Blue Test
- Shape Test
- Gradation Test

- Soundness Test
- Aggregate Impact Value Test
- Water Absorption Test
- Stripping Test

The significance and brief of various tests are described below:

4.3.1 *Sand equivalent value test*

This test is used to determine the amount of fine clay particles. This test is done as per ASTM D 2419 (AASHTO T 176) or IS:2720 (Part 37). The value of sand equivalent shall be minimum 50.

4.3.2 *Methylene blue test*

This test is a measure of the relative surface area and surface reactivity of an aggregate's fine fraction. A measured amount of methylene blue dye is mixed with aggregate fines until the fines can no longer absorb additional dye. The amount of dye necessary to surface saturate the fines is an indication of surface area and reactivity. This test is a good method of quality control. As aggregates are supplied for a job, a steady Methylene blue value is an indication that the clay fines content is unchanging. The test shall be done as per ISSA procedure given in EN 933-09.

4.3.3 *Shape test*

The mineral structure of rocks plays a big role in determining the shape of aggregate after crushing. For example, the minerals that contain certain planer crystalline structures will fracture into flat pieces. The shape of aggregate is determined by using flakiness and elongation index tests, as per IS:2386 (Part-IV). The value of combined FI + EI shall not exceed 35.

4.3.4 *Gradation test*

Gradation test is conducted as per IS:2386 (Part-I) for conformity of construction specifications.

4.3.5 *Soundness test*

The test procedure is described in IS:2386-1963 (Part-V). This test indicates the susceptibility of aggregates to disintegration under the action of water containing sodium and magnesium sulphates. Washed and dried aggregates of specified sizes are immersed in saturated solution of sodium sulphate or magnesium sulphate for 16 to 18 hours. This is then removed and dried to constant weight. This forms one cycle. The test is repeated for 5 cycles. After 5 cycles, the sample is washed, dried in an oven and re-sieved on those very sieves which were used before the test. The weight of material retained on each sieve is recorded. The cumulative difference between the amounts weight of material on each sieves before and after the test is the loss due to disintegration and is expressed as percentage of total initial weight of the sample. The permissible values for loss in sodium sulphate and magnesium sulphate after 5 cycles are 12 percent and 18 percent respectively. If the loss is more, then the aggregates are likely to disintegrate by water containing such salts. The test result is to be used as caution rather than as a definite evidence for rejection of the aggregates. The test is carried out when adequate information is not available from service record of the aggregates actually exposed to such weathering conditions.

4.3.6 *Aggregate impact value test*

Aggregate Impact value test is a measure of resistance of aggregates to the disintegration due to impact, which in some aggregates differs from characteristics value of resistance to crushing under slow compressive load. In the aggregate impact value test, as given in IS:2386-1963 (Part-IV) 12.5 to 10 mm sized clean dry aggregates of specified volume are subjected to 15 blows by as 13.5 to 14.0 kg hammer falling from a height of 380 ± 5 mm. The weight of sample of aggregate passing 2.36 mm sieve obtained after the test is expressed as a percentage of the original weight of aggregate and is the aggregate impact value. The aggregate impact values specified for base, binder and surface courses are 30, 27 and 24 percent respectively.

4.3.7 *Water absorption test*

Water absorption is the difference in weight of aggregates between 24 hours water saturated surface-dry condition and oven-dry condition expressed as percentage of the latter. The test procedure is given in IS:2386-1963 (Part-III). Water absorption is high for porous aggregates. The maximum value of water absorption is restricted to 2 percent for aggregates to be used in road construction.

4.3.8 *Stripping test*

Stripping is the displacement of bitumen film from a coated road aggregate particle in the presence of water. The details of test procedure are given in IS:6241. In this test, 200 g of 12.5 to 20 mm sized aggregates are coated with 5 percent bitumen under specified conditions and immersed in distilled water at 40°C for 24 hours. The average percent uncoated area is observed under water. The amount of stripped area, expressed as per cent, is the stripping value. A higher stripping value indicates possibility of loss of adhesion between aggregates and bitumen in the presence of water. The degree of stripping is related to the type of aggregates, shape, size, grain-size, surface texture, mineralogical composition, presence of dust or clay, moisture, acidity or alkalinity etc.

If there is found to be any slight evidence of stripping either by qualitative estimation or by quantitative measurement, incorporation of commercially available anti-stripping agent in bitumen is recommended. It is also recommended to carry out water sensitivity test (Retained Tensile Strength, as per ASTM D 4867) if the minimum retained coating in the test is less than 95 %, meeting the requirement of MoRT&H standard.

5 SPRAY APPLICATIONS

5.1 Prime Coat

Prime coat is an application of a low viscosity bitumen emulsion on a compacted granular base course which penetrate into the base (>8mm). A prime coat performs several important functions as given below:

- Coats and bonds loose mineral particles on the surface of the granular base
- Hardens or toughens the surface of the base
- Waterproof the surface of the base by plugging capillary or interconnected voids
- Provides adhesion or bond between the base and the bituminous mixture.

The emulsion grade like SS-1 (Inverted Emulsion) has been developed for priming. The amount and size of voids in the granular base, temperature, sunshine, and wind will influence the penetration process. In case of very dense surface, it may be necessary to make multiple applications. This is done to improve penetration (>8 mm) and prevent runoff and pudding of the emulsion. For better penetration and reduced tyre pickup catronic emulsion, additives may also we used.

The choice of a bituminous primer shall depend upon the porosity characteristics of the granular surface to be primed as classified in IRC:16. These are listed below:

i) **Surface of low porosity:** Wet Mix Macadam (WMM) and Water Bound Macadam (WBM)

ii) **Surfaces of medium porosity:** Mechanically stabilized soil base, lime/ cement stabilized soil and lime cement base

iii) **Surface of high porosity:** Gravel base, Crusher Run Macadam (CRM) and Crushed Rock Base

The type and viscosity of the primer shall comply with the requirements of IS:8887, as sampled and tested for SS-1 grade in accordance with standard. The quantity of SS-1 grade bitumen emulsion for various granular surface shall be as per **Table 5.1**.

Table 5.1 Quantity of Bitumen Emulsion as Primer for Various Surface Types

Type of Surface	Rate of Spray (kg/10 m^2)
Low porosity (WMM/WBM)	7 to 10
Medium Porosity (Mechanically stabilized soil base, lime/ cement stabilized soil and lime cement base)	9 to 12
High porosity (Gravel Base, Crusher Run Macadam (CRM) and Crushed Rock Base)	12 to 15

Primer shall not be applied during a dust storm or when the weather is foggy, rainy or windy or when the temperature in the shade is less then 10ºC. Surfaces to receive emulsion as primer shall be damp, without standing water. The application of primer in progress is shown in **Photos 5.1 and 5.2**. The details of prime coat application are given in IRC:16.

Photos 5.1 and 5.2 Priming in Progress Using Bitumen Emulsion

5.2 Tack Coat

Tack coat is a light application of low viscosity liquid bituminous material like emulsion to an existing surface (bituminous/cement concrete/primed granular surface) to facilitate a bond between the surface being paved and the overlaying course. The tack coat is recommended for all types of overlays. The only possible exception might be when an overlay is to be placed within 48 hours on a freshly laid bituminous surface that has not been subjected to any traffic or contaminated by dust. Bitumen emulsions commonly used for tack coat are RS-1, SS-1h, CSS-1 and CSS-1h. The detailed requirements of tack coat are given in IRC:16. The recommended rate of application of tack coat is given in **Table 5.2**.

Table 5.2 Rate of Application of Tack Coat

S. No.	Type of Surface	Rate of Spray (kg/10 m^2)
1)	Bituminous surface	2.0 to 3.0
2)	Granular surface treated with primer	2.5 to 3.0
3)	Cement concrete pavement	3.0 to 3.5

The best results of tack coat are obtained if it is applied while the pavement surface is wet and the surface temperature is normally above 25ºC. The surface to be tack coated must be clean and free of loose mineral material. A good tack coat results in a very thin but uniform coating of residual bitumen on the surface, when the emulsion has broken. After spraying the tack coat, sufficient time must be allowed before an overlay is placed for the complete breaking of the emulsion (brown to black colour).

The tack coat distributor shall be a self propelled or towed bitumen pressure sprayer, equipped for spraying the material uniformly at a specified rate. Small areas, inaccessible to the pressure distributor, or in narrow strips, may be sprayed with a pressure hand sprayer.

The details of application of tack coat are given in IRC:16. The tack coat spraying in progress is shown in **Photo 5.3**. The view of good tack coat is shown in **Photo 5.4**. The quality of tack coat can be quantitatively determined by measurement of bond strength (by shear test) on cores taken out from test section. A shear strength value of 2.0 kg/cm^2 is acceptable for good tack coat. A procedure for testing of bond strength is given in **Appendix-1**.

Photos 5.3 & 5.4 Application of Tack Coat Using Bitumen Emulsion and View of Good Tack Coat

Speed additives may be used for quick setting and reduced tyre pick up.

5.3 Crack Sealing

Cracking in the bituminous surface occurs in many forms varying from small hairline cracks (less than 1 mm) to wide cracks having a width of 6 mm or more. Large or severe cracks may not always be correctable by crack sealing using bitumen emulsion. Cracks generally fall into one of the following categories.

- ***Alligator Cracks :*** Interconnected cracks forming a series of blocks resembling to skin of alligator or chicken wire.
- ***Edge cracking :*** Cracking that occurs along the outer edge of the pavement, usually within 300 to 600 mm of the edge. Such cracking occurs when paved shoulders do not exist.
- ***Reflective cracks :*** Cracks in bitumen overlays and surface treatments that reflect the crack pattern of the underlying pavement layers.
- ***Shrinkage or block cracks :*** Interconnected cracks forming series of large blocks, usually with sharp corners or angles.
- ***Slippage cracks :*** Crescent shaped cracks that point in the direction of the thrust of the wheels on the pavement surface.
- ***Linear cracks :*** A crack that may be parallel or transverse to the center line, or randomly located in the pavement surface.

If cracking results from a deflection beneath the pavement surface, it is always doubtful that sealing the cracks by emulsion will provide a longer lasting solution.

The best time of sealing cracks is as soon as these develops. A crack can continue to widen, so crack sealing must be done at the earliest. The failure to seal cracks properly can lead to further and more severe pavement damage due to water intrusion or freeze-thaw. Sealing of cracks with bitumen emulsion is relatively simple and inexpensive and can delay or postpone major maintenance. Before cracks are to be filled, loose material in the crack should be blown out using compressed air. The left out of foreign material in cracks not removed by air blowing should be removed by steel wire brush or compressed in.

Small and medium cracks, less than 6 mm width, are difficult to seal effectively. For large cracks, bitumen emulsion (SS-2) mixed with sand, should be forced into the crack until it is about 3 to 6 mm from the surface. After curing has occurred, finish sealing by filling the remaining depth by light application of dry sand to prevent pickup of material by traffic. The recommended bitumen emulsion grade to be used for crack sealing is SS-2 or its equivalent. A pressure distributor or sprayer may be used for application of bitumen emulsion. The **Table 5.3** provides recommended criteria for crack sealing.

Table 5.3 Recommended Criteria for Crack Sealing

Crack Characteristics	Crack Treatment Activity	
	Crack Sealing	Crack Filling
Width, mm	5 to 19	5 to 25
Edge deterioration (i.e., spalls, secondary cracks)	Minimal to None (≤ 25 percent of crack length)	Moderate to None (≤ 50 percent of crack length)
Annual horizontal movement, mm	≥ 3	< 3
Type of crack	Transverse Thermal Cracks Transverse Reflective Cracks Longitudinal Reflective Cracks Longitudinal Cold joint Cracks	Longitudinal Reflective Cracks Longitudinal Cold joint Cracks Longitudinal Edge Cracks Distantly Space Block Cracks

5.4 Fog Seal

Fog seal is defined as "a light application of diluted (SS-2 or tailor made) bitumen emulsion used primarily to seal an existing bitumen surface to reduce raveling and enrich dry and weathered surfaces. Fog seal is a method of incorporation of bituminous binder to an existing pavement to improve its waterproofing characteristics, preventing further stone loss by holding aggregate in place, rejuvenating surface and improving the surface appearance. However, its inappropriate use can result in a slick pavement. During application, bitumen emulsion wets the surface of the aggregate. Cationic emulsion can displace water from the surface of binder on the aggregate and existing binder film. The rate of breaking emulsion is dependent on several factors including weather conditions (e.g. wind, rain, temperature, etc.).

Rejuvenating emulsion has oils that help in softening of the oxidized binder in existing surface, thus reducing its viscosity. This also improves the flexibility of the binder, which reduces the possibility of cohesive failure. This may be beneficial in situations where the surface has an open texture and the existing binder has become hard and brittle due to aging. As with conventional emulsions, if these do not penetrate the surface, they may create a surface prone to skidding after they break. Fog seals are also useful in chip seal applications to hold chips in place in fresh seal coats. These are referred to as flush coats. This can help prevent vehicle damage arising from flying chips.

A Fog seal is

- Designed to coat, protect, and/or rejuvenate the existing oxidiseal bitumen binder.
- Improve the waterproofing of the surface.
- Reduce aging susceptibility of the surface by lowering permeability to water and air.
- To renew an old bituminous surface that has become dry, brittle and hungry with age.
- To seal small cracks and surface voids
- To inhibit raveling and whip-off chipping by traffic on freshly laid surface dressing

Properly calibrated truck mounted distributors shall be used to apply the emulsion. Spray nozzles with 4 to 5 mm openings are recommended. The emulsion may be heated to maximum 50°C, although, generally the emulsion is sprayed at ambient temperature. The emulsion is sprayed at a rate that is dependent on the surface conditions. A test section representative of the entire surface should be chosen to decide application rate. The total quantity of emulsion in fog seal is normally from 0.5-1.0 l/m^2 of diluted SS emulsion (1:1 dilution). The surface condition or texture, dryness and degree of cracking of the pavement determine the quantity required. Excessive application of the fog seal must be avoided as this will result in pickup of bitumen by vehicles leading to a slippery surface. When excess emulsion is applied, a light application of fine sand on the affected area may be applied to prevent formation of sliding surface. **Photos 5.5 & 5.6** show Fog Seal application.

Photos 5.5 & 5.6 Fog Seal in Progress on a Oxidized Surface

Limitations of Fog Seal : These are given below

1) Fog seals are not useful as seal coats on close graded surfaces without the addition of aggregates as they may create a slippery surface.

2) Fog seals should not be used on Rubberized Asphalt Concrete (RAC) or polymer modified mixes unless the pavements are over five years old as these binders age at a different rate.

3) The application of fog seals is also limited by weather. It should be ensured that the emulsion should fully cure before freezing conditions are encountered. In addition, seal coats applied in the winter have less time to penetrate the pavement and are more prone to cause slick surface conditions.

4) Over application of the fog seal results in the pickup of the bitumen by vehicles and possibly a slippery surface. When excess emulsion is applied, a light application of fine sand on the affected area may correct the problem.

6 SURFACE TREATMENTS

6.1 Introduction

Surface treatments, involving the use of bitumen emulsion, are vital from routine as well as preventive maintenance point of view. The thin surface treatments are used primarily for the following applications:

- To provide an economical, all-weather surface for light to medium traffic. When polymer modified emulsion and high quality aggregates are used, surface treatments may also be used for high volume traffic applications like National Highways.
- To provide a waterproof barrier that prevents the intrusion of moisture into underlying layers
- To provide a skid-resistant surface for the pavements that have become slippery because of bleeding or polishing of aggregates.
- To rejuvenate dry and weathered surface. A weathered and raveled pavement surface can be restored to useful service by application of a single or multiple surface treatments.
- To provide temporary surface for a new granular or bituminous base course.
- To rejuvenate old pavements that have deteriorated because of aging, shrinkage or cracking. Such treatments have little or no structural strength

but can preserve the existing structural value by water proofing and serve as stop-gap measure until the regular rehabilitation is done.

The need for a strong base or sound pavement under surface treatments cannot be overemphasized since surface treatments are not designed to correct a pavement strength that is structurally deficient. The various types of surface treatments, involving the use of bitumen emulsion, are discussed in the following sub-sections.

