MAINTENANCE OF HIGHWAY BY SURFACE RECYCLING

Sushil Poonia¹, Dr. Bharat Nagar², Mukesh Choudhary³ and Parvez Choudhary⁴
¹M.Tech Scholar, Jagannath University, Jaipur (Rajasthan)
²Head of Department, Civil Engineering, Jagannath University, Jaipur (Rajasthan)
³Assistant Professor, Civil Engineering, Jagannath University, Jaipur (Rajasthan)
⁴M.Tech Scholar, Jagannath University, Jaipur (Rajasthan)

Abstract- Pavement recycling is becoming an important alternative worldwide for maintenance of highways, once sustainability and environmental issues have continued to receive more attention. The existing road surface asphalt mix has been 100% reused and recycled with new admix added as designed. By comparing all methods, hot in place recycling method is the best method for the maintenance of highway (flexible pavement) by surface recycling. India is faced with a challenge of the urgent need to rehabilitate the existing roads as well as to construct new roads under growing concerns with energy prices, aggregate shortages and the global warming. The reference point is that of considering the use of road materials in a closed cycle, in which a natural material, previously used in road construction, should not be rejected in the following life-cycle. The objective of this paper is that of analyzing flexible pavement recycling alternatives techniques, including reclaimed material from flexible pavements recycled with emulsion, cement and reused in a hot-mix. With the results obtained from the pavement design, the cost savings of using recycled materials in the different pavement structures were quantified and compared to a standard option, where new natural aggregates and binders would be used. In this analysis, the consideration of the reduction in the disposal of reclaimed pavement materials was also addressed. The results of this research will support the production of specifications, thus facilitating a more accurate reuse of natural resources, assisting in the protection of the environment, as well as in a more effective use of financial resources available for the activity of pavement maintenance and rehabilitation.

Keywords- HMA, RAP, HIR, CIR, FDR

I. INTRODUCTION

1.1 GENERAL

Surface Recycling is a very simple but powerful concept. Pavement recycling is a logical and practical way to conserve our decreasing supply of construction materials and also help to reduce the cost of preserving our existing pavement network. When properly designed and constructed, recycled pavements have been found to perform as well as pavements built with all new materials. The asphalt pavement industry recycles approximately 73 million tons of material annually, which is more than twice the combined total for recycled paper, glass, plastic, and aluminium. Several recycling techniques, such as hot mix recycling, hot in-place recycling, cold mix recycling, cold in-place recycling, and full depth reclamation, have evolved over the past 35 years. In-place recycling not only reduces the use of new materials but also reduces emissions, traffic, and energy associated with the transport and production of these materials. As with new pavement construction, well thought-out materials evaluation, mix design, structural design, and quality control and quality assurance procedures and specifications are all important elements of successful recycling projects. Technical assistance from industry organizations or experienced highway agencies is available to local agencies seeking guidance on the selection of appropriate recycling strategies. The specific benefits of recycling can be summarized as follows:
- Reduced costs of construction.
- Conservation of aggregate and binders.
- Preservation of the existing pavement geometrics.
- Preservation of the environment.
- Conservation of energy.
- Less user delay.

Rehabilitation alternatives:

There are large numbers of rehabilitation alternatives available for asphalt pavement. As shown in figure below. Recycling is only one of the several rehabilitation alternatives. Some of the other common methods are thick or thin hot mix asphalt (HMA) overlay. The HMA overlays may be dense graded or open graded, cold milling is also used as a rehabilitation technique. The choice of the rehabilitation alternative depends on observed pavement distress, laboratory and field evaluation of existing material, and design information. Also, maintenance of geometrics and original thickness of pavements, especially in underpasses, influence the choice of rehabilitation method. HMA overlays can be used with or without milling or recycling. Except asphalt surface recycling, all other recycling methods such as hot mix or hot in-place or cold in-place recycling, have the potential to improve the structural capacity of pavements. In addition to this, recycling has some unique advantages which are not available with other types of rehabilitation techniques. The Asphalt Recycling and Reclaiming Association define four different types of recycling methods:

(1) Hot recycling
(2) Hot in-place recycling
(3) Cold in-place recycling
(4) Full depth reclamation.

