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Bituminous Pavement Recycling

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ABSTRACT

A good road network is a critical infrastructure requirement for rapid economic growth. It provides connectivity to remote areas; provides accessibility to markets, schools, and hospitals; and opens up backward regions to trade and investment. Roads play an important role in inter-modal transport development, through links with airports, railway stations, and ports. Road network in India aggregates to about 4.2 million kilometers. This extensive road network, the second largest in the world only after US, caters to about 65 per cent of the freight traffic and 87 per cent of the passenger traffic. National Highways (NH) constitute about 70,934 kilometers which is only 2 percent of the total network. However, it caters to nearly 40% of the total road traffic. State Highways (SH) and Major District Roads (MDR) together constitute the secondary system of road transportation which contributes significantly to the development of the rural economy and industrial growth of the country.

The conventional method of providing bituminous surfacing on flexible pavements require significant amount of energy for production of bituminous binder from crude petroleum, drying aggregates and subsequently production of bituminous mix at hot mix plant (HMP).Hot mix recycling is the process in which reclaimed asphalt pavement materials are combined with new materials, sometimes along with a recycling agent, to produce hot mix asphalt mixtures. When properly designed, recycled mixtures can have better or similar performance to those of new conventional hot mix asphalt mixtures.

Recycling or Rejuvenating agents have been defined as organic materials with chemical and physical characteristics selected to restore properties of aged asphalt to desired specifications. In selecting the recycling agent, the viscosity characteristics of the combined aged asphalt binder and the recycling agent are the determining factors. These agents are also known as softening agents, reclaiming agents, modifiers, fluxing oils, extender oils, and aromatic oils. The choice of Recycling Agent (RA) grade will depend on the amount and hardness of the asphalt in the aged pavement. In general, the lower viscosity RA types can be used to restore aged asphalts of high viscosity and vice versa. Laboratory studies have been carried out on asphalt mixes with RAP material and rejuvenating agent and their performance has been compared with virgin asphalt mixes. Various performance tests such as Retained Stability, Indirect Tensile Strength (ITS), Creep test, beam fatigue test, resilient modulus and wheel tracking test has been carried out to compare the performance properties. This paper presents the results of all such performance tests carried out on asphalt mixes with RAP and virgin mixes. The laboratory results indicate that the asphalt mixes with RAP and rejuvenating agent provide better performance compared to virgin mixes. The paper also recommends that the Accelerated Pavement Testing Facility (APTF) should be put to use to evaluate the actual field performance of recycled pavements in a faster and effective manner.

INTRODUCTION

The bituminous pavement rehabilitation alternatives are mainly overlaying, recycling and reconstruction. In the recycling process the material from deteriorated pavement, known as reclaimed asphalt pavement (RAP), is partially or fully reused in fresh construction. Some of the advantages associated with pavement recycling are

- conservation of energy

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- less user delay
- preservation of environment
- reduced cost of construction
- conservation of aggregate and binder
- Preservation of existing pavement geometrics etc.

It is also reported that recycled mix has higher resistance to shearing and scuffing, which in turn increase the rutting resistance. Chances of reflective cracking are found to be less with recycled mix. Bituminous pavement recycling technology is not yet a popular in India. However, in advanced countries, bituminous material is the most recycled material in the construction industry.

- The RAP, as mentioned earlier, is a deteriorated bituminous mix that contains aged bitumen and aggregates. Hence, its performance is poorer when compared to the fresh mix.
- The purpose of the bituminous recycling is to regain the properties of the RAP, such that it tends to perform as good as fresh mix.
- Thus, the process of bituminous recycling involves mixing of the RAP, fresh bitumen, rejuvenators and new aggregates in suitable proportions.
- Rejuvenators are low viscosity oily substance, which helps to bring down the high viscosity of aged bitumen.
- The present article intends to discuss briefly the various possible methods of bituminous pavement recycling.

Example

- In USA, 33 million tons ofRAPs is used per year for recycling purpose which is around 80% of the total amount of RAP collected from old bituminous pavements.
- The amount of RAP used for recycling per year is about 7.3 million tons in Germany.
- In the year 1995, 20 million tons of recycled hot mix was produced in Japan, which constituted 30% of the total hot mix production.

RECYCLING METHODS

- Based on the process adopted in recycling the bituminous mix, it can be broadly classified as central plant recycling and in-situ recycling.
- If the RAP is modified at a plant, away from construction site then the process is known as central plant recycling.
- In-situ recycling process the RAP modified in place, where from it is available. Further, the RAP could be heated to condition it. If heat is applied then the process is known as hot mix recycling.
- In case of cold mix recycling, old materials are conditioned using recycling agent (like, low viscosity emulsion) without application of heat.
- The classification system is presented schematically in Figure.