6.2 Seal Coat

Seal coat is an application of bitumen emulsion based thin layer to an existing bituminous surface. This type of maintenance treatment is applied primarily to improve the existing pavement surface by providing a uniform treatment of seal coat to the surface and to improve its resistance to water percolation. Therefore, seal coat provides an impervious membrane that will slow down the rate of weathing of bituminous layer. The types of bitumen emulsion that can be used for seal coat are SS-2, RS-2, SS-1, SS-1h, CSS-1 and CSS-1h. Seal coats are classified in two categories, as given under:

1) Sand seal coat
2) Liquid seal coat

Sand seal coat with bitumen emulsion many a time is problematic due to lump formation during mixing of sand with emulsion in mixer. Therefore, liquid seal coat should be preferred over open graded premix carpet. For liquid seal coat, bitumen emulsion of RS-2 grade @ 12-14 kg per 10 m^2 area shall be spread over premix carpet and then 6.3 mm passing aggregate shall be spread over it. The aggregate layer shall be compacted with 8-10 tonne roller immediately after the spreading of aggregates to get the finished surface. The details of this technique of construction are given in IRC-14.

6.3 Sand Seal

Sand seal is a spray application of bitumen emulsion followed by light cover of fine aggregates, such as clean sand or screenings. Cold mixed sand seal can be useful in correcting a number of surface defects. Usually, RS-1, CRS-1, MS-1 or HFMS-1 emulsions are applied at a rate of about 0.70 to 1.25 liter/m^2. This is followed by application of about 5.5 to 12 kg/m^2 of sand or screenings cover. In some locations, sand seals are used when good sources of aggregates for chip seals are not available. The cold mixed sand seal is used primarily for following applications.

- Enrich a dry, weathered or oxidized surface. The sand seal will help to prevent loss of material from the old surface by traffic due to abrasion.
- Prevent the intrusion of moisture, when an existing pavement surface begins to crack, moisture may pass into the underlying pavement structure thereby reducing its load bearing ability. A sand seal can provide a barrier to prevent this intrusion.

- Develop a skid-resistant surface texture. By selecting sharp and angular fine aggregate, a highly skid-resistant surface can be provided.

6.4 Surface Dressing

Surface dressing consists of application of bitumen emulsion onto an existing road surface, followed by the application of a single-sized cover aggregates. The aggregates are applied in a single thickness over the emulsion layer and are then rolled in order to "seat" the aggregate particles in the residual bitumen. This application may also be done in two or multiple layers. Such seals are produced with large aggregate in the bottom layer and progressively smaller aggregate in the upper layers. The aggregate size, number of layers, and binder type are chosen based on the projected traffic loading and the condition of existing surface.

Surface Dressing is applied to an existing road surface as an economical maintenance treatment. This should be used on roads that are in good structural conditions but are at a stage in their life cycle, where stresses are developing. Surface Dressing will seal the underlying layer from water intrusion, correct the surface cracking, raveling, surface hardening, and would be able to improve the skid resistance. Normally, surface dressing will not be able to correct the full depth cracking, rutting, or conditions caused by base failures or incorrect mix design reflected by shoving or bleeding.

The emulsion is applied by a mechanical spray distributor truck and aggregates are applied by a specialized chip spreader. The application rates of emulsion and aggregate are determined by a laboratory design method. The ultimate objective is to achieve 60 percent depth embedment of aggregate in the cured residual binder layer with 40 percent of aggregates remaining exposed. Some illustrations of surface dressing are shown in **Photos 6.1 & 6.2**.

For Surface Dressing either rapid setting cationic or anionic (including high float) or modified emulsions can be used. Clean aggregates containing very low fines usually require rapid setting types, while lower quality aggregates with higher water absorption may require medium setting types emulsion to allow proper binder adhesion to the aggregate. For high traffic roads or in more severe climatic conditions, latex or polymer modified bitumen emulsion may be used. Since most of available aggregates are siliceous, cationic types emulsions are preferred for desired adhesion, while anionic including high float emulsions may provide better adhesion with calcareous aggregates under high temperature. The emulsions are of typically higher viscosities which allow them to resist running off and to maintain an appropriate thickness prior to the addition of aggregate. Emulsions offer several advantages over other types of bituminous material as binder for surface dressing:

- Emulsion can be used with damp aggregate
- They do not need elevated temperatures for application
- They eliminate the fire hazard associated with cutback bitumen
- They eliminate pollution associated with cutback bitumen
- They provide quicker chip retention than the cutback bitumen

Photo 6.1 Views of Surface Dressing Work

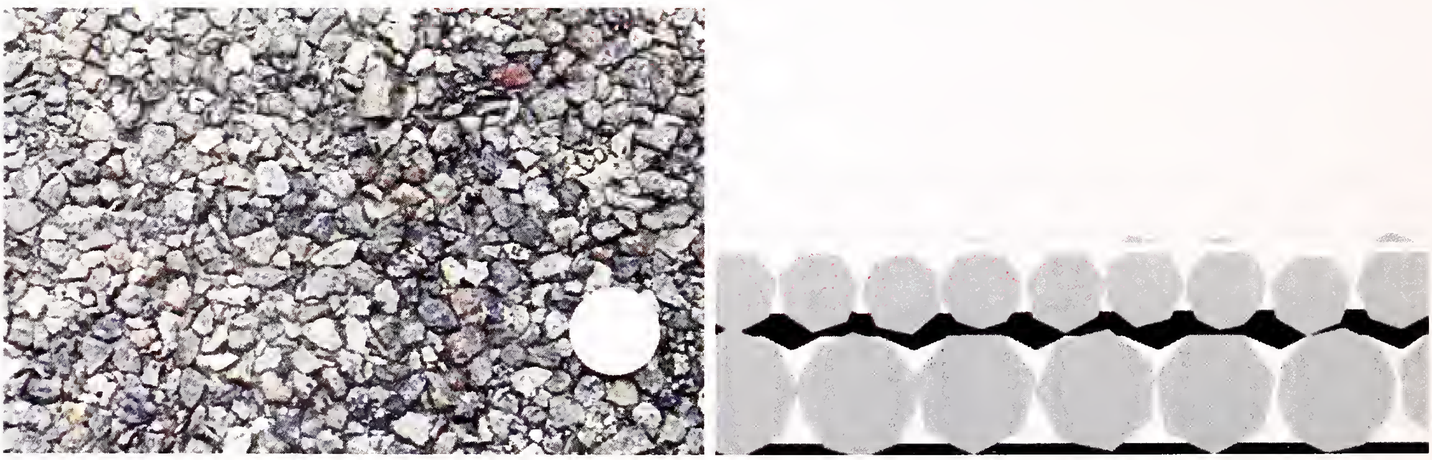


Photo 6.2 Illustrations of Surface Dressing Using Bitumen Emulsion

One of the most important aspects of good performance of surface dressing using emulsion lies in the selection of correct type, grade, and application rate of emulsion as well as the aggregates. When a proper grade is selected, bitumen emulsion for the surface treatment will have the following benefits.

- Be fluid enough during application to spray properly and to cover the surface uniformly

- Retain proper consistency after application to wet the surface being treated and the aggregate applied
- Cure and develop adhesion to the aggregate and surface quickly
- Hold aggregates tightly to the road surface after rolling and curing; preventing loss of aggregate
- Not bleed or strip with changing weather conditions when applied at the correct rate

Table 6.1 presents the types of bitumen emulsion recommended for surface dressing. High volume trafficked roads may require a polymer modified rapid-setting emulsion. For modified emulsion, the aqueous phase of emulsion may be modified by 3 percent latex or SBR or Natural Rubber. **Table 6.2** gives the nominal application rates both for emulsion and chipping. The use of these materials with relatively low temperature produces significant energy-saving. For traditional surface dressing, RS-2 type cationic bitumen emulsion conforming to IS:8887, is recommended. Type and grades of bitumen emulsion and the corresponding temperatures recommended for spraying are given in **Table 6.3**.

Table 6.1 Types of Bitumen Emulsion Recommended for Surface Dressing

Specification	Description and Uses	Construction Guidelines	Typical Bitumen Emulsion
Single Coat Surface Dressing	This is the most important low cost maintenance treatment. It produces an all-weather surface, renews weathered pavements, improves skid resistance, and seals the pavement effectively.	Spray-applied in one layer. Many types of textures available. Keys to success: Use cubical aggregates, Coordinate construction, Use hard and clean aggregate, and properly calibrate spray equipment.	RS-2, Modified
Double Coat Surface Dressing	Two applications of binder and aggregate. The second chip application uses a smaller size stone than the first. It is durable, provides some leveling and is available in a number of textures.	Spray applied in two layers	RS-2, HFRS-2
Triple Coat Surface Dressing	Three application of binder and three sizes of aggregates/chips are applied. It provides upto about 20 mm thick surface.	Spray-applied in three layers	RS-2, HFRS-2

Note : IRC:110 recommends the use of RS-2 grade of bitumen emulsion, mainly because of lack of availability of other grades of bitumen emulsion in India.

Table 6.2 Nominal Application Rates for Binder and Chipping

Nominal Chipping Size (mm)	Emulsion (Residual Binder) (Kg/m²)	Chips (cum/m²)
19	1.2	0.015
13	1.0	0.010
10	0.9	0.008
6	0.75	0.004

Table 6.3 Recommended Spraying Temperature for Various Bitumen Emulsions

Type and Grade of Emulsion	Spraying Temperature °C
CRS-2	50-85
RS-2	50-85
HFRS-2	50-85
Modified	55-85

The aggregate's quality used on the surface is subjected to the abrasive action of traffic. If aggregates are not hard enough to resist wear and tear, the pavement may become a skid hazard when wet. Most of the hard aggregates can be used successfully for surface treatments. The aggregate selected must also meet the job requirements in terms of size, shape, and cleanliness. The grading requirements are given in **Table 6.4**.

Table 6.4 Grading Requirement for Surface Dressing

IS Sieve Designation (mm)	Cumulative Percent Passing by Weight of Total Aggregate Nominal Size (mm)			
	19	13	10	6
26.5	100	-	-	-
19.0	85-100	100	-	-
13.2	0-40	85-100	100	-
9.5	0-7	0-40	85-100	100
6.3	-	0-7	0-35	85-100
4.75	-	-	0-10	-
3.35	-	-	-	0-35
2.36	0-2	0-2	0-2	0-10
0.60	-	-	-	0-2
0.075	0-1.5	0-1.5	0-1.5	0-1.5

The temperature of emulsion shall be 50-75°C using whirling spray jets and 50-70°C using slot jets. The complete details of chip seal/surface dressing are given in IRC:110.

6.5 Open Graded Premix Carpet

Cationic bitumen emulsion of MS grade shall be used for preparation of cold mixed open graded premix. The materials shall be proportioned as per the quantities given in **Tables 6.5 and 6.6** for aggregate and bitumen emulsion respectively.

The existing pavement surface shall be cleaned off dirt, dust and loose materials. The cold mixed open graded premix carpet shall be laid when tack coat turns black from brown. The blended aggregates of 13.2 mm and 11.2 mm nominal sizes in 2:1 ratio, as per the specified requirement, shall be charged in the hot mix plant which shall be used without heating arrangement and suitable modification for incorporation of emulsion. The optimum water content 1 percent by weight of aggregates (if needed) shall then be added to wet the aggregates. The emulsion of MS grade/SS grade/Special grade in required quantity approximately (7 percent by wt. of aggregates) shall then be added into wet gradually aggregate and mixed for two minutes to get uniform coating. Prolonged mixing shall be avoided as it will decoat the aggregates.

The cold mix shall be transported to laying site and shall be spread manually for loose thickness of about 30 mm over the tack coated area. Rolling shall be done as described in IRC:14. The surface shall be opened after 2-3 hours.

Table 6.5 Quantities of Aggregate for 10 m² Area

S. No.	Premix Carpet	
a)	Coarse aggregate of nominal 13.2 mm size: passing IS:22.4 mm sieve and retained on IS:11.2 mm sieve	0.18 m^3
b)	Coarse aggregate of nominal 11.2 mm size; passing IS:13.2 mm sieve and retained on IS:5.6 mm sieve	0.09 m^3

Table 6.6 Quantities of Bitumen Emulsion per 10 m² of Area

A)	For Premix Carpet (MS)		20 to 23 kg
B)	For Seal Coat		
	i)	For Liquid seal coat (RS-2)	12 to 14 kg
	ii)	For Premix seal coat (SS-2)	10 to 12 kg

The cold mixed open graded premix carpet may also be prepared in a concrete mixer. For this purpose, the blended aggregates of 13.2 mm and 10 mm size in 1:2 ratios shall be charged into concrete mixer. The premixing water content @ 1 to 2 percent by weight of aggregate shall be added into the mixer and uniformly mixed to wet the aggregate surface. The required quantity of emulsion of MS grade or tailormade shall then be added and mixed with aggregates for two minutes. Prolong mixing (move then one minute) shall be avoided as it tends to de-coat the binder from aggregate. The cold mix while indicating brown colour shall be discharged into trolleys to transport to the construction site. Tack coating, spreading of cold mix and compaction of cold mix with 8-10 tonne roller shall be carried out to get the finished premix carpet surface. The details of construction are given in IRC:14.

6.6 Mix Seal Surfacing

Cold Mixed Mix Seal Surfacing (MSS), which is a continuous graded mixture, may be used as renewal coat on low trafficked roads. This sub-section deals with the materials and construction procedure for laying cold mixed mix seal surfacing using cationic bitumen emulsion.

For premixing, the binder shall be Slow Setting (SS-2)/Special grade complying with IS:8887 standard or tailor made to be compatible with available aggregate . For tack coat, Rapid Setting (RS-1) grade of cationic bitumen emulsion, complying with IS:8887 standard will be used. The coarse aggregates shall satisfy the entire physical requirements as specified in Section 4. The fine aggregate shall be the fraction passing 2.8 mm sieve and retained on 90 micron sieve. It shall be clean, hard, durable, uncoated and free from soft or flaky and organic or deleterious matter the gradation of aggregates as given in **Table 6.7** shall be used.

Table 6.7 Gradation of Aggregates for Cold Mixed Mix Seal Surfacing

Sieve size	% Passing by weight	
	Type A	Type B
13.2 mm	-	100
11.2 mm	100	88-100
5.6 mm	52-88	31-52
2.8 mm	14-38	5-25
0.090 mm	0-5	0-5

Note : The coarser side of the grading is desirable.

The quantity of aggregate shall be 0.27 m^3 for 10 m^2 area. The quantity of bitumen emulsion (SS-2) shall be 30 kg for Type A and 33 kg for Type B grading.

The base over which cold mixed MSS is to be laid shall be completely free from dust and mud. Where the existing base is having potholes or rutting, defects shall be rectified before laying MSS. For tack-coat, bitumen emulsion of Rapid Setting (RS-1) grade shall be used. The bitumen emulsion is applied on an existing pavement, preferably on damp surface, at the rate of 2-3 kg per 10 sq.m area. In case of dry and hungry surface, emulsion shall be used at the rate of 3.5 kg per 10 sq.m. The tack coat with emulsion shall be applied not earlier than 30 minutes before laying the cold mix. The cold mix shall be laid when tack coat binder turns black from brown colour. It is imperative to prepare the cold mixed MSS using conventional hot mix plant switching off heating arrangement or cold mix plant or any other suitable mixer of adequate capacity. The plant may be either a batch type or a continuous type having two-stage mixer. The bitumen emulsion shall be added into the mixer by having a separate outlet from emulsion tank.

The aggregate shall be charged first into the mixer/pug mill followed by the addition of optimum water content (approximately 1-2 percent) to mixer and then adding the required quantity of bitumen emulsion. The above ingredients shall be mixed for about one minute to achieve the uniform coating. The cold mixed MSS shall be discharged for transportation to laying site. The cold mixed MSS shall be transported from plant site by tipper trucks to the laying site and spreading will be done preferably by means of a self-propelled mechanical paver at an appropriate speed capable of spreading, tamping and finishing the mix, true to the proper grade, line and cross-section. The mix shall be spread in such a manner that, after compaction, the required thickness of layer is laid uniformly for desired thickness.

Longitudinal joints and edges shall be constructed true to the line marking parallel to the centre line of road. Longitudinal joints should be offset by at least 150 mm from those in binder course, if any, and transverse joints or construction joints shall be placed in the original thickness of previously laid mix. The vertical cut face shall be painted with bitumen emulsion prior to the laying of fresh mix against it.

The cold mixed MSS laid with the paver, after change of colour from brown to black due to breaking of emulsion on surface of coated aggregate, shall be thoroughly and uniformly compacted through a set of rollers at a speed not more than 5 km per hour. The initial or break down rolling shall be done with 8-12 tonnes three wheel steel roller followed by final rolling with 8-10 tonnes tandem roller. Before finishing with tandem roller, break down rolling shall preferably be followed by an intermediate rolling by smooth wheel pneumatic roller of 15 to 30 tonnes having a tyre pressure of 7 kg./sq.cm.