**Hot mix asphalt recycling** is the process in which reclaimed asphalt pavement (RAP) materials are combined with new materials, sometimes along with a recycling agent, to produce hot mix asphalt (HMA) mixtures. Both batch and drum type hot mix plants are used to produce recycled mix. The RAP
material can be obtained by milling or ripping and crushing operation. The mix placement and compaction equipment and procedures are the same as for regular HMA.

**Figure No 2: Introduction of RAP material in a drum plant**

**Hot in-place recycling (HIR)** consists of a method in which the existing pavement is heated and softened, and then milled to a specified depth. New HMA (with/without RAP) and/or recycling agent may be added to the scarified RAP material during the recycling process. HIR can be performed either as a single pass or as a multiple pass operation. In single pass operation, the scarified in-place material can be combined with new material if needed or desired. In multiple pass operation, the restored RAP material is re compacted first, and a new wearing surface is applied later. The depth of treatment varies between 20 to 50 mm (¾ in to 2 in). The Asphalt Recycling and Reclaiming Association have identified three HIR processes;
(a) Surface recycling  
(b) Repaving  
(c) Remixing.

**Cold in-place recycling (CIR)** involves reuse of the existing pavement material without the application of heat. Except for any recycling agent, no transportation of materials is usually required, and aggregate can be added, therefore hauling cost is very low. Normally, an asphalt emulsion is added as a recycling agent or binder. The emulsion is proportioned as a percentage by weight of the RAP. Fly ash or cement or quicklime may also be added. These additives are effective for over asphalted and low stability mixes. The process includes pulverizing the existing pavement, sizing of the RAP, application of recycling agent, placement, and compaction. The use of a recycling train, which consists of pulverizing, screening, crushing and mixing units, is quite common. The processed material is deposited in a windrow from the mixing device, where it is picked up, placed, and compacted with conventional hot mix asphalt lay down and rolling equipment. The depth of treatment is typically from 75 to 100 mm (3 to 4 in). The advantages of cold in-place recycling include significant structural treatment of most pavement distress, improvement of ride quality, minimum hauling and air quality problems, and capability of pavement widening.
Full depth reclamation (FDR) has been defined as a recycling method where all of the asphalt pavement section and a predetermined amount of underlying base material are treated to produce a stabilized base course. It is basically a cold mix recycling process in which different types of additives such as asphalt emulsions and chemical agents such as calcium chloride, Portland cement, fly ash, and lime, are added to obtain an improved base. The four main steps in this process are pulverization, introduction of additive, compaction, and application of a surface or a wearing course. If the in-place material is not sufficient to provide the desired depth of the treated base, new materials may be imported and included in the processing. New aggregates can also be added to the in-place material to obtain a particular gradation of material. This method of recycling is normally performed to a depth of 100 mm to 300 mm (4 to 12 in). The train consists of recycling machine hooked to a water tanker and steel drum roller with pad foot shell. The advantages of full depth reclamation are that most pavement distresses are treated, hauling costs are minimized, significant structural improvements can be made (especially in base), material disposal problems are eliminated, and ride quality is improved.

1.1 OBJECTIVE

Increase the speed of construction is the main objective of this research. Less user delay also very main objective. Conserve resources and energy. By using hot in place recycling we can reduce cost, time. The aim of this paper is to obtain same strength by using some admixtures. The main objectives are:

a) Increase the speed of work
b) Increase the strength of recycled paved surface by using some admixtures.
c) Reduce the cost of project.
d) Maintain the quality of surface.
e) Less user delay.
f) Maintain geometry of existing pavement.

II. LITERATURE REVIEW

James, 1990 the construction sites visited all used different procedures for recycling and used different manufacturer's equipment. The recycling operations at Marshall, Texas, and Trinity, Texas, were single-pass methods of HIP; whereas, the recycling at Richmond, Virginia, and Grand Prairie, Texas, were multiple-pass methods of HIPR.

Kandhal, 1997 His paper gives a brief overview of the recycling of asphalt pavements. Five recycling methods are presented: (1) cold planning; (2) hot recycling; (3) hot in-place recycling; (4) cold in-place recycling; and (5) full depth reclamation. Strategies for selecting an appropriate recycling method are discussed. The performance of different recycling processes based on the review of literature is presented. Economics, legislation/specification limits, and structural design associated with recycling of asphalt pavement are also presented.