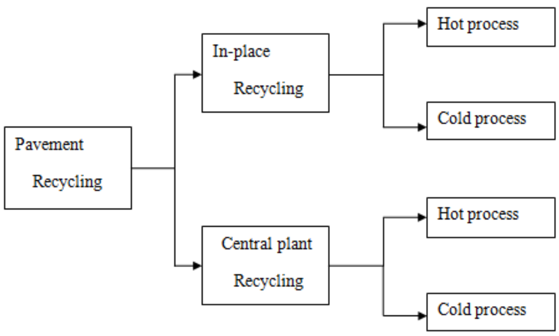

Fig: 2.1: Recycling process

Hot in-place recycling

- Initially the pavement intended to be recycled is heated to a higher temperature using suitable heating arrangement. This facilitates easier removal of materials. After heating, the pavement surface is scarified to the required depth.
- Further, depending on the requirement fresh aggregate and binder are added. The material is mixed well and compacted to the required thickness. As this process consumes less time, least disruption to traffic is caused.

- Also the transportation cost is less, as materials need not be taken away. Machinery required for this purpose being bulky in nature, sufficient right-of-way is required. This becomes an important consideration for in-place recycling within the city areas.

Cold in place recycling

- In cold in-place recycling process, first, the pavement is scarified with a scarifier. The scarified material is crushed to the required gradation.
- Then the required amount of fresh aggregates and binder in cold form (emulsion or cutback) is added. It is compacted and left for aeration. During this process additives like, cement, quick lime, fly ash may be used.
- The cold mix recycling takes care of local geometric correction, correction of pavement distresses like surface cracks. Being an in-situ process the hauling cost is considerably low.

- The air quality related problems during construction is almost negligible as compared to hot mix process. Similar to hot in place recycling process the machinery required being bulky, sufficient maneuvering space should be available for operating the equipment.

Hot central plant recycling

- In this process, RAP is combined with required quantity of bituminous binder, and fresh aggregates in a hot mix plant. The resultant mix is heated to an elevated temperature and mixed thoroughly.
- The hot mix is transported to paving site, placed, and compacted to the required compaction level. The main advantage of this process is that the mix properties and performance is comparable to that of virgin mix.
- It has noted that the quality control in this process is better when compared to hot in-place recycling. As RAP is susceptible to moisture, care needs to be taken while storing it.
- Less workspace is required for laying the recycled mix; hence this is suitable for the roads where the right of-way is somewhat restricted. The RAP should not be exposed to extremely high temperature as it causes pollution due to smoke emission.

Fig 2.2:Recycling plant

Cold central plant recycling

- This is the similar process as is the hot central plant mixing, except it does not involve any heating, and therefore emulsion bitumen is used binder in most of the cases.
- Precise control on the mixing time is important, over-mixing may cause premature breaking of emulsified bitumen, under-mixing results in insufficient coating of aggregat

STUDY OF NON-PERMISSIBLE CRACKING AND UNDULATION DISTRESS ON NH-5 (UNDULATIONS AND FAILURE OF BITUMINOUS SURFACING)

Main Reasons for Distresses

(i) Sudden increase in traffic loading especially on new roads where the design is based on lesser traffic is

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a major cause of cracking. After construction of good road, traffic of other roads also shifts to that road.
This accelerates the fatigue failure (Alligator Cracking).
(ii) Temperature variation ranging from 50° C to below zero conditions in the plain areas of North and Central India leads to bleeding and cracking.
(iii) Provision of poor shoulders leads to edge failures.
(iv) Provision of poor clayey subgrade results in corrugation at the surface and increase in unevenness.
(v) Poor drainage conditions especially during rainy seasons, force the water to enter the pavement from the sides as well as from the top surface.

Form of distress	Possible causes
Rutting	Inadequate pavement thickness. Post construction compaction. Instability of base of surfacing.
Shoving	Poor bond between layers. Lack of edge containment. Inadequate pavement thickness.
Depression	Settlement of service trench or embankment. Isolated consolidation. Volume change of sub grade.
Corrugations	Instability of AC (asphaltic concrete) or base course.

TABLE 3.1: Deformation

Form of distress	Possible causes
Edge drop	Inadequate pavement width. Erodible shoulder material (lack of plasticity).
Edge break	Inadequate pavement width. Inadequate edge support. Traffic travelling on shoulder edge drop. Weak seal coat/loss of adhesion.