The joints and edges shall be rolled with 8-12 tonnes three wheel roller. All the compaction operations i.e. breakdown rolling, intermediate rolling and final rolling shall be accomplished by using a vibratory roller of 8-10 tonnes weight. During final rolling, the vibratory system shall be switched off and wheels of roller shall be kept moist to prevent the mix from sticking to them. Rolling shall commence longitudinally from edges and progress towards the centre except on super elevated portions where it shall progress from lower to the upper edge. Rolling shall be continue till the desired density is achieved and all roller marks are eliminated. Traffic shall be allowed after 3-4 hours provided the mix has been set and does not stick to tyres of vehicles.

Adequate quality control at every stage of the work is essential. A field laboratory shall be set up to ensure the controls. Sieve analysis of each type of aggregate at feeder end should be made to see that the gradation of aggregate reasonably follows the specified designed gradation. The number of samples per day would depend upon the bulk supply of aggregates made in a day at the plant site. The characteristics of these materials shall be determined at the rate of one test for every 50-100 m^3 of aggregates. Periodic checks on emulsion covering binder content, viscosity and residue on 600 micron sieve should be done, in accordance with IS:8887. The emulsion should be thoroughly mixed by rolling the drum to and fro to a distance of 10 metre for about 5 minutes before using emulsion for premixing with graded aggregate. At least one sample for every 100 tonne of cold mix discharged at the pug mill chute or a minimum of one sample per plant per day shall be collected and necessary tests carried out. Bitumen shall be extracted from about 1000 gm of the mix and bitumen content determined. Sieve analysis of aggregates after the bitumen is extracted shall be done to determine compliance of standard gradation.

6.7 Slurry Seal

Slurry seal is a mixture of dense graded aggregate, emulsified bitumen, filler, additive and water. The mixture is applied as surface treatment on the existing surface. Slurry seal can be used for both preventive and corrective maintenance needs. This treatment dose not increase the structural strength of a pavement. A pavement which is structurally weak, should be repaired first for structural deficiency before applying slurry seal. Ruts, humps, distressed pavement edges, crown deficiencies, or other surface irregularities that affect riding quality should be corrected before placing slurry seal. Slurry seal is considered to be a very effective maintenance technique for the surfaces of older pavements. It will fill the surface cracks, stop raveling and loss of matrix, improve skid resistance, generally protect the pavement, reduce water and oxidative deterioration, and finally extend the overall pavement service life. Slurry seal has the following major advantages:

- Rapid application and quick return of traffic to the pavement
- Excellent surface texture and friction resistance
- Ability to correct minor surface irregularities
- Minimum loss of kerb height
- No need for manhole and other structure adjustments
- Excellent low cost treatment for urban streets

Slurry seal is applied in a very thin layer of 3 to 6 mm. The grade of emulsion to be used is SS-2 conforming to IS:8887 or tailor made. The machine used for mixing and application is a self-contained, continuous-flow mixing unit, which accurately delivers materials (pre-determined amount of aggregate, mineral filler, additive, water, and bitumen emulsion) to the mixing chamber. **Tables 6.8 and 6.9** gives the specification requirements for slurry seals and properties of aggregates to be used in slury seal and **Table 6.10** described mix design criterion for slurry seal mix. The details of slurry seal application and construction procedure are given in IRC:SP:81.

Table 6.8 Specifications Requirements for Different Types of Slurry Seal Treatments

Items	Type I (2-3 mm) **	Type II (4-6 mm)**	Type III (6-8 mm)**
Applications	For filling hair cracks on surface cracks less than 1 mm	For filling surface cracks (1-3 mm), and preventive/ renewal treatment (Upto 450 CVPD)	For filling surface cracks (3-6 mm) and preventive/ renewal treatment (Upto 1500 CVPD)
Quantities of Slurry (kg/m^2)	4.3 to 6.5	8.4 to 9.8	10.1 to 12
Residual binder (percent by weight of dry aggregate)	10 to 16	4.5 to 13.5	6.5 to 12

* By weight of dry aggregate only

** Indicative only

CVPD + Commercial Vehicles Per Day

Table 6.9 Properties of Aggregates

Properties	Test Method	Specification
Sand Equivalent Value	IS:2720 (Part 37)	Min. 50
Water Absorption*	IS:2386 (Part 3)	Max. 2.0%
Soundness (with Sodium Sulphate) Soundness (with Magnesium Sulphate)	IS:2386 (Part 5)	Max. 12% Max. 18%

* In case water absorption exceeds 2 percent but is less than 4 percent, the same may be permitted subject to conformity of soundness test and wet stripping test.

Table 6.10 Mix Design Criteria for Slurry Seal Mix

Requirements	Specification	Test Method
Mix Time, Minimum	180 s	Appendix-2
Consistency, Maximum	3 cm	Appendix-3
Wet Cohesion (within 60 min), Minimum	20 kg.cm	Appendix-4
Wet Stripping, Value minimum	90	Appendix-5
Wet Track Abrasion Loss (one hour soak), Maximum	800 g/m^2	Appendix-6

6.8 Microsurfacing

6.8.1 *Introduction*

The Microsurfacing shall consist of mixture of modified (Polymer or Rubber Latex) bitumen emulsion, well graded mineral aggregate, water, filler and additive (if needed) proportioned, mixed and uniformly spread over a properly prepared surface. The finally laid microsurfacing shall have a homogeneous mat, adhere firmly to the prepared surface and provide friction resistant surface texture throughout its service life. The mix is to be a quick setting system i.e. it should be able to receive traffic after a short period of time preferably within about one hours of its laying depending upon weather conditions.

It is applied on an existing pavement surface which is structurally sound but is showing the signs of functional distress such as loss riding quality, cracking and polishing. Generally, microsurfacing is laid in single layer, but when the existing surface is highly polished and/ or cracked, it is advisable to apply it in two or more layers. Microsurfacing can be used for surface treatment on roads, taxi ways and runways. Normally two layers of microsurfacing are advisable on cement concrete surface.

As a surface treatment, micro-surfacing imparts protection to the underlying pavement and provides renewed surface. Special emulsifiers in micro-surfacing emulsions contribute to the quick setting characteristics. Minor re-profiling can be achieved with multiple applications. Special equipment permits the filling of wheel ruts up to 40 mm deep in one pass.

6.8.2 *Benefits of microsurfacing*

The major benefits of microsurfacing technology are given as under:

- Quick application (One lane- km in 35 minutes)
- Minimum traffic hold up (work is done in lane wise manner) quick opening to traffic
- Life span exceeds the life span of ordinary Bituminous Concrete
- Non-polluting for environment since no heating or hot paving is required
- Does not require sensor paver or compaction equipments
- Longer life since oxidation is reduced
- Waterproof Surface – Protection from rains
- Ideal for surface sealing treatment since it improves skid resistance and provides surface durability
- Does not increase pavement height significantly (This saves from water logging, drainage and other associated problems)
- Cost effective as compared to Hot-Mix (Almost 40% saving in Cost)
- Reduces noise caused by movement of traffic
- Environment friendly (reduced emissions)
- No change in road furniture or drainage
- Savings in natural resources

Microsurfacing helps in preservation of pavement strength and can be used both as a preventive maintenance treatment or and periodic renewal treatment on a preferably low, medium or heavy traffic. It can be used for pavements in urban and rural areas, primary and inter-state routes, residential streets, highways, and toll roads. It can also be used on the top of single coat surface dressing (Cape Seal), on open graded premix carpet without seal coat and also on Dense Bituminous Macadam/Bituminous Macadam. Various types of microsurfacing that can be used for different applications; quantity of microsurfacing mix and the residual binder content in each type are presented in **Table 6.11**.

Table 6.11 Different Types of Microsurfacing

Items	Type II (4-6 mm)**	Type III (6-8 mm)**
Applications	For roads in urban and rural areas, residential streets, as preventive and renewal treatment (< 1500 CVPD)	For primary and inter-state routes, highways and runways to give maximum skid resistance, preventive and renewal treatment (> 1500 CVPD)
Quantity* of Microsurfacing (Kg/m²)	8.4 to 10.8	11.1 to 16.3
Residual binder (percent by weight of dry aggregate)	6.5 to 10.5	5.5 to 10.5

* By weight of dry aggregate

** Indicative only

6.8.3 *Constituent materials*

Bitumen emulsion shall be a modified (polymer modified/latex modified) conforming to requirements, as specified in **Table 6.12**. The modifier shall be polymer/ rubber preferably synthetic or natural rubber latex blended into bitumen or aqueous phase of emulsion prior to or during the emulsification process. It may also be required to be specifically designed bitumen emulsion for a particular with regard to the quantity and grading of aggregates. The grading of aggregates is presented in **Table 6.13**.

Table 6.12 Requirements of Modified Bitumen Emulsion for Microsurfacing

Requirement		Specification	Method of Test
Residue on 600 µm IS Sieve (Percent by mass), maximum		0.05	IS:8887
Viscosity by SayboltFurol Viscometer, at 25°C, second		20-100	IS:8887
Coagulation of emulsion at low temperature		Nil	IS:8887
Storage Stability after 24 h (168h), %, maximum		2(4)	IS:8887
Particle charge, + ve / -ve		+ ve	IS:8887
Tests on Residue:			
a)	Residue by evaporation, % minimum	60	IS:8887
b)	Penetration at 25°C /100 g/5 s	40-100	IS:1203
c)	Ductility at 27°C, cm, minimum	50	IS:1208
d)	Softening Point °C, minimum	57	IS:1205
e)	Elastic Recovery*, %, minimum	50	IS:15462
f)	Solubility in Trichloroethylene, %, minimum	97	IS:1216

* In case, elastic recovery is tested for Torsional Elastic Recovery as per **Appendix-7**, the minimum value shall be 20 percent.

Table 6.13 Grading Requirements for Microsurfacing and Slurry Sealing

Sieve Size (mm)	Percentage by Mass Passing (Minimum Layer Thickness)		
	Type I	Type II	Type III
9.5	-	-	100
6.3	-	100	91-100
4.75	100	90-100	70-90
2.36	90-100	65-90	45-70
1.18	65-90	45-70	28-50
0.600	40-65	30-50	19-34
0.300	25-42	18-30	12-25
0.150	15-30	10-21	7-18
0.075	10-20	5-15	5-15

The mineral aggregate shall consist of crushed stone dust, clean hard, durable, uncoated, dry particles and shall be free from dust, soft particles, organic matter or other deleterious substances. Mineral filler shall be Ordinary Portland Cement (OPC). The quantity of filler shall be preferably in the range of 0.5 to 2 percent by the weight of dry aggregate. The water shall be potable, free from harmful salts and contaminants. The pH value of water shall be in the range of 6 to 7. Chemical additive may be used to accelerate or retard the break-set time of the micro-surfacing mix or to improve the resulting finished surface. The quantity of additive, if used, shall be decided by undertaking the mix design and is o be adjusted as per the field/climate conditions such as humidity and temperature at site. The specification of additive needed shall be supplied by suppliers of emulsion. The additive and emulsion shall be compatible with each other.

6.8.4 *Design of microsurfacing mix*

The mix design of Microsurfacing shall be prepared in a fully equipped laboratory and the Job Mix Formula so evolved shall be approved by the client. The compatibility of aggregate, emulsion, filler and additive shall be verified by mix design for the selected grading (Type II or Type III), as specified in **Table 6.14**. The indication values at the ingradients for Microsurfacing mixture is specified in **Table 6.15**. and proposed Microsurfacing mixture shall conform to the requirements specified, when tested in accordance with specified tests. The mix design report shall clearly show the proportions of aggregate, filler, water, and residual bitumen content based on the dry weight of aggregates and additive used (if any).

Table 6.14 Mix Design Criteria for Microsurfacing Mix

Requirement	Specification	Method of Test
Mix Time, minimum	120 s	Appendix-2
Consistency, maximum	3 cm	Appendix-4
Wet Cohesion, within 30 min, minimum	12 kg.cm	Appendix-3
Wet Cohesion, within 60 min, minimum	20 kg.cm	Appendix-3
Wet Stripping Value, % minimum	90	Appendix-6
Wet Track Abrasion Loss (one hour soak), maximum	538 g/m²	Appendix-7

Table 6.15 Indicative Limits of Ingredients in Mix

Ingredients	Limits (Per cent by weight of aggregate)
Residual Bitumen	6.5 to 10.5 for Type II 5.5 to 10.5 for Type III
Mineral Filler	0.5 to 3.0
Additive	As needed
Water	As needed

Aggregate, modified bitumen emulsion, water and additive (if used), shall be proportioned by weight of aggregate utilizing the mix design approved by the Engineer-in-Charge. If more than one type of aggregate is used, the correct amount of each type of aggregates which have been used to produce the required grading, shall be proportioned separately prior to adding other materials of the mixture, in a manner that will result in a uniform and homogeneous blend. Final/completed mixture, after addition of water and any additive, if used, shall be such that the microsurfacing mixture has proper workability and permits traffic within one hour depending upon the weather conditions, without occurrence of raveling and bleeding. Trial mixes shall be prepared and laid for the designed mix and observed for breaking time and setting time. The wet track abrasion test is used to determine the minimum residual bitumen content. Procedure for calibration of microsurfacing machine is given in **Appendix-8**.

Details of Microsurfacing application are given in IRC:SP:81.

6.9 Cape Seal

Cape seal involves application of a slurry seal or micro-surfacing to a newly-constructed single coat surface dressing treatment. The slurry or microsurfacing application helps to fill the voids between the chips. Cape seals provide highly durable surface treatment. The slurry or microsurfacing bonds the chips to prevent loss of the chips due to traffic abrasion. For a successful cape seal, it is important to have single coat surface treatment with lower residual bitumen content than a traditional chip seal. The most critical element to avoid in a cape seal is an excess of slurry that eliminates the desired knobby surface texture. Curing time of four to ten days should be allowed between placement of the broomed surface after surface dressing and before application of slurry seal or microsurfacing to remove loose cover material or other foreign material that would prevent adherence. **Table 6.16** gives quantities of bitumen emulsion and aggregates required to execute a cape seal. For surface dressing RS-2 emulsion shall be used. For slurry seal SS-2 grade emulsion shall be used. Polymer modified emulsion shall be used if microsurfacing is used as top layer.

Table 6.16 Quantities of Bitumen Emulsion and Aggregate for Cape Seal

Thickness of Cape Seal	Nominal Size of Aggregate	Quantity of Aggregate (kg/m^2)	Quantity of Emulsion (kg/m^2)	Slurry Mixture (Type 1), kg/m^2
12.5 mm Thick	9.5 to 2.36 mm	14-16 (25-30)	1.4-2.0 (0.30-0.45)	2.7-4.5 (6-10)
19.0 mm Thick	19.0 to 9.5 mm	22-27 (40-50)	1.8-2.3 (0.40-0.50)	3.5-5.5 (8-12)

Details of construction of chip seal and slurry seal are given in IRC:110 and IRS:SP:81. respectively.

7 COLD MIXES

A cold mix is defined as a mixture of bitumen emulsion and aggregate that is mixed together at ambient temperature. Bitumen emulsion being liquid at room temperature, there is no need to heat or dry the mineral aggregate. Cold mix is useful in the areas, where there is long distance between the job site and plant and temperature of climate is low and moderate (<40°C). Further, the versatility of cold mix allows it to be mixed in-place at the job site as well as at a plant site and then subsequently transported to the job site. Cold mix may be used in bituminous base (BM), binder course (BM/SDBC) as well as wearing course (SDBC) of flexible pavement. These mixes may be designed for a broad range of bitumen emulsions, aggregates, field conditions and tailored to specific performance requirement. The cold mix should be designed to meet the performance requirements which include workability, coating, strength development, and other applicable targets. The quality of residual bitumen, aggregate, and climatic conditions should be taken into account.

The important elements for design of an acceptable cold mix are described below:

a) ***Coating :*** The emulsion should have ability to coat the aggregate effectively without balling of fines. Sometimes, the quality of emulsion, mixing water and aggregate may also influence the coating.

b) ***Workability :*** The mixture must maintain its workability during production, laying and storage (in case of stockpiled mixes) prior to its application.

c) ***Run-off :*** The design should ensure that emulsion run-off from mixture will not occur. For open graded mixes, it is important that emulsion does not drain down through the voids in aggregate.

d) ***Aggregates quality :*** The sand equivalent value test shall be carried out to ensure that clay content is not in excess. A sand equivalent value (as per IS:2720) of 50 and above is preferred.

e) ***Bitumen content :*** The amount of residual bitumen required in the mix is determined based on the surface area of the aggregate and typically varies between 4 to 6 percent residual bitumen by weight of dry aggregate depending upon gradation selected.

f) ***Moisture susceptibility :*** For moisture susceptibility of the mix to intrusion of water, boiling or immersion tests may be used in conjunction with coating by visual observations.

g) ***Strength :*** Progressive strength gain can be determined using Marshall Stability Test. Minimum strength requirements will be set by the design criteria depending upon the type of mixture (open graded/dense graded).