Widyatmoko, 2002 The literature review carried out for this preliminary investigation into asphalt pavement recycling for Hong Kong found that recycling of pavement materials was a viable, cost-effective and environmentally friendly procedure, both for pavement rehabilitation and for new construction. Hot in Plant Recycling (HIPR) was considered the most appropriate process for Hong Kong's densely populated environment, with its heavily trafficked urban/rural mix of bituminous pavements primarily in need of surfacing renewal.

Kim, 2006 compared the compaction properties of specimens prepared by typical proctor Methods with specimens prepared with a gyratory compactor and found that the OMC And MDD of the specimens compacted via gyratory compactor were found to more Closely correlate with field density measurements. Kim also found that at low confining
Pressures, pure aggregate and 50%/50% blends of RAP and aggregate had an equivalent stiffness, but at high confining pressures the 50%/50% blends had a higher stiffness than the pure aggregate.

### III. METHODOLOGY

#### 3.1 GENERAL

**Hot in-place recycling (HIR)** consists of a method in which the existing pavement is heated and softened, and then scarified/milled to a specified depth. New HMA (with/without RAP) and/or recycling agent may be added to the scarified RAP material during the recycling process. HIR can be performed either as a single pass or as a multiple pass operation. In single pass operation, the scarified in-place material can be combined with new material if needed or desired. In multiple pass operation, the restored RAP material is re compacted first, and a new wearing surface is applied later. The depth of treatment varies between 20 to 50 mm (¾ in to 2 in). The Asphalt Recycling and Reclaiming Association have identified three HIR processes:

(a) Surface recycling
(b) Repaving
(c) Remixing.

Hot in-place recycling operation in which the existing asphalt surface is heated and scarified to a specified depth. The scarified material is combined with aggregate and/or recycling agent. The mix is then compacted. A new overlay may or may not be placed in the recycled mix. In the second type of HIR method, repaving, the surface recycling method is combined with a simultaneous overlay of new hot mix asphalt (HMA). Both the scarified mix and the new HMA are rolled at the same time. In the case of remixing the scarified RAP material is mixed with virgin HMA in a pug mill, and the recycled mix is laid down as a single mix. The advantages of hot in-place recycling are that surface cracks can be eliminated, ruts and shoves and bumps can be corrected, aged asphalt is rejuvenated, aggregate gradation and asphalt content can be modified, traffic interruption is minimal, and hauling costs are minimized.

#### 3.2 APPLICATION OF HOT IN PLACE RECYCLING

HIPR is best suited for roadways with light truck traffic.

HIPR can treat pavement distresses and surface irregularities including:

- Ravelling
- Bleeding
- Corrugations
- Shoving
- Slippage
- Poor ride quality

![Figure No. 6: Pavement before HIR](image)

![Figure No. 7: Pavement after HIR](image)
Shallow rutting
Shallow potholes
Non-fatigue cracking (longitudinal, transverse, or reflection)

3.3 LIMITATIONS OF HOT IN PLACE RECYCLING
HIPR should not be used on pavements with:
- Multiple chip seals
- Rubberized Hot Mix Asphalt (RHMA)
- Geo synthetic Pavement Interlayer (GPI)
- Structural inadequacy
- Greater than 5% alligator cracking
- Moderate to excessive filled cracks
- Base or sub grade failure
- Moisture related problems:
  - Poor drainage
  - Pumping
  - Saturated sub grade material

3.4 FUNCTIONING OF EACH MACHINE
i) **Pre-Heater** Two Pre-Heaters, operating in tandem, gently heat and soften the existing asphalt pavement surface. With the Hot Air Heating System incorporated, air is heated to about 600 degrees Celsius and in combination with low level infrared heat, blown directly onto the pavement surface. A cover that prevents loss of circulation shields the hot air.

ii) **Pre-Heater-Miller** The Pre-Heater-Miller applies additional heat, which helps its milling heads easily loosen and mill the softened pavement. The automated depth control feature permits asphalt mixture removal to a desired depth depending on the rehabilitation work and the milling heads can be adjusted to a working range from 3.3m to 3.9m.