TABLE 3.2: Edge effects

Form of distress	Possible causes
Meandering	Reflection of underlying cracking. Differential settlements. Trees.
Transverse	Reflection of shrinkage cracking. Construction joints.
Longitudinal	Reflection cracking. Poor paving lane joint. Pavement widening. Cut/fill differential settlement. Fatigue failure of AC.
Diagonal	As for meandering.
Block	Reflection of joints or shrink cracking in underlying concrete or cemented pavement. Thermal cycling in AC.
Crocodile (crazing)	Fatigue failure due to flexible/brittle base. Inadequate thickness.
Crescent (shear)	Poor bond between wearing and base courses, flexible base. Thin wearing course. High horizontal stress due to breaking, etc.
Environmental cracking (diagonal, long)	Reactive sub grade (often cracks centered on trees).
Pumping of fines through cracks	Traffic forces water in and out from the cracks extending full depth of surfacing leads to washing out of fines from granular material or sub grade.

TABLE 3.3: Form of cracking

Current Distress Modes

The following distress modes have been observed by all concerned within a year of completion of stretches of the highway:

- Minor hair cracks.
- Hair cracks up to the BC (Bituminous Concrete) thickness less than 35 mm.
- Hair cracks up to the BC thickness more than 35 mm.
- Alligator cracks up to full BC and DBM thickness, and
- Riding surface undulations beyond permissible limits.

Current Rectification in Progress

The following have been in progress for some time, respectively, for each of the above:

- Sealing with emulsion and covering with coarse sand grit.
- Removal of full-depth BC min 2 m (width) x 5 m (length) and BC reinstatement plus 25 mm overlay.
- Same as above with 40 mm overlay.
- Removal of full-depth BC+DBM and reinstatement of both, plus hard shoulders.
- Same as second point above, min 3.5 m (width) x 5 m (length).

ANTI REFLECTIVE CRACKING PRESERVATION MEASURES

Overlay Thickness

- Overlay thickness is one of the prominent factors in minimizing the cracks. Increased overlay thickness of bituminous layer with or even without modified binder helps in preventing the reflecting cracks. The remedy may lie in placement of a Stress Absorbing Membrane (SAM) or Strain Absorbing Membrane Interlayer (SAMI), bituminous impregnated geotextile or geogrids adhering to the old structures and the new structure.
- It may be pertinent that, all solutions be checked involving pavement components,

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such as overlays inter layer and old pavement structure and the type of soil.

- Interlayer Between the Old Surfaces and the New Overlay
- The differential movement of the thermal origin may be absorbed by the interlayer and has an important stress release effect on the structure.
- The stress release should also effectively be transferred between the pavement layers.
- The interlayer developed should be based on polymer modified bitumen
- (for Indian condition)since the viscoelastic behavior of this material meets our specific requirements.

Modification of Overlay Characteristics

- The effective way to prevent propagation of cracks is to inflict sufficient tensile resistance into the overlay system.
- This may be brought about by:
- Use of short fibers spread in entire mass, and
- Use of reinforcing elements located in the lower part of the overlay.

MANAGING THE RECLAIMING PROCESS

RAP may be obtained from several sources. The most common method isthrough milling operations, also known as cold planning. Two other commonsources of RAP are full-depth pavement demolition and asphalt plant waste.

This section discusses the different types of RAP sources.

Milling

Milling is a beneficial part of pavement rehabilitation. Advantages of millinginclude the following:

- removes distressed pavement layers,
- maintains clearances under bridges and avoids buildup of pavement weight on bridge decks,
- avoids filling up curbs and avoids drop-offs at drainage inlets and pavement edges,
- restores pavement grades and profiles, which are important for smoothness,
- leaves a rough texture on the remaining surface that creates a very good bond with an overlay, and
- is an efficient removal process that can be done within a short lane closure with the paving operations.

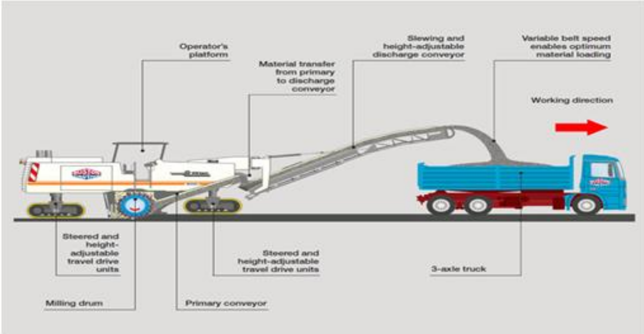

Fig 4.1: Milling machine

TESTS FOR BITUMEN

There are eight types of tests for bitumen

a. Bitumen content
b. Penetration
c. Softening point
d. Specific gravity
e. Ductility
f. Marshall stability
g. Flash and fire point
h. Absolute viscosity and kinematic viscosity

ABSOLUTE VISCOSITY TEST

Determination of Absolute Viscosity with the following components:

1.Constant Temperature Bath – A suitable bath for immersion of at least 6vacuum capillary viscometer tubes with a digital temperature controller. The accuracy of the temperature in the bath should be +/- 0.1°C throughout the bath.