This section deals with the different types of cold mixes which may be used for construction and maintenance of roads.

7.1 Cold Mixed Bituminous Macadam (CMBM)

Bituminous Macadam (BM) is an open graded bituminous mixture suitable for moderate traffic roads used for construction of bituminous base course as well as for strengthening of flexible pavements. Cold Mixed Bituminous Macadam (CMBM) shall involve construction of one or more courses of compacted mixture prepared with bitumen emulsion and mineral aggregate, laid immediately after mixing to required grade and camber using appropriate machinery.

7.1.1 *Properties of materials*

The aggregates shall consist of crushed stone, crushed slag, crushed gravel (shingle) or other suitable. The aggregates shall be clean, strong, durable and fairly cubical, free from clay and disintegrated pieces, organic and other deleterious matter. The coarse aggregates shall be crushed material retained on 2.36 mm IS sieve while fine aggregates shall be fraction passing, 2.36 mm sieve and retained on 75 micron sieve. The aggregate shall satisfy the physical requirements as given in **Table 7.1** with sand equivalent value of more than 50. The requirement of filler (material passing 75 micron sieve) in CMBM shall be met from stone dust, cement, hydrated lime or any other non-plastic mineral matter. The blended aggregates for CMBM shall satisfy the grading given in **Table 7.2**.

Table 7.1 Requirements of the Aggregates for Cold Mix

Property	Test	Specification	Method of Test
Cleanliness (dust)	Grain size analysis	Max 5% passing 0.075 mm sieve	IS:2386 Part I
Particle shape	Combined Flakiness and Elongation Indices*	Max 35%	IS:2386 Part I
Strength	Los Angeles Abrasion Value or Aggregate Impact Value	Max 35% Max 27%	IS:2386 Part IV
Durability	Soundness either: Sodium Sulphate or Magnesium Sulphate	Max 12% Max 18%	IS:2386 Part V
Water Absorption	Water Absorption	Max 2%	IS:2386 Part III
Stripping	Coating and Stripping of Bitumen Aggregate Mix	Minimum retained coating 95%	IS:6241
Water Sensitivity	Retained Tensile Strength**	Min. 80%	AASHTO 283
Fine clay particles	Sand Equivalent Value	Minimum 50	IS:2720 (part 37)
Surface reactivates	Methylene blue	Max 10	ISSA

Bitumen emulsion for preparation of CMBM shall be Medium Setting (MS), Slow Setting (SS-2) grade or a tailor made for compatibility with available mineral aggregates, conforming to IS:8887 or other international standard (ASTM or AASHTO). The actual grade of the emulsion to be used would depend on the characteristics of the aggregates. If the sand equivalent value of the aggregates is between 50 to 70, use SS-2 grade of emulsion and for sand equivalent values more than 70, use MS grade of emulsion. The Rapid Setting (RS-1) grade of bitumen emulsion, conforming to IS:8887 shall be used in Tack Coat.

Table 7.2 Grading of Aggregates for Compacted Thickness of 50 mm CMBM

Sieve size, mm	Percent passing by weight
26.5	100
19.0	90-100
13.2	56-88
9.5	20-55
4.75	16-36
2.36	4-19
0.30	2-10
0.075	1-4
Sand Equivalent Value (ASTM D2419)	50 Minimum
Percent Crushed Faces	75% Minimum
Bitumen Emulsion % by Weight of Mix	5% Minimum

* Minimum residual bitumen 3.5 percent

7.1.2 *Quantities of materials*

The approximate quantity of mineral aggregates required for 50 mm compacted thickness of CMBM shall be 0.60 to 0.75 m^3 for 10 m^2 area. Bitumen emulsion (MS,SS-2 grade or any other suitable grade) required for premixing of bituminous Macadam shall be added at the rate specified rate depending on the gradation of aggregates after adding premixing water (1 to 3 percent). The quantity of emulsion may be slightly higher for an absorptive type of aggregates (water absorption exceeding 2 percent). RS-1 grade shall be applied for tack coat @ 3.0 kg/10 m^2 on primed Water Bound Macadam (WBM) or Wet Mix Macadam (WMM) surface. In case, CMBM is to be laid over the existing bituminous surface, the tack coat of RS-1 grade shall be applied @ 2.5 kg/10 m^2 area which should also meet the requirement of bond strength, as determined by the method given in **Appendix-1**. The CMBM shall be laid when the color of tack coat turns black from its original brown colour.

7.1.3 *Mixture design*

The detailed procedure for determining the job mix formula for CMBM is given in **Appendix-9**.The indicative design criteria for CMBM is given **Table 7.3**.

Table 7.3 Indicative Design Requirements for CMBM

i)	Number of compaction blows on each side of Marshall specimen	50
ii)	Marshall Stability at 25°C in kg (minimum), after curing the specimen in air (72 hours)	350
iii)	Marshall flow (mm) at 25°C	Max. 8
iv)	Per cent voids in mixture	10-14
v)	Binder content (residual bitumen) by weight of total mix (%),min	3.5
vi)	Retained indirect tensile strength at 25°C after conditioning for 72 hours in air and 24 hours at 40°C, in water %.	50

7.1.4 *Construction of CMBM*

CMBM shall not be laid during raining or when the granular base course is wet or when the atmospheric temperature in the shade is below 8°C. All equipment necessary for the proper construction work shall be available at the work site in good working condition. Adequate provisions for safe movement of vehicular traffic shall be made in advance. The underlying surface on which CMBM is to be laid shall be prepared, shaped and conditioned to a uniform grade and camber. Depressions, ruts or potholes shall be repaired in advance at least before the day of laying. The surface of underlying course shall be thoroughly swept, made clean free from the dust and foreign materials. If the existing base is extremely uneven, a profile correction course may be considered. The tack coat with emulsion shall be applied not earlier than 10 minutes before laying the cold mix.

It is imperative to prepare cold mix of proper and uniform quality by using a cold mix plant or a modified hot mix plant switching off the heating. The production of high quality cold mixes requires a well-controlled operation. The set up for a central cold mix plant may vary depending on the quality required and the type of mix. It is recommended that the plant shall have (1) a twin shaft pug mill, (2) a tank for emulsion storage, (3) metered pumps for emulsion transfer to pug mill and water, valves and spray bars, (4) aggregate feeder bins, (5) conveyor belts for moving aggregate and mix, and (6) a power source. The pug mill should allow a variation in the mixing time to ensure proper coating of aggregate with emulsion. The use of a surge bin or storage silo is desirable for continuous mixing and improved mix uniformity. Batch type pug mills can be used but the production of cold mixes is ideally suited for continuous type mixers. The ingredients shall be mixed for about one minute to achieve the uniform coating of bitumen on mineral aggregates. Excessive mixing may un-coat the aggregates.

For plant produced cold mixes, the paving procedures are similar to those used for hot bituminous mixes. The self-propelled pavers are recommended. Cold mixes are generally stiffer than hot mixes or not as workable as hot mixed materials, with open-graded mixture being the most difficult to place. Proper paver operation is thus very critical for obtaining a uniform and smooth mat. This includes keeping the paver speed as constant as possible and the level of mix on the augers at a nearly constant depth. If the mix sticks to paver screed or tearing of the mat occurs, a change in the mixing time or the water content should be effected which would eliminate the problem. The screed should not be heated.

For an open-graded mix like the CMBM, the breaking of bitumen emulsion usually occurs quickly. With open-graded mixes, rolling may normally begin immediately behind the paver. Vibratory rolling for open-graded mixes is not recommended because fracture of aggregate and bitumen debonding may occur. A light “choke” or “blotter” of a coarse sand or fine crusher screenings may be applied after steel-wheeled rolling. The choke or blotter permits rolling with a pneumatic-tired roller and prevents pick-up of mix and damage of compacted cold mix layer by the traffic. Properly designed uniformly cold mix shall be discharged to the tippers for transportation to site. The spreading of cold mix will be done preferably by means of a self propelled mechanical paver at a suitable speed capable of spreading, tamping and finishing to the proper grade, line and cross-section. The mix shall be spread in such a manner that, after compaction, the required thickness of surfacing layer is achieved. The paver laid cold mix, after becoming black from original brown colour due to breaking of emulsion on surface of aggregate, shall be thoroughly and uniformly compacted by a set of rollers at a speed not more than 5 km per hour. The break down rolling shall be done with 8-12 tonne three wheel steel roller and the final rolling shall be done with 8 to 10 tonne tandem roller. Before finishing rolling by tandem roller, break down rolling shall preferably be followed by an intermediate rolling with smooth wheel pneumatic roller of 15 to 30 tonne capacity having a tyre pressure of 7 kg/cm^2. The wheels of the roller shall be kept moist to prevent the picking up of mix. Rolling shall commence longitudinally from edges and progress towards the centre except on super elevated portions, where it shall progress from lower to the upper edge. Rolling shall be continued till the specified density is achieved and all roller marks are eliminated. Traffic shall be allowed after 2-3 hours, when the cold mix is well set and is not picked up by the vehicles.

Adequate quality control at every stage of the work is essential. Therefore, field laboratory must be set up. Periodic sieve analysis of each type of mineral aggregate shall be done to ensure that the gradation of aggregate follows close to the original gradation of designed job mix. The number of samples to be taken per day would depend upon the bulk supply of aggregates made in a day at the plant site. The characteristics of mineral aggregate shall be determined at the rate of one test for every 100 m^3 of aggregates. Periodic checks of the properties of emulsion such as residue content, viscosity and residue on 600 micron IS sieve shall be done in field, in accordance to IS:8887-2004. At least one sample for every 100 tonnes of cold mix discharged at the pug mill chute or a minimum of one sample per plant per day shall be collected and various tests shall be carried out. These specimens shall be tested for density. Residual bitumen shall be extracted from mix after curing and emulsion shall be determined.

For the compacted surface of every 700 m^2 or less, one field density test shall be conducted to determine the density of mix as laid and compacted. The density shall not be less than 95 percent of the maximum laboratory density. The longitudinal profile of the finished surface shall be tested by 3 m straight edge, parallel to the centre line, and the transverse profile by a camber template. Any irregularity greater than 6 mm shall be corrected.

7.2 Cold Mixed Semi Dense Bituminous Concrete (CMSDBC)

Semi dense bituminous concrete (SDBC) is a continuously graded mix, which can be used as binder course or wearing course in a flexible pavement. This section deals with the design and construction of 40 mm thick Cold Mixed SDBC using cationic bitumen emulsion.

7.2.1 *Properties of materials*

CMSDBC shall consist of coarse aggregate, fine aggregate and filler (Conforming the requirement given in **Table 7.1**) in suitable proportion mixed with sufficient quantity of mixing water and cationic bitumen emulsion. Representative samples of aggregates, proposed to be used for the specific job, shall be tested in the laboratory and proper blend of aggregate shall be worked out so that the gradation of final aggregate mix will satisfy the specified gradation, set forth in **Table 7.4**.

Table 7.4 Gradation of Aggregate in CMSDBC

Sieve Size (mm)	Percent Passing by Weight
13.2	100
9.5	90-100
4.75	35 -51
2.36	24-39
1.18	15-30
0.300	9-19
0.075	2-8
Sand Equivalent Value (ASTM D2419)	50 Min.
Percent Crushed Faces	75 Min.
Bitumen Emulsion(SS-2 or tailor made) by Weight of Mix	8-10%

The optimum bitumen emulsion content (OBEC) shall be arrived at by Marshall method of mix design worked out in the laboratory and by using SS-2 grade of cationic bitumen emulsion.

Coarse aggregate shall be the fraction retained on 2.36 mm sieve and fine aggregates shall be the fraction passing 2.36 mm sieve and retained on 75 micron sieve. These shall consist of crushed screenings, natural sand or a mixture of both and shall be clean, hard, durable, uncoated and free from injurious, clay, soft or flaky pieces, organic or deleterious matter. The aggregate shall satisfy physical requirements given in **Table 7.1**. The shelf life of bitumen emulsion shall be such that it meets the physical requirements, as given in earlier **Table 3.2**, at the time of its use. The dates of manufacture and expiry shall be clearly indicated on the drums.

7.2.2 *Design of CMSDBC*

Design criteria for CMSDBC is given in **Table 7.5**. The laboratory mix design gives proportions of different mineral aggregates in terms of individual sieve size, for the purpose of actual construction in the field. Blending of two or more sizes of aggregates (each size having within it a range of individual sieve sizes) would be necessary. The blending ratio is obtained on a weight basis, giving the percent weight of coarse aggregate, fine aggregate and filler needed to give the ultimate gradation based on unit weight or bulk density of aggregates supplied. The mineral aggregate in combination with the optimum premixing water content and bitumen emulsion content, as determined in the laboratory, constitutes the job mix formula for implementation during the construction. The cold mix design shall be worked out based on a correct and truly representative sample of materials that will actually be used in the given construction project. The detailed procedure evolved for mix design of CMSDBC using cationic bitumen emulsion, is given in **Appendix-9**.

Table 7.5 Requirements of Cold Mixed SDBC

i)	Number of compaction blows on each side of Marshall specimen	50
ii)	Marshall Stability at 25°C in kg (minimum), after curing the specimen at room temperature for 72 hours	500
iii)	Marshall flow (mm)	Max. 8
iv)	Per cent voids in mixture	6 – 10
v)	Binder content (residual bitumen) by weight of total mix (%),min	4.5
vi)	Retained indirect tensile strength at 25°C after conditioning for 72 hours in air and 72 hours at 40°C, in water %	75

7.2.3 *Construction of CMSDBC*

Same as described in Section 7.1.4.

7.2.4 *Quality control*

The quality control tests and frequency are given in **Annexure-II**.

7.2.5 *Precautions in laying of cold mixes (BM and SDBC)*

Following precautions should be taken to ensure successful laying of cold mixes and to achieve good performance

- Cold mixes generally have good resistance to detrimental effects of water damage during construction. However, if rain occurs before the mixture is cured, traffic should be kept off, until the mix is cured and the necessary compaction is accomplished.
- The mixing water content should be just sufficient required to adequately disperse the emulsion and achieve good workability
- Mixtures should be mixed only enough to properly disperse the emulsion. Excessive mixing may cause the emulsion to break prematurely or strip from the mineral aggregates
- For faster curing, place the cold mix in several thin layers rather than in a single thick layer.
- If case raveling observed due to traffic, the loose material should be broomed off as soon as possible to prevent further damage to the surface. If the raveling continues, the surface should be fog sealed with a light application of a slow-setting emulsion diluted with soft water in 1:1 ratio.

7.3 Bituminous Cold Mixes (Including Gravel Emulsion)

This includes providing cold mix consisting of mixture of unheated mineral aggregate and bitumen emulsion, laid in a single layer of 25-75 mm. Details are given in Clause 518 (Specification for Roads and Bridges Works), 5th Revision 2013.

8 HALF WARM MIXES

Half warm mixes are those mixes in which the bituminous binder is either a bitumen emulsion or foamed bitumen, which is mixed with warm aggregates (100 ± 10°C), laid and compacted at temperature between 80-90°C.

Half warm mixes are considered as low energy mixes, which can be used for construction and maintenance of bituminous courses for all climatic and traffic conditions. The production of a half warm mix using bitumen emulsion as the binder is comparable to production of hot mix using hot and melted paving bitumen. However, the mixing time is less in case of half warm mix and the plant operating temperatures are also lower. The prime advantages of producing half warm mixes (DBM, SDBC and BC) using warm aggregate and cationic bitumen emulsions are as under:

- ➢ Reduced mixing time
- ➢ Ability to coat large size aggregate at lower temperature
- ➢ Reduction of bitumen hardening during mixing

8.1 Materials for Half Warm Mixes

The half warm mixed dense bituminous macadam, semi-dense or dense bituminous concrete shall consist of coarse aggregate, fine aggregate and filler in suitable proportion mixed with sufficient quantity of cationic bitumen emulsion. Representative samples of the aggregates proposed to be used for the specific job shall be tested in the laboratory and a proper blend of the aggregate shall be worked out so that the gradation of final aggregate mix will satisfy specified aggregate gradations, of DBM, SDBC and BC.

Half warm mixes shall consist of coarse aggregate, fine aggregate and filler (Conforming the requirement given in **Table 7.1**). The bitumen emulsion shall be cationic SS-2 grade confirming to IS:8887 specification or a tailor made for the aggregate to be used in construction. The requirements of bitumen emulsion are given **Table 3.2 (Section 3)**. Design of half warm aggregate based mix prepared with bitumen emulsion shall be done by Marshall Method. The design criteria is given in **Table 8.1**.