iii) **Post-Heater Mixer** Post-Heater Mixer has installed a series of devices to be used to continuously mix and expose the milled asphalt mixture to hot air and infrared heat. The asphalt mixture is taken up and transferred to the 300tph twin-shaft pug mill, where the transferred asphalt mixture and new admix as required by a mixture design are mixed. The Post Heating and Stirring Process, which is a patented technology, helps thorough and uniform heating of the recycled asphalt mixture and also removes excess moisture from the materials.

iv) **Paver** The fully mixed material is transferred from the pug mill to the hopper of a conventional paver for lay down.

v) **Rollers** Compaction is done by conventional rubber-tired and vibratory rollers.

3.5 CASE STUDY OF WORK DONE BY A HOT IN-PLACE RECYCLING METHOD IN INDIA

3.5.1. Introduction
This is the first single project of such a large scale HIR work ever done by the same train of machines in the world. The experiences of success, which have overcome technical problems and difficulties, will give a good solution to the above challenge. AR2000, which has made such a work possible, is based on the concept of using jet hot air to soften the surface layer of pavement with milling, mixing and repaving processes to follow for recycling. Thus it consists of two pre-heaters, one pre-heater miller and one post-heater mixer as a train. Thus AR2000 implements a 100% recycling work of required quality with the original gradation unchanged and with the temperature of milled asphalt mixture maintained, as required, for compaction, which has been confirmed by a quality control check.
done by the job owner. The job owner did every day quality control check with results of each day operation. Marshall Test concerning Stability, Density, Void and other items was done and the results have been confirmed to clear the strict quality criteria. 90 days were taken for the whole recycling work done by AR2000. The average operation speed was 3.77m/min, which is far beyond the speed of work by the conventional manual method. In conclusion the AR2000 recycling work done on the above highway has assured the economic viability of HIR method using AR2000 and the efficiency of the method. Deteriorated pavements are characterized by poor ride quality and physical distress, such as cracking, ravelling, corrugations, rutting and potholes. Pavement deterioration is greatly influenced by harsh climatic conditions, high traffic volume and excess loads as well as by road construction process and maintenance. The deterioration of asphalt pavements will be accelerated in several years after the start of service but timely rehabilitation such as resurfacing and recycling can restore pavement quality and extend a roadway’s lifetime. The surface course of asphalt pavement is made of bituminous material and mineral aggregates which are mixture of high-quality rocks and sands. The world of today, conservation of environment is of utmost importance and more so in the road construction industry which uses huge quantity of natural resources and energy. The above mentioned situation being considered, the Hot In-place recycling process by using the AR2000 Super Recycler was adopted, which is an innovative method in road recycling besides being environmentally friendly. The superiority of HIR was confirmed over CIR which was an alternative method. Table 3.1 shows results of the comparison between HIR and CIR in terms of economics, quality and execution characteristics.

|                    | Hot in place recycling | Cold in place milling + hot mix asphalt from asphalt plant | Cold in place milling + cold mix asphalt in place |
|--------------------|------------------------|-----------------------------------------------------------|--------------------------------------------------|
| Existing aggregates to be recycled | Maintained             | Crushed                                                   | Crushed                                          |
| New asphalt binder required | Less; because of existing surface maintained | More; because of existing aggregate crushed and smaller average size of particles | Asphalt emulsion (+ cement or lime) |
| Mixture design      | Original design maintained | Redesign                                                  | Redesign                                        |
| Truck delivery frequency | Less; one way delivery | Much more; two way deliveries                            | Less; one way delivery                          |
| Surface course durability | Good                   | Good                                                      | Poor                                             |

3.5.2 Construction Summary

a) A road rehabilitation work was done by Hot In-place recycling method at Vadodara, Gujarat State on the highway between Vadodara and Holol.
b) 128km lane, i.e., 32km x 4lanes was rehabilitated with the total lane pavement surface 100% recycled.
c) The machine used was AR2000, which already did successful recycling work in Canada, the U.S., Mexico, Italy, Japan and some other countries.
d) But for the first time in India and in terms of scale as a single recycling project for the first time in the world.
e) AR2000 It is a train of machines consisting of two Pre-Heaters, which heat and soften the existing pavement surface, the Pre-Heater-Miller, which mills the softened surface while still heating and a Post-
Heater Mixer, which mixes for re-pavement milled materials to be recycled and new admix, to be followed by a conventional paver.