2. Silicone Bath Oil suitable up to 150°C

3.Vacuum System – Capable of maintaining a vacuum within +/- 0.05 cm of the desired level up to and including 30 cm of mercury. The system shall consist of vacuum pump, moisture trap, vacuum regulator, manometer with electronic controller; bleed valve, all

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interconnecting tubing/piping, and any other accessories as needed to complete the vacuum system.
4.Thermometer for Bath – Mercury in glass, range 37.8 to 82°C, and graduations of 0.2°C
5.Timing Device – A stop watch or stop clock capable of reading up to ½ second.
6. Cannon-Manning Vacuum Viscometers- With manufacturers' calibration certificate viscometer holder and silicone cork. Size 12 and Size 13 (one each)[Size 12 is suitable for testing VG-10 and Size 13 is suitable for testing VG-20, VG-30, and VG-40 bitumen.]
7. Viscometer Stand – for holding 6 viscometers.
8. Installation of the quoted instrument in client's laboratory and operational training.

Procedure

Preparation of Sample

Heat the bitumen sample to a temperature not more than 90°C above its approx. softening point until is has become sufficiently fluid (like motor oil) to pour easily. Transfer about 20 ml into a suitable container and maintain at a temperature of 135 +/- 5.5°C stirring occasionally to allow entrapped air to escape.Pour the hot bitumen in the Canning-Manning vacuum viscometer through the larger diameter filling tube A so that bitumen is within +/- 2 mm of the fill line E. Place the charged viscometer in an oven or bath maintained at 135 +/- 5.5°C for a period of 10+/- 2 minutes to allow larger air bubbles to escape.

Testing:

Maintain the test bath temperature at 60 +/- 0.1 C. Place the charged viscometer vertically in the test bath with the help of a holder so that that the uppermost timing mark is at least 2 cm below the surface of the bath liquid. Establish a vacuum of 30 +/- 0.05 cm of mercury in the vacuum system and connect to the viscometer with the valve closed. After the viscometer has been in the bath for30 +/- 5 min, open the valve and allow the bitumen to flow in the viscometer.Measure the time required (to within +/- 0.5 sec) for the leading edge of the meniscus to pass between successive pairs of timing marks.

Calculation:

Calculate and report the absolute viscosity in poises to three significant figures as follows: Viscosity in poises = K t Where: K = Calibration factor in poise per second supplied with the viscometer tube for the pair of timing marks where the flow time exceeded 60 seconds. t = flow time in seconds

Test Equipment:

Fig 5.8: Absolute and kinematic viscosity

Grade of Bitumen: VG-30
Test Temperature: 60°C

Rise of Bitumen	Time taken in seconds	Correction Factor	Viscosity in Poises	Average Viscosity
From Timing Mark F to Timing Mark G	86	31.4	2700.4	-
From Timing Mark G to Timing Mark H	170	16.2	275.4	2727.2
Specifications as per IS:1206(Part-2)	-	2400 poise (min)	-	-

Table 5.8.1: Absolute viscosity test

Grade of Bitumen: VG-30
Test Temperature: 135°C

Rise of Bitumen	Time taken in seconds	Correction Factor	Viscosity in centi-stokes
From Timing Mark E to Timing Mark F	558	0.75	418.5
Specification as per IS:1206 (Part- 3)	-	350CST(Minimum)	-

Table 5.8.2: kinematic viscosity test

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Result:

Report the test temperature and vacuum level with the viscosity test results such as viscosity in poises @ 60°C and 300 mm mercury vacuum.

REQUIREMENTS FOR PAVING BITUMEN

Characteristics	Paving grades				Method of test Reference No IS
	VG 10	VG 20	VG 30	VG 40	
Absolute viscosity at 60°c, poises, min	800	1600	2400	3200	IS 1206 Part-2
Kinematic viscosity at 135°c σ_{st} min	250	300	350	400	IS 1206 Part-3
Flash point	220	220	220	220	IS 1203
Solubility in trichloroethylene percent Min	99	99	99	99	IS 1216
Penetration at 25°c 100g, 5°c, 0.1 mm	80-100	60-80	50-70	40-60	IS 1203
Softening point (R&B), °C, Min	40	45	47	50	IS 1205
Test on residue from thin film oven test/RTFOT					
Viscosity ratio at 60°C, Max	4	4	4	4	IS 1206 part-2
Ductility at 25°c, cm, min after thin film oven test	75	50	40	25	IS 1208

CONCLUSION

This article has described briefly the various processes of bituminous pavement recycling and their relative advantages and disadvantages. Pavement recycling technique is an excellent way of rehabilitation of deteriorated pavements.

With reference to Indian context –

1) Depleting natural resources,

2) Unwanted increase of road elevation due to periodical overlay (specially with the city roads),

3) Disposal problem with the RAP etc.

Necessitate adoption pavement recycling techniques in near future.

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