Table 8.1 Requirements of the Warm Mix Prepared with Bitumen Emulsion

i)	Number of compaction blows on each side of Marshall Specimen	75
ii)	Marshall Stability at 60°C in kg (minimum), after curing the Marshall Specimen for 24 h	900
iii)	Marshall flow (mm)	Max. 5
iv)	Per cent Voids in Mix	3-6
v)	Binder content (Residual Bitumen) by weight of total mix (%),min	4.5
vi)	Retained Marshall Stability, Ratio	80

8.2 Preparation of Mixture

The mixing plant may be either a batch or drum mix plant. Incase of batch plants, the pug mill mixing chamber should be vented to allow for the steam to escape. The discharge end of the bitumen emulsion circulating pipe should be kept below the surface of the emulsion in the storage tank to prevent foaming. The bitumen transfer system must allow turning off or reducing the heat on all lines, pumps and jacketed bitumen weigh buckets. The temperature of the emulsion should never reach 90°C and it should be kept about 75 to 85°C. The minimum mixing time needs to be established and shall be based on the amount of coating of aggregate particles as determined by ASTM D 2489, "Test for Degree of Particle Coating of Bituminous-Aggregate Mixture". The minimum acceptable percentage of coated particles will vary with aggregate gradation, particle shape, surface texture, bitumen content and use of the warm or hot mixed material. Warm bitumen emulsion mixes are produced at a temperature between 80 to 85°C. The temperature of aggregate is kept in between 95 to 105°C.

8.3 Construction Procedure

Procedure for construction shall be same as for cold mixes. Warm or hot emulsion mixes typically are spread with a self-propelled sensor paver. For warm emulsion mixtures, a minimum delay should occur between discharge from the mixing plant and placement of mixture to prevent it from becoming stiff and difficult to spread. However, some warm emulsion mixtures, produced with emulsions having very soft bitumen residue and a small quantity of solvent, may be stockpiled and placed cold. For warm emulsion mixes, compaction should begin when the mix will support the roller without shoving. For warm mixes, the breakdown rolling can be completed with a self-propelled pneumatic or double drum (tandem) vibratory roller followed by finish rolling with a steel wheeled roller.

8.4 Quality Control

The details of quality control may be referred to **Annexure-II**.

9 MAINTENANCE MIXTURES USING BITUMEN EMULSION

9.1 Introduction

Maintenance is essential for upkeep of the road. The most time consuming and neglected maintenance activities include patching, filling potholes and repair of other failed local areas of the pavement. It is well known that the use of, hot mix is preferred for patch work. The quality hot mix is not available throughout the year at many locations like areas of cold climate and high rainfall. Therefore, patching may be accomplished using cold mixes. Maintenance mixes consist of the following types:

1) Mixes for Immediate Use
2) Storable Mixes
3) Maintenance mixes using RAP
4) Ready Made Mixes

9.2 Maintenance Mixes for Immediate Use

Such emulsion-aggregate mixes can be mixed in a pug mill or in a concrete mixer and transported to the site where these are to be used. The heating of the aggregate is normally not necessary. In cold weather conditions, warm aggregates and emulsions heated upto 50 to 85ºC can be used for better workability. Precautions to be taken during heating of emulsion are given in **Section 2.8**. Procedure for preparation of mix for immediate use and storable mixes is given in **Appendix-10**.

The bitumen emulsions recommended for patching mixes are MS, SS-2 grades or tailor-made. Aggregates should meet the requirements specified previously in **Section 4**. The aggregate gradation recommended is given in **Table 9.1**. Bitumen emulsion containing small amounts of solvents generally produces the acceptable patching mixes for immediate use.

Table 9.1 Grading for Maintenance Mixes

Sieve Size	Percent Passing
9.5	100
4.75	40-100
2.36	10-40
1.18	0-10
0.075	0-2

The quantity of emulsion shall be 7 to 8 percent by weight of aggregate.

9.3 Storable Maintenance Mixes

During the cold weather and rainy months, most of the maintenance mixes used are those which may be stored/stockpiled, which can be produced in late summer or early months of winter, transported and stored for later use. Such mixes are usable for periods up to six months and are workable without the use of heat. These must be covered by polythene or tarpoline. The production of stockpile maintenance mix is simple and includes a pug mill type mixer. Slow setting (SS-2) grade or tailor made emulsion is to be used for this purpose. The aggregate gradation for stockpile mixes is same as given in **Table 9.1**. The duly mixed material shall be stored in a clean, covered area to prevent contamination and not stored in a low area or depression where water could get into the mix. For prolonged stockpiling and to be usable at lower temperatures, a high float medium setting emulsion is recommended. These mixes may contain residual bitumen in the range of 4.5 to 5.5 percent depending on gradation and surface characteristics of aggregates.

9.4 Maintenance Mixes Using RAP (MMRAP)

Many bitumen pavement overlay projects include cold milling of bituminous surface and can produce large quantities of Reclaimed Asphalt Pavement (RAP). There are a number of uses for RAP in pavements application, and an increasing one is to use it in maintenance mix.

It is recommended that, when possible, cold milling be used which produces RAP material in small pieces so that it would not require further crushing. Bitumen emulsion is usually incorporated to the RAP by plant mixing. Special emulsion formulations have been developed for preparing RAP maintenance mixes, since softening of the aged RAP asphalt binder is desired. Emulsion contents in the range of 1.5 to 2.5 percent by dry weight of RAP are typical for these mixes. RAP maintenance mixes are stored in stockpiles and their handling is very similar to traditional emulsion maintenance mixes. Normally extra slow SS-2 emulsion with more solvent is useful. These mixes may be used successfully for both thin and deep patching including potholes repair. In area where coarse, crushed aggregates are not available, the use of RAP usually results in superior maintenance mixes to those produced from local aggregates.

9.5 Readymade Maintenance Mixes

Ready to use proprietary cold mix patching materials are also effective for instant repair of potholes on roads under inclement weather and operating conditions. These mixes are expected to contain 5 to 6 percent of residual bitumen and continuously graded aggregates. A typical grading for such mixes is given in **Table 9.1**. Such mixes can be stored upto six months from date of manufacture.

9.6 Quality of Maintenance Mixes

The following tests shall be carried out for assessment of the quality of maintenance mixes. Test procedures are given in **Appendics 11 to 13**. The procedure for carrying out the bond test is given in **Appendix-1**.

- Water resistance test
- Workability test
- Binder content
- Bond test

9.7 Procedure for Repair of Potholes Using Maintenance Mixes

9.7.1 *Preparation of potholes*

Pothole shall be cleaned of loose material and dust with a stiff wire brush. Pothole need not be dry. However, excess water, if any in the pothole, shall be removed. A tack coat shall be applied to WMM/granular surface before placing the mix to ensure good bond at the bottom.

9.7.2 *Placing mix in potholes*

The mix is intended for filling potholes up to 75 mm deep. For deeper potholes (more than 75 mm), patching mix shall be placed and compacted in 2 or more layers of 25 to 75 mm. Initially the pothole may be filled using Crusher Run Macadam (CRM) conforming to the grading given in **Table 9.2**.

Table 9.2 Grading of Crusher Run Macadam

Sieve size	% Passing by weight	
	53 mm Max. Size	37.5 mm Max. Size
63 mm	100	-
45 mm	87-100	100
22.4 mm	50-85	90-100
5.6 mm	25-45	35-55
710 mm	10-25	10-30
90 mm	2-5	2-5

9.7.3 *Compaction of the mixes*

First the outside edge or periphery of the patch shall be compacted with a hand rammer and then compaction shall proceed inwards. To prevent initial pick up of the loose mix by the hand rammer either continue to wet the hand rammer with water or place empty plastic lined bags on the loose mix. For deep potholes, place the patching mix and compact in 75 mm thick layers. After compaction, the compacted patch shall be about 10 mm higher than the existing road surface to allow for further compaction by traffic. If there are numerous closely spaced patches, it is preferred to use a small roller rather than a hand rammer. If a roller is used, the compacted patch shall be about 3 mm higher than the existing road surface.

Before opening the compacted patch to traffic, sufficient amount of clean sand shall be sprinkled on the patch to prevent pick up by traffic. The quality control shall be done as per **Annexure-II**.

10 COLD RECYCLING USING BITUMEN EMULSION

10.1 Introduction

Recycling is defined as "the process involving the reuse of material that already has performed its first-intended use". In relation to bituminous pavement recycling, there are several methods available. Therefore, projects being considered for recycling of pavement must be carefully evaluated to decide the most appropriate recycling technique. The factors to be considered should include (1) existing pavement condition (2) existing pavement material quality, specifications and layer thickness (3) structural integrity of pavement (4) availability of recycling additive and (5) recycling machinery. The Asphalt Recycling and Reclaiming Association (ARRA) recognized five types of recycling for bituminous pavements:

a) ***Cold Planning :*** The bituminous pavement is removed to a specified depth and the surface is restored to a desired grade and camber. Surface shall be free of humps, ruts and other surface irregularities. The milling of pavement is done with a suitable self-propelled rotary drum and cold planning machine. The Reclaimed Asphalt Pavement (RAP) materials are then transferred to tippers for transportation to site of work.

b) ***Hot Recycling :*** RAP is combined with virgins aggregates, bitumen and recycling agent to produce a usable bituminous mix. Although batch type hot mix plants are used, drum mix plants may also be used to produce the mix containing RAP. Most of the RAP is produced by cold planning, milling and crushing. The mix placement, compacting equipments and procedures are same as used hot mix bituminous construction.

c) ***Hot In-Place Recycling :*** This type of recycling is performed on-site; in-place. The aged pavement is typically reworked to a depth in the range of 20 to 40 mm. The bituminous pavement is heated, softened and scarified. A bitumen emulsion or other suitable recycling agent is added. The three hot in-place recycling methods are defined as heater-scarification, repaving and remixing.

d) ***Cold Recycling :*** The cold recycling is performed using the central or mobile plant. The most commonly used method is cold in- place recycling. In this type of recycling, the depth of pavement may be in the range of 50 to 100 mm. The pavement is pulverized and the reclaimed material is mixed with a bitumen emulsion or emulsified recycling agent, spread and compacted to produce a base course layer. Cold recycled base requires a fresh bituminous surface over it. The pavements with less traffic may use a bitumen emulsion for surface treatment. Higher traffic pavements may use a modified bitumen emulsion or a surface treatment of hot bituminous mix.

e) ***Full-Depth Reclamation :*** In this category, all of the pavement sections, and in some cases, a predetermined amount of underlying material, are mixed with bitumen emulsion to produce a stabilized base course. Full depth reclamation consists of six basic steps such as pulverization, additive and/or emulsion incorporation, spreading, compacting, shaping, and placement of new bituminous surface.

10.2 RAP Material for Cold Recycling

The term ‘RAP’ is given to bituminous material that is recovered from an old existing pavement. There are two ways that RAP material can be used in road construction:

a) ***In-situ Treatment :*** The existing bituminous mix can be reclaimed and simultaneously treated using ‘cold in-place recycling” technology (also referred to as CIR or partial depth recycling). This process uses a large truck-mounted recycler to recover the upper portion of bituminous layer of the existing pavement (normally between 100 mm to 150 mm depth) and simultaneously RAP in mixed with additives.

b) ***In Plant Treatment :*** The milled bituminous mixture is stockpiled locally and treated in a suitable mixing plant. The treated RAP material is then returned to site and paved back in the areas that were milled. The “cold in plant recycling” technology introduces flexibility into the recycling process by separating the recovery and reuse operations. In addition, where required, this process provides the opportunity to crush and/or screen RAP material, as well as blend it with fresh aggregate (eg., graded crushed stone), if required, before it is recycled.

The quality of RAP is most important. From a cold recycling perspective, it is most important to know whether the bitumen in the RAP material is "Active or Inactive". RAP maybe a "Black Aggregate" (Inactive) with properties similar to those of graded crushed stone or it may be a "Sticky Material" (Active) with inherent cohesiveness due to the less brittle bitumen in the RAP material. This is important since the state of the binder in RAP will have a significant influence on how the recycled material will behave when it is reused.

The following observations will indicate inactive RAP:

a) Visual appearance : The RAP is dull grey in colour with no black shining surfaces.

b) Brittleness : A chunk of RAP breaks cleanly into pieces.

c) Adhesion : Pieces of RAP (at ambient temperature) do not stick to the hand, when a sample is firmly squeezed.

In case, there is a doubt as to whether or not the RAP can be classified as Active or Inactive, a representative sample may be tested in a laboratory to determine following properties:

a) The amount of bitumen in the RAP material (percentage by mass),

b) Rheological properties of the recovered bitumen (Penetration, Softening Point, Shear Modulus and Viscosity).

c) Chemical composition of bitumen (asphaltenes, aromatics, resins and saturates)

10.3 Cold Recycling

The cold recycling process has numerous applications for maintenance and rehabilitation of old bituminous pavements. However, each application will be a project specific. The following three factors are considered responsible to decide process of recycling:

- The type of pavement and the distress that needs to be addressed
- The quality of material in existing pavement
- The service life expectations after recycling

The materials involved with the cold recycling process can be classified in to two types:

- 100 percent Reclaimed Asphalt Pavement (RAP) material, where the depth of recycling is restricted to bituminous layers
- Blend of RAP and Granular material, where the recycling depth includes granular layers also. Such RAP includes bituminous materials, crushed stone and natural gravels, as well as materials previously stabilized.

- Cold recycling may involve use of foam bitumen as well as bitumen emulsions.

10.4 Recycling Using Bitumen Emulsion

The use of bitumen emulsions as binder in cold recycling and full depth reclamation process is well known. The essential part for selection of a bituminous pavement rehabilitation method is the determination of the existing pavement condition. The type and area of pavement surface defects need to be scientifically evaluated. The strength of the current pavement structure and its material needs are to be examined. The current and future traffic needs must be investigated. The steps and methods for evaluation of pavement materials for cold recycling is given in **Table 10.1**.

Table 10.1 Evaluation Procedure for Cold Recycling and Full Depth Reclamation

Characteristics	Method of Test	
	ASTM	IS
Bitumen content in bituminous mixture	D 2172	-
Recovery bitumen from a bituminous paving mixture (by Abson Recovery method or Rotary Evaporator)	D 1856/ D 5404	-
Sieve analysis of fine and coarse aggregates	C 136	IS:2386
Amount of materials finer than 75 μm sieve in mineral	C 117	IS:2386
Liquid limit, plastic limit and plasticity index of soil	D 4318	IS:2720
Sand equivalent value of soil or aggregate	D 2419	IS:2720
Penetration of bituminous materials	D 5	IS:1203
Viscosity of asphalt by vacuum capillary viscometer	D 2171	IS:1206

For bituminous materials, testing typically includes bitumen extraction for bitumen content, aggregate quality sieve analysis of aggregates. For cold recycling, a solvent or "Abson Recovery (ASTM D472 and 1856)" method may be adopted which includes to determine the bitumen properties, Chemical Composition (asphaltenes, resins, saturates and paraffins) Penetration as 25°C, Absolute Viscosity at 60°C. For aggregate bases and sub grade soils, a wet sieve analysis and sand equivalent value or plasticity index are necessary done. A mixture design is required to determine the type, grade and amount of bitumen emulsion to be added in mixture. The premixing water content, the stability and strength (modulus) properties of the recycled mixture tests are needed to be investigated.

10.5 Mix Design Procedure

Considering the number of variables that need to be addressed and the amount of material required to study these variables, the mix design procedure involves several steps depending on the magnitude of design traffic and life. The mix design procedure always begin with testing of the material to be stabilized (preliminary tests) to determine whether it is suitable for treating with bitumen emulsion and, if not, the type of pre-treatment required to make it suitable. Once the suitability of the material has been proven, the actual mix design procedure begin those provides an indication of the application rate of bitumen emulsion and filler (if necessary) required to achieve the class of mix. Thereafter, depending on the design traffic (structural capacity requirement), additional tests are undertaken to refine the application rate of bitumen emulsion and gain confidence in the performance potential of the treated material. Procedure described in Asphalt Academy (May 2009) Technical guideline : Bitumen Stabilized Material. A guideline for design and construction of bitumen emulsion and foam bitumen stabilized material (TG-2) may be used for mix design. In summary, the mix design procedure consists of following steps.

a) ***Preliminary Tests :*** These include standard laboratory tests to determine the grading, moisture, density relationships and Atterberg limits, where the results indicate that some form of pre-treatment is required, additional tests must be undertaken after such pre-treatment to ensure that the desired benefits were achieved.

b) ***Level 1 Mix Design :*** Level 1 Mix design begin with the preparation of samples that will be used to prepare the specimens required for all levels of mix design. 100 mm diameter Marshall Specimens (Marshall Specimen) are prepared and cured for Indirect Tensile Strength (ITS) testing.Test results are used to:

   - Identify the preferred stabilizing agent
   - Indicate the target bitumen content
   - Identify the need for filler.