3.5.3 AR2000 and Characteristics of the System

AR2000 was developed by a Canadian company, Martec and has been installed with the internationally patented technologies. The concept was based on the Japanese company’s patented technology of on-site recycling by heating the surface layer. The technological advance of the AR2000 more efficiently allows for 100% recycling of the existing asphalt mixture on-site without crushing aggregates in use as well as without burning the surface layer. The AR2000 can generate 38,000 mega-joules/hours.

3.5.4 Characteristics of the System

3.5.4.1 Technology Designed and Manufactured to Operate Virtually Emission Free
i) It uses a hot jet air circulation system utilized to soften asphalt pavement surface, not using direct flames. Results are more environmentally friendly.
ii) Existing asphalt is 100% recycled, generating no waste from the site.
iii) The deafening noise associated with conventional digging is significantly reduced through softening asphalt pavement surface.

3.5.4.2 Securing On-site Construction Safety
i) Machine operating skills are required and have to be acquired by operators. But they can easily do so. Once acquired it becomes on easy job operation and offers safe working conditions for workers.

ii) Diesel fuel rather than propane is used as radiant heating method, and minimizes the risk of explosion.

3.5.4.3 Substantial Time Saving
vi) Based on the actual job records, the average operation speed was 3 to 5m/min. depending on then working conditions the highest speed was over 5m/min., which could not have been achieved by the conventional resurfacing method.

vii) Consequently compared to the conventional resurfacing method, HIR method considerably reduces project duration.

3.5.5 Temperature Management

The temperature level of EAM heated by Pre-Heaters is essentially important for the efficiency of milling, mixing and compaction. The existing pavement surface was heated enough by the two Pre-Heaters to be milled. The temperature of asphalt mixture right after paving work done by an asphalt paver was almost 130 degrees Celsius, which falls in the range of required compaction temperature. Therefore the enough heating capacity of AR2000 has been proven to secure good quality work.

| Measurement point          | Av. Temperature | Measurement point     | Av. temperature |
|---------------------------|-----------------|-----------------------|-----------------|
| Existing pavement         | 40              | d. Milled asphalt mix.| 140             |
| Heated pavement           | 110             | e. New asphalt mix.   | 148             |
| Heated pavement           | 137             | f. Before compaction  | 130             |

3.5.6 Operational Speed

AR2000 works fast and enables to significantly shorten the conventional work duration. Usually there are 2 shift work schedule. The average working hours were from 6:00 to 20:00 and the actual working hours of AR2000 were 10 hours from 7:00 to 18:00 including one hour for lunch. It is essentially important to keep the machines always in a good condition, which would shorten working hours. In the beginning of work, which started in February, 2006, the operation speed varied due to the then learning process of operation, interruption of asphalt supply from the asphalt plant and lack of
every day mechanical check as well as mechanical problems. As from April, however, smoother operation started.

3.5.7 Conclusion
The Vadodara Highway rehabilitation work done by AR2000 HIR method has proven:
1. The mechanical work results meet the Requirement of India.
2. The work will be economically viable, saving the total cost, working hours, new asphalt mixture requirement, new aggregates and etc as well as shortening job duration by high speed operation once the operating conditions get normalized.
3. The work is environmentally friendly in terms of the total energy use, and of asphalt and aggregate use as well as in terms of gas emission.

3.6 MATERIALS CHECKS
- Determine whether cores and samples were obtained as part of the subsurface investigation.
- Examine samples for consistency over the length of the project.
- Note the presence of any surface treatments, paving fabrics, or exotic mixes.
- Select the appropriate HIR process to correct deficiencies found in the field investigation.

3.7 PRECONSTRUCTION INSPECTION RESPONSIBILITIES
This section identifies activities that should be performed before proceeding with construction activities.

3.7.1 Preconstruction Meeting
- Ensure that all necessary contractor and agency personnel attend the preconstruction meeting.