   Level 1 mix design is sufficient for lighter and medium traffic roads with a limited structural capacity of 5 msa. Where the structural capacity requirements exceed 5 msa, the mix design procedures described as Levels 2 and 3 should be undertaken.

c) ***Level 2 Mix Design :*** This procedure uses 150 mm diameter by 127 mm higth specimens (Proctor specimens) prepared using vibratory compaction, cured at the equilibrium moisture content and tested for Indirect Tensile Strength. This level is recommended for roads carrying traffic up to 10 msa. Test results are used to:

   - Optimize the required bitumen content
   - Obtain ITS values for increased confidence

d) ***Level 3 Mix Design :*** This procedure uses triaxial testing on 150 mm diameter by 300 mm high specimens for a higher level of confidence. This level is recommended for design traffic exceeding 10 msa.

e) ***Materials Selection Criteria :*** The guidelines are given below:

   i) The PI of material to be treated with bitumen emulsion should be less than 8.

ii) Bitumen emulsion must coat coarse particles, not only the fines.

iii) Fines content of 2 percent is sufficient.

iv) Material at a temperature of 15°C or higher can be treated with bitumen emulsion

v) The selection of the correct grade or category of bitumen emulsion for each application is essential

These are listed below:

i) Slow set cationic bitumen emulsions are exclusively used worldwide. These bitumen emulsions or tailormade emulsions having longer workability to ensure good dispersion and are formulated for needed mix stability.

ii) A number of developments in bitumen emulsion technology are happened to improve stability without prolonging the breaking time. These emulsions are typically slower setting than the traditional SS products, and should be used on projects where the treated layer can be cured for a shorter period before opening to traffic. During the mix design, and on site before full-scale application begins, the breaking rate should be tested with representative samples of material, active filler, water at realistic temperatures.

iii) The selection of the bitumen emulsion type and grade is influenced by the type of material and climatic condition that is to be treated. Certain material types are not suitable for treatment with anionic bitumen emulsions. These are the acidic rocks with silica contents above 65 percent and alkali contents below 35 percent such a quartzite, granite, rhyolite, sandstone, syenite and felsites. Treatment of such materials requires a cationic bitumen emulsion.

iv) Manufacturers normally recommend that undiluted bitumen emulsion may be heated to 50 and 60°C to prevent premature breaking due to the increase in pressure and shearing action while pumping and injecting through the spray bar on the recycler.

v) The pH levels of the water must be checked for the compatibility of the bitumen emulsion and the water.

vi) Breaking is the separation of the bitumen from the water phase through flocculation and the coalescence of the bitumen droplets to produce films of bitumen on the individual particles of the material. The rate at which the bitumen droplets separate from the water phase is referred to as the breaking time.

vii) The breaking process with anionic bitumen emulsions is a mechanical process (evaporation), whereas cationic bitumen emulsions produce a chemical break. For dense mixtures, more time is needed to allow for mixing and placement besides slower breaking times. As the bitumen emulsion breaks, the colour changes from brown to black. Although this can be observed with the naked eye, it is recommended that a magnifying glass may also be used.

viii) Curing is the displacement of water and the resultant increase in stiffness and tensile strength of the mix. This is important as a mix needs to develop sufficient stiffness and cohesion between particles before traffic is opened.

ix) Rate of absorption of water by such materials is also important. Rough-textured and porous materials reduce the breaking and setting time of emulsion mix by absorbing water contained in the bitumen emulsion.

x) Moisture content of the mix prior to mixing influences breaking time. While moisture content of the mix after compaction influences curing rate.

xi) Grading of the material and voids content of the mix also influence setting process.

xii) Type, grade and quantity of the bitumen emulsion also influence setting process.

xiii) Mineral composition of the material play a vital role. The rate of cure may be affected by physico- chemical interactions between the bitumen emulsion and the surface of the individual material particles.

xiv) Quantum of electrical charge on the material particles in relation to that of the bitumen emulsion also influence breaking as well as setting.

xv) Active filler addition, the amount of cement or lime also influence setting.

xvi) Temperature of material and air: The higher temperature, the quicker the bitumen emulsion breaks and cures.

xvii) A minimum of 1 to 2 percent moisture is required in the mineral material prior to adding the bitumen emulsion.

11 EQUIPMENT FOR BITUMINOUS ROAD CONSTRUCTION USING EMULSIONS

11.1 Introduction

This section deals with the basic information of equipments required for construction and maintenance of the roads using bitumen emulsion in cold and warm mixes besides other application. The following equipments are dealt in this Section.

1) Emulsion sprayers
2) Pressure distributors
3) Chip spreaders
4) Cold mix plants
5) Pavers
6) Rollers
7) Microsurfacing machines
8) Cold recycling machines
9) Patching machines

11.2 Emulsion Sprayers

The hand operated as well as mechanized bitumen emulsion sprayers may be used for spraying bitumen emulsion for small areas. These sprayers are available in different sizes (25 liters to 500 liters) capacity. A picture of hand operated sprayers and mechanized bitumen emulsion sprayers are given in **Photo 11.1**.

Photo 11.1 Different Type of Bitumen Emulsion Sprayers

11.3 Pressure Distributors

The bitumen emulsion distributor is the most important equipment used in tack coat, prime coat and other surface treatments **(Photo 11.2)**. It is used to uniformly apply the bitumen emulsion over the surface at the specified rate. The distributor consists of either a truck-mounted or trailer-mounted insulated tank with controls to set the bitumen emulsion application rates. A spray bar equipped with nozzles through which the bitumen emulsion forced under pressure onto the pavement surface is placed at the end of tank. Spray bars can cover widths of 3 to 9 m in a single pass, depending on the pump capacity. A hand sprayer may be used to apply the emulsion to areas that cannot be reached with the spray bar. The distributor tank-typically has a capacity of 3,000 to 20,000 liters. The tank shall contain a circulating system. Pressure generated when a non circulating or not bypassed spray bar is shut off can cause the emulsion to break and plug the unit with bitumen. The tank is also equipped with one or more heaters used to bring the bitumen emulsion to the desired spraying temperature. Extreme care is required when using these heaters while emulsion is used as material. Premature breaking of the emulsion may occur, if heating temperature is too high (>70°C) and heaters are to be used, the emulsion should remain circulating while heat is applied and excessive temperatures should not be allowed. Two extremely important adjustments are the spray nozzle angle setting and spray bar height. The angle of the nozzle openings must be adjusted so that the spray showers will not interfere with each other. The recommended angle, measured from the spray bar axis, is from l5 to 30 degrees. To ensure a uniform spread, the spray bar must be set and maintained at the proper height above the pavement surface. If it is set too high, distortion of spray fans may occur. The best results usually are achieved with an exact double coverage, but triple coverage can sometimes be used with spray bars with 100 mm nozzle spacing. **Fig.11.1** illustrates the heights of the spray bar necessary to achieve these coverage. Three controls are standard equipment on most distributors. One is a valve system that governs the flow of bitumen emulsion. Another is a pressure gauge that registers pump output. The third is a bitumen emulsion with an odometer that indicates the number of meters per minute and the total distance traveled. Despite the precise controls on a distributor, it is always advisable to check the rate of application in the field. This can be done with a shallow metal tray exactly one square meter in the area. If a tray is not available, a sheet of heavy paper or cardboard can also serve the intended purpose. The tray is weighed and placed on the surface to be sprayed. Immediately after the distributor has passed, the tray is removed and weighed again. The difference between the two is the weight of the bitumen emulsion applied on the surface in one sq. meter area.

Photo 11.2 Emulsion Sprayer

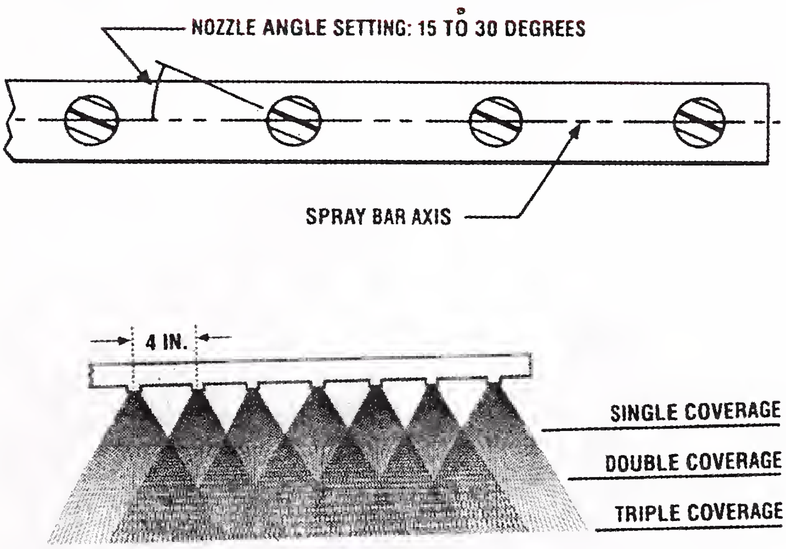


Fig. 11.1

11.4 Aggregate Spreaders

The aggregate spreader is an important equipment for surface dressing. It applies a uniform aggregate cover at the specified rate. Spreaders range from the simple vane type attached to a truck tail gate to the highly efficient self-propelled type. Tail gate spreaders are usually of two types. One is a steel plate to which is attached a series of vanes to provide coverage across the lane. Another is a truck-mounted hopper with a feed roller activated by small wheels driven by the truck wheels. In each case, the truck backs up to spread the stone. This prevents the freshly applied bitumen emulsion from being picked up by the truck tires. Mechanical aggregate spreaders contain hoppers and a built in distribution system to ensure a uniform spread of the cover aggregate across the entire lane width. Mechanical spreaders are either truck-attached or self-propelled. In both types, the aggregate is dumped from a truck into a receiving hopper for spreading. The truck attached spreader typically contains an auger and a roughened spread roll in the hopper that ensures a positive and uniform feed of material. The self-propelled unit has a similar feed mechanism. One difference is that the self-propelled spreader contains a scalping screen over the aggregate receiving hopper. Another is that there can be a sloped screen that allows the larger particles to drop into the asphalt film first with the finer particles falling afterwards through the screen. This system ensures that the larger particles are sufficiently embedded in the asphalt to hold them in place. The self-propelled unit has the advantage of being able to closely follow behind the bitumen emulsion distributor, with minimum stopping to change aggregate trucks. Mechanical self propelled aggregate spreaders should be calibrated to apply the designed quantity of cover stone for any given project. The required equipment can be very simple and may consist only of several sheets of canvas, each exactly one square meter (square yard), and a scale. By making several runs at different speeds and gate openings ever the sheets of canvas and carefully weighing the aggregate deposited on them, the gate opening and spreader speed required to apply the cover stone at the specified rate per square meter can be quickly determined. A typical chip spreader is shown in **Photo 11.3**.

Photo 11.3 A Typical Chip Spreader

11.5 Cold Mix Plants

Cold bituminous mix involving use of bitumen emulsion as binder is manufactured in a pug mill, which blend water based bitumen emulsion with pre wetted aggregates according to a laboratory job mix formula. The aggregate may be virgin, or RAP and may be used to produce a low cost and low energy paving material. These cold mixes may be manufactured by a centrally located or by mobile plant. The mixes may be used for base, binder, leveling or wearing course or structural overlays. The resiliency of cold mix products to self-heal with movement from freeze thaw cycles makes them ideal. The key benefits of cold mix paving are described below:

- Flexible but strong to withstand temperature fluctuations
- Can be mixed at a central plant or portable at remote locations
- Eco-friendly materials used at ambient temperatures be reduce emissions, Energy security
- Cold bituminous mixes minimizes transportation and materials cost
- Cost-effective paving for upgrading rural roads far from a hot mix plant
- Small jobs can be done using concrete mixes.

A typical cold mix plant comprises various parts as listed below :

1) Cold aggregate feeding system
2) Dryer system
3) Combustion system
4) Heat material hoisting system
5) Dust remover system
6) Vibrating screen system
7) Weighing system
8) Mixer system
9) Powdery material feeding system
10) Main body of mixing plant
11) Compressed air supply system
12) Electrical control system
13) Bitumen emulsion spraying system
14) Bitumen emulsion supply system
15) Finished product bin

Typical cold mix plant are shown in **Photo 11.4**.

Photo 11.4 Centrally Located and Mobile Cold Mix Plants

11.6 Pavers

For plant produced emulsion mixes, the paving procedures are similar to those used for hot mixed materials. Base courses may be laid with self-propelled base spreaders or even with a blade. However, self-propelled pavers are recommended for surface courses. Cold mixes generally are stiffer than hot bituminous mix, with open-graded mixtures being the most difficult to place. Proper paver operation is very critical for obtaining uniform and smooth mat. This includes keeping the paver speed as constant as possible and the level of mix on the augers at a nearly constant depth. If mix sticks to the paver screed or tearing of the mat occurs, change in the mixing time or the water content can eliminate the problem. The screed should not be heated. Plant produced emulsion mixes are placed in lifts of 100 mm or more but compaction and curing proceeds quicker with lifts of 50 to 75 mm. For open-graded mixes, the breaking of the bitumen emulsion usually occurs quickly. With open-graded mixes, rolling normally may begin immediately behind the paver. However, the emulsion in dense-graded mixes typically does not break for some time. Because of the higher moisture contents for mixing, a delay in the compaction of dense-graded mixes is usually required. The amount of delay is dependent on the lift thickness and the curing conditions of air temperature, humidity and wind. The rate of water loss controls when compaction may begin.

Because-of the extreme tackiness of open-graded mixes and an initial low stability until obtaining some aggregate interlock, the breakdown rolling is best accomplished with a static steel-wheeled roller. Vibratory rolling of open-graded mixes is not recommended because fracture of aggregate and asphalt bonding can occur. A light “choke” or “blotter” of a coarse sand or fine crusher screenings may he applied after steel-wheeled rolling. The choke or blotter permits rolling with a pneumatic- tired roller and prevents pick-up and darn age by traffic. The sand or screenings is applied with a correctional self-propelled chip spreader or sand spinner at the rate of 3.30 to 06.6 kg/10 m^2.

11.7 Rollers

Rolling presses the aggregate down into the bituminous binder, promoting better adhesion. Unless the cover aggregate is properly embedded in the bitumen film, there is a good possibility that some may be lost through traffic abrasion. For single surface treatments, pneumatic-tired fillers produce best results. They force the aggregate firmly into the bitumen binder without crushing the particles. The tires press into small depressions to better seat the particles. Steel wheeled rollers tend to bridge over such depressions and may fracture the aggregate. If the roller speed is too high, the roller may dislodge the aggregate. Different types of rollers are shown in **Photo 11.5**.

Photo 11.5 Different Type of Rollers

11.8 Microsurfacing Machines

The machine shall be specially designed for application of slurry microsurfacing mixture. It shall be a self-propelled equipment, truck mounted, consisting of the following sub-assemblies used to manufacture and simultaneously spread these mixes on the surface. **(Photo 11.6)**

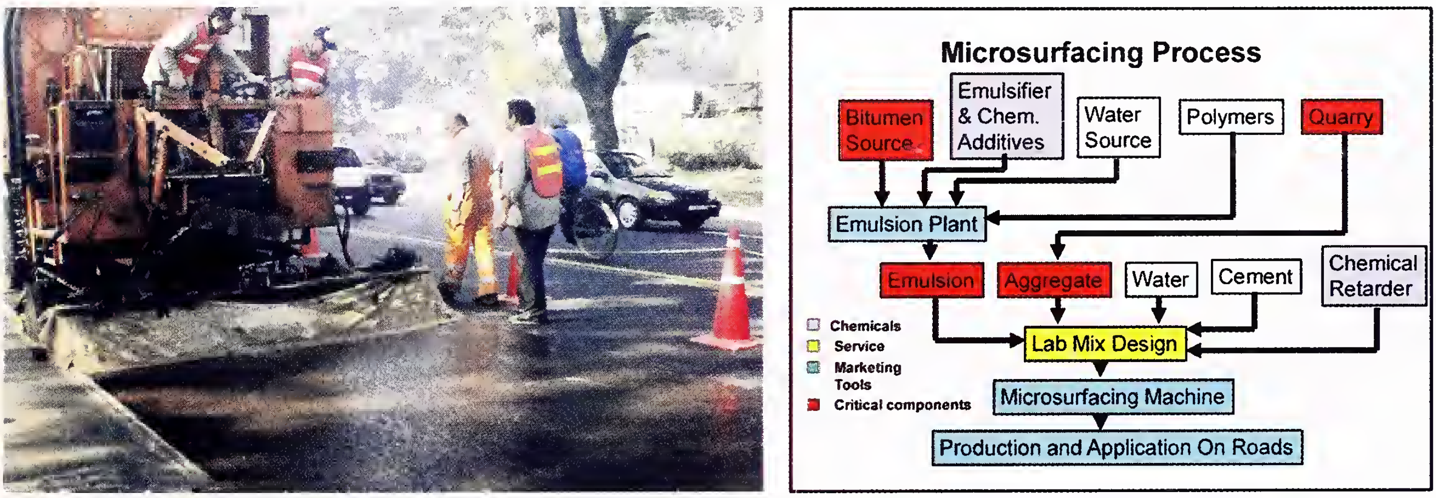


Photo 11.6 Microsurfacing in Progress and Microsurfacing Process

- Aggregate Bin
- Filler Bin
- Water and Emulsion Tanks
- Additive Tanks
- Aggregates and filler conveyors to supply the mixer box
- Pump or compressed air system to supply the emulsion/water
- Mixer Box
- Spreader Box to place the mixed slurry on the job

11.9 Cold Recycling Machines

A view of cold recycling machine is given in **Photo 11.7**. Such machines are useful for surface and full depth recycling involving use of bitumen emulsion.

Photo 11.7 Cold Recycling Machine

11.10 Patching Machines

A view of various patching machines is given in **Photo 11.8**.

Photo 11.8 A View of Patching Machines

Annexure-I

Choice/Selection of Cold Mix Treatments for Different Climate/Traffic Conditions (Warrants)

Title of Treatment	Traffic (CVPD)	Climate		Choice of Emulsion
		Temperature	Rainfall	
Prime Coat	No Limit	No Limit	No Limit	SS-1
Tack Coat	No Limit	No Limit	No Limit	RS-1
Seal Coat	<1500	No Limit	No Limit	SS-2
Sand Seal	<1500	No Limit	No Limit	SS-2
Cap Seal	<3000	No Limit	No Limit	RS-2 , SS-2 and Modified
Chip Seal	<1500	Avoid in Cold Climate	No Limit	RS-2, Modified
Slurry Seal	<1500	No Limit	No Limit	SS-2
Microsurfacing	No Limit	No Limit	No Limit	Modified
OGPC	<1500	Moderate & cold climate (maximum air temperature 40°C)	Medium	MS/SS-2 and Tailormade
MSS	<1500	Moderate & cold climate (less than 40°C)	Low	MS/SS-2 and Tailormade
BM	<1500	Moderate & cold climate (maximum air temperature 40°C)	Low	MS/SS-2/ Tailormade
SDBC	<3000	Moderate & cold climate (maximum air temperature 40°C)	Low	SS-2/Tailormade
Half Warm Mix (DBM, SDBC, BC)	<4500	Moderate & cold climate (maximum air temperature 40°C)	No limit	SS-2/Tailormade
Cold Recycling	No limit	Moderate and cold climate	No limit	SS-2/Tailormade
Patching	No Limit	No Limit	No limit	MS/SS-2/ Tailormade

Annexure-II

Quality Control Tests for Emulsion and Cold Mixes

S. No	Specification		Tests	Methods	Frequency
1)	Prime Coat/Tack Coat/ Fog Seal	i)	Quality of Emulsion	IS:8887	Number of samples (two) per lot of 20 tonne
		ii)	Rate of Spread of Emulsion	Tray test	One test per 500 m^2 and not less than two tests per day.
2)	Seal Coat/Surface Dressing	i)	Quality of Emulsion	IS:8887	Same as mentioned under Serial No. 1
		ii)	Aggregate Impact Value	IS:2386 (Part IV)	One test per 50 m^3 of aggregate
		iii)	Flakiness Index and Elongation Index	IS:2386 (Part I)	-do-
		iv)	Stripping value of aggregates	IS:6241	Initially one set of 3 representative specimens for each source of supply. Subsequently when warranted if change in the aggregates source.
		v)	Water absorption of aggregates	IS:2386 (Part III)	One test per 50 m^3 aggregate
		vi)	Water sensitivity of mix	AASHTO T-283	Initially one set of 3 representative specimens for each source of supply. Subsequently when warranted by changes in the quality of aggregates (if required)
		vii)	Grading of aggregates	IS:2386 (Part I)	One test per 25 m^3
		viii)	Soundness (Magnesium and Sodium Sulphate)	IS:2386 (Part IV)	Initially, one determination by each method for each source of supply, then as warranted by change in the quality of the aggregates.
		ix)	Rate of spread of materials		One test per 500 m^2 of work, and not less than two tests per day
		x)	Sand Equivalent Value	IS:2720 (Part 37)	One test for 50 m^3 by aggregate
3)	Open-graded Premix Surfacing/Close-graded Premix Surfacing	i)	Quality of Emulsion	IS:8887	Same as mentioned under Serial No. 1
		ii)	Aggregate Impact Value	IS:2386	Same as mentioned under Serial No. 2
		iii)	Flakiness Index and Elongation Index	IS:2386 (Part IV)	-do-

S. No	Specification		Tests	Methods	Frequency
		iv)	Stripping value	IS:6241	Same as mentioned under Serial No. 2
		v)	Water absorption of aggregates	IS:2386 (Part III)	Same as mentioned under Serial No. 2
		vi)	Water sensitivity of mix	AASHTO T-283	Same as mentioned under Serial No. 2
		vii)	Grading of aggregates	IS:2386 (Part I)	Same as mentioned under Serial No. 2
		viii)	Soundness (Magnesium and Sodium Sulphate)	IS:2386 (Part V)	Same as mentioned under Serial No. 2
		ix)	Temperature of binder at application	-	At regular close intervals
		x)	Binder content	**Appendix-13**	One test per 5000 m^3 and not less than two tests per day
		xi)	Rate of spread of mixed material	-	Regular control through checks of layer thickness
4)	Bituminous Macadam (Cold Mixed)	i)	Quality of Emulsion	IS:8887	Same as mentioned under Serial No. 1
		ii)	Aggregate Impact Value	IS:2386 (Part III)	Same as mentioned under Serial No. 2
		iii)	Flakiness Index and Elongation Index	IS:2386 (Part I)	Same as mentioned under Serial No. 2
		iv)	Stripping Value	IS:6241	Same as mentioned under Serial No. 2
		v)	Water sensitivity of mix	AASHTO T-283	-do-
		vi)	Grading of aggregates	IS:2386 (Part I)	Two tests per day per plant both on the individual constituents and mixed aggregate form the dryer
		vii)	Water absorption of aggregate	IS:2386 (Part I)	Same as in Serial No. 2
		viii)	Soundness (Magnesium and Sodium Sulphate)	IS:2386 (Part III)	Same as mentioned under Serial No. 2
		ix)	Binder content and aggregate grading	**Appendix-13**	Periodic, subject to minimum of two tests per day per plant
		x)	Rate of spread of mixed material	-	Regular control through checks of layer thickness
		xi)	Density of compacted layer	-	One test per 250 m^2 of area
5)	Slurry seal	i)	Quality of Emulsion	IS:8887	Same as mentioned under Serial No. 1
		ii)	Sand Equivalent value of aggregate	15:2720 (Part 37)	One test for 50 m^3

S. No	Specification		Tests	Methods	Frequency
6)	Recycled Materials	i)	Binder content and aggregate grading	-	Minimum of one test per 25 m^3 of recycled material
		ii)	Recovered binder penetration	-	Minimum of one test per 50 m^3 of recycled material
		iii)	Mix stability (Remix/ Repave)	-	For each 400 tonnes of mix recycled, a set of 3 Marshall specimens to be prepared and tested for stability, flow, density and void content, subject to a minimum of two sets of tests per day
7)	Cold Mix (BM/SDBC)	i)	Quality of Emulsion	IS:8887	Same as mentioned under Serial No. 1
		ii)	Aggregate Impact Value	IS:2386 (Part IV)	Same as mentioned under Serial No. 2
		iii)	Flakiness Index and Elongation Index	IS:2386 (Part I)	-do-
		iv)	Stripping Value	IS:6241	-do-
		v)	Water sensitivity of mix	AASHTO T-283	-do-
		vi)	Grading of aggregates	IS:2386 (Part I)	Two tests per day per plant both on the individual constituents an mixed aggregates for the dryer
		vii)	Sand Equivalent Value	IS:2720 (Part 24)	Test for 50 m^3
		viii)	Percentage minimum coating	-	Two test per day per plant
		ix)	Water absorption of aggregate	IS:2386 (Part III)	Same in Serial No.2
		x)	Soundness (Magnesium and Sodium Sulphate)	IS:2386 (Part III)	Same as mentioned under Serial No. 2
		xi)	binder content and aggregate grading	**Appendix-13**	Periodic, subject to minimum of two tests per day per plant
		xii)	Mix stability		For each 400 tonnes of mix produced, one set of 3 Marshall specimens to be prepared and tested for stability, flow, density and void content, subject to a minimum of two sets of test per plant per day
8)	Patching Mix	i)	Bond Test	**Appendix-1**	One test per lot (10 tonnes)
		ii)	Workability	**Appendix-12**	One test per lot (10 tonnes)
		iii)	Binder Content	**Appendix-13**	Two tests per lot (10 tonnes)
		iv)	Water Resistance	**Appendix-11**	One test per lot (10 tonnes)

Appendix-1

Test Method for Determination of Bond Strength

Scope : This test method is intended to determine the bond strength between two superimposed bituminous layers of field and laboratory prepared samples

Apparatus : Marshall Testing Apparatus, Hammer and Shear Mould

Method :

a) Test on samples from field

The cores of the two superimposed bituminous layers such as BC over BC or BC over DBM shall be taken out from the field using the core cutting machine. The core shall be allowed to cure in the laboratory for atleast 24 hours. After the curing period, the sample shall be placed in the shear mould and tested in the Marshall testing machine at 25°C. The failure load is noted down and shear strength shall be calculated as follows:

$$\text{Shear Strength} = \frac{\text{Load (at Failure)}}{\text{Area of the surface (resisting the load)}}$$

b) Test on laboratory samples

In the laboratory, Marshall Samples are to be prepared by 50 blows on one side, such that the thickness of the sample is about 30-35 mm. Once the samples are taken out from the mould, tack coat is applied at the specified rate on the samples and allowed to cure for 24 hours at room temperature. After the curing period, the other half part of the Marshall sample is prepared by applying 50 blows. The sample should be such that half of the sample is of the one type of material and the other superimposed half is of other type of the material and tack coat membrane is interlayer between two layers. The sample is taken out and allowed to cure for 24 hours. After the completion curing period, the sample shall be placed in the shear mould assembly Marshall testing machine. Test setup for testing of bond strength of tack coat between two bituminous layers is showing in **Photo 1**.

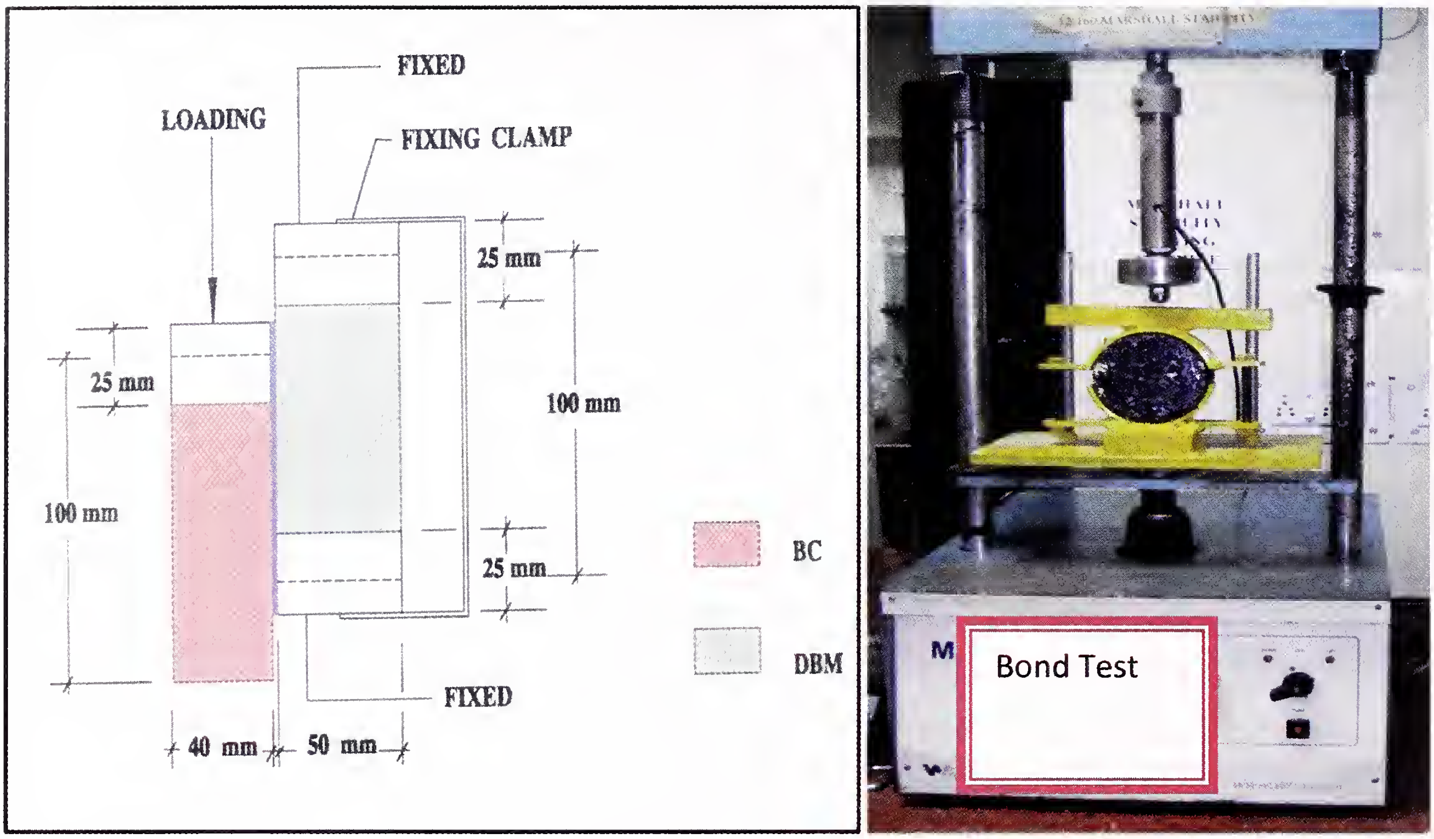


Photo 1 Test Set up for Testing of Bond Strength of Tack Coat Between Two Bituminous Layers

Appendix-2

Method for Determination of Mixing Time

Scope : This test is intended to determine breaking time of emulsion in a slurry seal or microsurfacing mixture.

Apparatus : Stainless Steel Bowl, Spatula, Beakers, Measuring Cylinders, Spoon, Balance.

Method : Take 1000 g of the graded aggregate and needed cement in a bowl, mixed gently. Add required quantity of mixing water containing required dose of additive (if needed), to the aggregate and cement mixture. Mix the contents in bowl vigorously with the help of spatula so that a homogenous paste is formed. Add requisite quantity of emulsion and then mix the contents in bowl with the help of spatula till the emulsion commences breaking (colour turns brown to blackish brown) and mix begins ceasing its workability. The time required for initiation of breaking emulsion is known as mixing time.

Report : Minimum time in seconds required for initial breaking of emulsion is reported as "Maximum Mixing Time".

Appendix-3

Method for Determination of Consistency

Scope : This Test is used to determine the consistency of slurry seal and microsurfacing mixture.

Apparatus : Mould of metal, in the form of a frustum as a cone, 38 mm in diameter at top, 89 mm in diameter at the base and 76 mm in height. The centre of 228 mm metal plate is inscribed with a circle of 89 mm in diameter. Three to four additional circles each 13 mm greater in diameter than the preceding circle are inscribed on the metal plate around the centre.

Method : Mould is loosely filled with slurry seal/microsurfacing mixture and struck off. The mould and contents are then inverted in the centre of the metal plate by placing the inscribed surface of the metal plate on the slurry filled cone, which while holding cone and plate firmly together, is quickly inverted. The mould is removed and contents allowed to flow over the inscribed circles until flow of the slurry stops.

Report : The outflow of slurry is measured at four points 90° apart from each point. The average value is reported in cm.

Appendix-4

Method for Determination of Cure Time

Scope : This Test is intended to determine cure time of slurry seal and microsurfacing mix for complete cohesion.

Apparatus : Cohesion Tester capable to apply varying pressure to a slurry pad, air compressor (0 to 700 kPa), Torque meter (35 kg.cm torque), 60 mm dia. Steel mould of 6 mm and 10 mm thickness, 4.75 mm and 8.00 mm size sieves, mixing pan, spatula, balance, bituminous roofing felt of 10 cm^2 size and 13.6 kg weight, 20-30 mesh standard Ottawa sand, 3-M brand sand paper.

Procedure : A suitable number of identical specimens of mix are cast in the 6 mm or 10 mm ring mould centered on the bituminous roofing felt base of shape. Specimen shall be uniform, whose surfaces are horizontally parallel. A template is recommended to obtain uniform thickness of slurry/Microsurfacing mixture mat. After setting of slurry mat, it is placed beneath the pneumatically actuated rubber foot (25.4 mm dia.) of the calibrated cohesion tester. A pressure of 193 kPa considered to be equivalent to the pressure exerted by tyres of vehicle is applied. The torque measurements are made at intervals of 30, 45, 60, 75, 90, 120, 180 and 240 min after casting of samples by means of a torque tester, till highest and stable torque reading is obtained.

Report : The time required to reach constant and maximum torque or rubber foot rides freely over slurry mat without dislodgement of aggregate particles is recorded as the Curve Time. In case of quick traffic system, a cohesion torque of 20-21 kg.cm is required to reach within 60 min. For a quick – set system, a cohesion torque of 12-13 kg.cm is required to reach within 30 min.

Appendix-5

Method for Wet Stripping of Cured of Slurry

Scope : The purpose of this test is to help in selection of compatible slurry seal/Microsurfacing system with a given aggregate. This is generally useful for screening of emulsion formulation, fillers and additives by examination of ability of system to remain coated under the specified test condition.

Apparatus : 600 ml beaker, hot plate with adjustable temperature, high wet strength paper.

Procedure : 400 ml of demineralised tap water or distilled water is added to the 600 ml beaker placed on the hot plate and brought to a vigorous boiling condition. 10 gm mixture of cured slurry is dropped in to the boiling water for three minutes duration. After three minutes, beaker with mixture is removed from the hot plate and allowed to cool up to room temperature. Subsequently, cold tap water shall be applied on the surface of the water beaker and continued until any free bitumen on the surface of the water flows over the sides of the beaker. The water is then decanted and the contents removed from the beaker are placed on the white absorbent paper/towel. After drying, the sample shall be examined for uncoated areas.

Report : Report the estimated coated area of the aggregate surface with bitumen as a percentage of the total aggregate surface.

- 90 percent retained coating is satisfactory.
- 75 percent to 90 percent retained coating is judged as marginal.
- Below 75 percent retained coating is unsatisfactory.

Appendix–6

Method for Wet Track Abrasion Test

Objective : This test procedure is used to determine the resistance to abrasion of slurry seal/ microsurfacing layer and to establish minimum permissible bitumen emulsion content in the microsurfacing/slurry seal mixture.

Apparatus : The required apparatus are as under:

i) Balance : Cap able of weighing 5000 g within ± 1.0 g.

ii) Planetary Type Mechanical Stirrer : such as the Hobart Model N-50, Model C-100 or Model A-120 made by the Hobart Manufacturing Co., Troy, Ohio) equipped with a weighted rubber hose holding device having free up and down movement in the shaft sleeve.

iii) Flat bottom Metal pan, Approximately 330 mm in diameter with 51 mm vertical side walls having four equispaced screw clamps capable of securing 285 mm diameter specimen to bottom of pan.

iv) Suitable Heavy Gauge round bottom bowl: to contain the sample during mixes.

v) Long handled serving Spoon: of sufficient length to project 101 mm or more out of the round bottom bowl during stirring.

vi) Circular Disks: Metal circular disk of 286 mm diameter and 6 mm and 8 mm thick.

vii) Oven: Forced draft constant temperature thermostatically controlled at 60 ± 3°C.

viii) Water Bath: Constant Temperature, controlled at 25 ± 1°C.

Sample Preparation :

i) The optimum ratio of Portland cement, additives, water and bitumen emulsion to the dry weight of the aggregates shall be predetermined in the laboratory.

ii) Dry the aggregates in the oven at 105°C to 110°C approximately for 16 hours, until constant weight is obtained.

iii) Remove the aggregates from oven and cool to room temperature.

iv) Weight the sufficient quantities of the individual components in compliance to mix design to obtain a sample of about 1000 g.

v) Place the weighed aggregates and the filler in to the mixing bowl.

vi) After proper mixing of dry aggregates in mixing bowl, add predetermined quantity of water and additive (if required) and mix again for one minute until all aggregate particles are uniformly wetted.

vii) Add predetermined quantity of bitumen emulsion and mix for a period of not less than 30s and not more than 180s.

viii) Centre the specimen mould on a felt disc. Immediately pour the Microsurfacing/ slurry seal mix in specimen mould placed on felt disk.

ix) Screed the slurry level on top of the mould and discard excess material.

x) Remove the mould without disturbing the casted sample and place the moulded specimen in the oven for 24 h, at 60°C to obtain constant weight.

xi) Cool the dried specimen up to room temperature and determine its weight.

Test Procedure :

Lock the rubber hose abrasion head on the shaft of the mixing machine. A new hose surface shall be used for each test. Place the specimen in 330 mm diameter flat bottom pan. Clamp the specimen to the pan and mount plate by tightening the quick release clamps. Ensure that the specimen is properly centered and the rubber, hose will not run close to the edge. Add water at 25°C to the pan to cover the specimen to a minimum depth of 6 mm. Elevate the bowl resting on the platform of the mixer until the rubber hose bears freely on the surface of the specimen. Operate the mixer at its low speed setting and abrade the specimen for five minutes. Remove the specimen from the pan after the abrasion cycle and wash the specimen till it is free from debris. Place the washed test specimen in the oven at 60°C and dry to constant weight. Determine the loss in weight of the specimen expressed in gram per sqm and report it as the wear value or WTAT loss value.

Report : Report the wear value (WTAT Loss) in gram per square metre.

Appendix-7

Test Method for Determination of Torsional Elastic Recovery of Residual Binders

Scope : The test method is intended to determine torsional elastic recovery of modified residue using a simple bolt and cup assembly.

Apparatus : Bolt assembly – The bolt has a cylindrical head with diameter of 28.6 mm and thickness of 9.52 mm and threaded shank of the bold is 44.5 mm long. A metal spider with three radial pins and two nuts can be used to centre the assembly. A pointer is required for angle measurement in the absence of the spider. Sample tin of 85 ml capacity and internal diameter of 51 to 52 mm; angle measuring device and sample clamp assembly or an alternative means of clamping the sample/bolt assembly and determining the initial and recovered angle. The recommended device shall comprise a scale of 80mm radius graduated in degrees around at least half its circumference and a clamp capable of holding the sample cup within 3 mm of its centre and without deforming the cup by more than 3 mm in any direction; water bath capable to operate at 25°C fitted with thermometer; forced convection oven – capable of operating in the range 60°C to 200°C; stop watch, spanner to suit bolt assembly.

Method : The torsional elastic recovery apparatus operates by manually rotating an aluminum bolt previously embedded in a cup containing modified binder through an angle of 180° and measuring the extent of recovery of the original applied rotation. Initially 180° twist is applied with a spanner for period of 10s. The recovery after 30s is measured.

Pour the residue into the cup of assembly until it begins to form a meniscus on the top surface of the bolt. Allow the assembly with sample to cool for one hour by allowing it to stand at room temperature and adjust the assembly height to keep the top surface of the bolt flush with the surface of the sample. Place the assembly at constant temperature of 25°C in a water bath for one hour. Adjust the spider to a position 7 mm above the rim and return the assembly to the bath. Place the sample assembly on the base plate and fit the pointer to the 180° position without disturbing the sample. With the help of spanner, turn the bolt moving the pointer from the 180° position to Zero degree position using a steady motion for 10s. Release the bolt when the pointer reaches the zero position and commence timing. Record the recovered angle after 30s. The torsion elastic recovery in percentage is calculated by following:

$$100 \times A/180$$, Where A is recovered angle in degrees

Report : Report the torsional elastic recovery as mean of three results together with temperature of test and recovery time.

Appendix-8

Calibration of Slurry Seal and Microsurfacing Machine

The purpose of these guidelines is to familiarize both the users of the slurry seal machine/ microsurfacing machine as well as the client regarding the basic features of modern slurry seal machine. Both slurry seal and microsurfacing system have three main ingredients i.e. aggregates, bitumen emulsion and cement as filler. Apart from these, water and additive, if used are other ingredients for the purpose of workability of the mix. Unlike conventional hot mix works wherein one crew is involved in mixing of the materials and the other in using it, the same crew uses machine to proportion and mix up all the ingredients while laying the finished product. The modern traffic systems are very sensitive to changes in any of the ingredients as the same can cause an unsatisfactory mix. This in turn necessitated the accurate calibration of the machine.

Each slurry seal/microsurfacing machine to be used for execution of this work shall be calibrated prior to construction. The machine is equipped with suitable means of accurately metering each individual material and is capable of delivering a predetermined proportion of aggregate, water, emulsion, cement and additive to the mixture. Since all feeding mechanism is continuous, fed and proportioning remains constant at all the time. This mechanism allows the accurate calibration of the machine so that the exact quantities of materials use during any period can be estimated.

The calibration document shall include individual calibration of each material at various settings, which can be related to the machines metering devices. Normally, counters are provided on the machine for the purpose of calibration. Weight per minute is calculated at a particular setting to determine the total outflow of individual material at the setting. Precisely, the calibrations of machine for aggregate is done first as other components are related to the quantity of aggregates. Based on the job mid formula approved for the work, the calibration of machine for other ingredients i.e. bitumen emulsion, cement, water and additive (if any) is done in the proportion set out therein after making adjustment to the outflow of these ingredients at different settings to get the desired results. Bitumen emulsion is adjusted first, followed by cement, water and additive. Flow chart diagram of outflow of various ingredients is made for future reference. Once calibrated, the contractor as well as the client notes the setting of counters for various ingredients and periodical check is made to control the quality of the mix.

Appendix-9

Method for Design of Cold Mixes

Presently, a standard design procedure is not available for design of cold mixed BM or SDBC. The cold mix design procedure involves optimization of water as well as content of bitumen emulsion for the aggregates in the mix. The aggregates are made moist with water to wet its surface and then coated with cationic bitumen emulsion. The different sizes of aggregates are blended in proportions to achieve the best standard gradation of BM or SDBC. The following steps are necessary to design cold mixed BM or SDBC with cationic bitumen emulsion.

a) **Testing of aggregate :** The aggregates supplied are subjected to sieve analysis and other physical tests for determining the properties such as specific gravity, aggregate impact value, water absorption and sand equivalent value.

b) **Testing of bitumen emulsion :** The samples of slow setting bitumen emulsion (SS-2) to be used for construction of BM shall be tested as per IS: 8887. The coating test of aggregates shall also be carried out as per ASTM D 2397 or AASHTO M 208.

c) **Determination of premixing water content :** For determination of optimum water content for premixing, the quantity of bitumen emulsion is first determined using the following equation.

$$P = 0.05A + 0.1B + 0.5C \qquad \text{... (1)}$$

where,

P = Quantity of bitumen emulsion (%)

A = Percent aggregate retained on 2.36 mm sieve

B = Percent aggregate passing 2.36 mm sieve and retained on 90 micron sieve

C = Percent aggregate passing on 90 micron sieve

Different samples of aggregates and emulsion mixes are prepared keeping the quantity of bitumen emulsion constant (as determined from Equation 1) and varying the water content. The coated aggregates are then visually observed for coated area of the aggregate by the binder. The optimum water content is the water content at which maximum coating of aggregate occur. This water content is taken as premixed water content in designing the cold mixed BM or cold mixed SDBC. The optimum water content for BM or SDBC is normally found to be 2 to 3 percent by weight of aggregate. However, this quantity may vary depending on the weather condition (temperature, humidity and wind velocity) and properties of aggregates.

Determination of Optimum Binder Content

The procedure for the design of cold mix utilises standard Marshall equipment. Marshall test specimens in triplicate are prepared with different binder content (bitumen emulsion). Different sizes of aggregates are blended to achieve the specified aggregate gradation. About 1100 gm of graded aggregates are made wet uniformly with optimum water content. The different percentage of bitumen emulsion, say 5 percent by weight of aggregate, are then added to the aggregates and mixed for 1-2 minutes for achieving uniform binder coating. The mixture is dried for about 1-2 hours using a fan. The cold mix is then kept in oven at 40°C for 2 hours. The cold mix is then transferred into the Marshall mould with a filter paper on base plate and compacted with 50 blows of Marshall hammer on both faces. Similarly, the Marshall specimen are prepared with optimum water content and bitumen emulsion contents of 5, 6, 7, 8 and 9 percent by weight of aggregates. The Marshall specimens are then extracted from the mould after 24 hours and cured in air oven at 40°C for 72 hours before subjecting to different Marshall Stability Tests. Marshall specimen are subjected to different tests viz. bulk density, stability and flow values. Marshall stability and flow values are determined in dry state at 25°C. Different properties of the mixes are determined and other design parameters like voids content, voids filled with binder etc. are calculated.

Appendix-10

Preparation of Storable Mixture at Site (For Immediate Use)

Materials : Aggregate conforming to standard and grading, MS or SS-2 grade emulsion conforming to IS:8887, water potable.

Equipments : Measuring buckets, balance, concrete mixer/pug mill type mixer or cold mix plants.

Procedure : Charge blended aggregate meeting standard grading to pug mill or cold mix plant or concrete mixer followed by adding mixing water @ 1-2 percent to wet the aggregate, mix contents for 1-2 minutes. Add requisite quantity of MS/SS-2 emulsion @ 7 percent by weight of aggregate and mix for 1 minute. Discharge mix when it is brown and then use.

Preparation of Storable Mixture at Site (For Storage)

Material : Aggregate conforming to standard and grading, SS-2 emulsion with higher solvent in residue, water potable.

Equipments : Same as above

Procedure : Same as above

Storage : Store mixes in shade at dry place in U shaped concrete boxes (2 m x 2 m x 4 m). Mix shall be covered with a cover of polymer sheet to reduce exposure of mix to air, rain and sunlight.

Appendix-11

Water Resistance Test

Fifty grams of patching mix, shall be heated at 120°C in a laboratory oven for 4 hours, and then cooled to 95°C in laboratory by air, and then placed in 400 ml of boiling water in a 600-ml glass beaker and stirred about 95°C with a glass rod at the rate of 1 revolution per second for 3 minutes. The water shall be decanted and the mix shall be spread on an absorbent paper for visual observation of the coating. The aggregate shall be at least 90 percent coated with a bituminous film.

Appendix-12

Workability Test

Approximately 2.5 kg of the patching mix shall be cooled to –7°C in a freezer. After cooling, the mixture shall be capable of being broken up readily with a spatula that has a blade length of approximately 200 mm. This test shall be performed when the mix is produced and thereafter anytime during storage. If the mix is not workable at –7°C, it shall be rejected and the composition of the mix shall be properly modified (for example, by increasing the bitumen content and/or gradation changes). This test is also applicable in areas with hot climate because it amplifies the workability characteristics of the mix by using a lower test temperature.

Appendix-13

Binder Content in Cold Mixes

Take 600 gm of cold bituminous mixture in preweighed bowl and place in a hot air oven for 4 hours at 120°C. Cool the mix to room temperature and weigh to nearest 0.1 gm. Place cooled mix in a tray at 100°C for about 1 hour and take 500 gm (W1) of mix in a bowl of bitumen extractor, while the temperature of mixture is 50-60°C. Close the lid of extraction bowl and allow the contents to remain is submerged condition in solvent (TCF) for about 1 h. Repeat this process till TCE is clear of colour and aggregate is free from bitumen. Dry aggregate in an oven at 120°C for about 2 h. Take the weight of bowl+ aggregate for determination of bitumen content (W2). The difference in W1 and (W2 + weight of filler) indicate weight of residual bitumen in mixture.

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6) MS 14 "Asphalt Cold Mix Manual", Asphalt Institute, USA.

(The Official amendments to this document would be published by the IRC in its periodical, 'Indian Highways' which shall be considered as effective and as part of the code/guidelines/manual, etc. from the date specified therein)