3.7.2 Pavement Preparation
- Ensure that any areas with drainage problems and isolated areas of base failure are repaired in accordance with the contract documents prior to starting HIR-related construction.
- Ensure that the pavement surface profile can be restored to the profile required in the contract documents by cold planning or preliminary levelling of localized areas of excessive deformation, i.e. 1 inch (25 mm) rutting or abrupt vertical change such as an overlay at a concrete joint.
- Ensure the pavement surface is clean and free of deleterious materials.

3.7.3 Equipment Inspections
3.7.3.1 Pre heaters
- Verify that the number of pre heaters is adequate to sufficiently heat the pavement to facilitate scarification to the depth specified in the contract documents typically a pavement surface temperature of 230 °F to 300 °F (11 °C to 149 °C).
- Verify that each pre heater unit is equipped with an enclosed or shielded thermal containment hood capable of heating the pavement surface to the required temperature.
- Verify that the pre heater hood is a minimum of 4 inches (100 mm) wider than the scarification on either side of the machine.

3.7.3.2 Milling/Scarifying Units
- Verify that the milling/scarifying units are capable of scarifying the existing pavement surface to the required depth.
- Verify that the milling/scarifying units are equipped with height controls to facilitate clearance of manholes and other obstructions in the pavement surface.
3.7.3.3 Rejuvenating Agent and Admixture System

- Verify that the discharge rate of the rejuvenating agent and admixture (new aggregates or HMA) is calibrated relative to the forward speed of the recycling unit so that the quantity of material added is consistent with the contract documents.

- Verify that the recycling unit is equipped with meters that show continuous readout for monitoring of quantities required in the contract documents.

3.7.3.4 Mixing System

- Verify that the mixing system is capable of thoroughly mixing the scarified material with rejuvenating agent and/or admixture (new aggregate or HMA) in accordance with the contract documents.

3.7.3.5 Spreaders

Verify that the equipment includes a form of spreader box and screed capable of spreading and levelling the blended material uniformly over the width of the pavement being processed, in accordance with contract documents.

3.7.3.6 Paver (Repaving)

- Verify that the paving machine is capable of automatically matching a longitudinal joint in accordance with contract documents.

- Verify that the screed pulled by the paving unit is equipped with slope and grade controls capable of automatic screed levelling to construct the pavement to the line and grade specified in the contract documents.

- Verify that sufficient heat is maintained on the screed to prevent scraping, scoffing, or gouging of the newly completed surface.

3.7.3.7 Rollers

- Verify that the rollers onsite are of the type, width, and operating weight specified in the contract documents.

- Verify that the number of rollers is sufficient to keep up with the process in accordance with the contract documents.

- Verify that water systems are installed and working on all rollers as required by the contract documents.

- Verify that working scrapers are in place on all rollers as required by the contract documents.

3.7.4 Weather Requirements

- Verify that the ambient air temperature meets contract specifications, typically the same as for hot mix asphalt, a minimum of 45 °F (7 °C) in the shade.

- Verify that no significant precipitation is predicted within construction operations, in accordance with contract documents.

- Consider that variations in temperature, humidity, and wind conditions will affect breaking and curing times. Specifications typically require that fog is not present during construction operations. Consider that at high altitudes, greater than 6500 feet (1980 m), the effect of temperature needs to be taken into account.

IV. RESULT AND ANALYSIS

4.1 DATA COLLECTION AND ANALYSIS

a) Maintenance of highway (Jammu to Srinagar)

Assume 1 K.M segment.

Normal method of maintenance:
1. Dismantling/Scarifying of premix damage surface with mechanical means:
For 1 K.M road segment, 7.5 m width, 75mm depth and dismantle 40% 
\[(1000*7.5*0.075) = 562.5\text{cubic meter.}\]
Take 40% of 562.5 cubic meters = 225cubic meter.
Cost = 800 Rs/cubic meter 
225x800 = 180000
Total cost = 180000 Rs

2. Laying WBM (wet mix) for 1 K.M segment. Take 30% potholes: 
\[(1000*7.5*.075) = 562.5\text{cubic meter.}\]
For 30% = .30*562.5 = 168.75cubic meter
Cost = 2000/cubic meter
2000x168.75 = 337500
Total cost = 337500 Rs

3. Laying premix carpet for 1 K.M segment, 50 mm depth
Find for 1 cubic meter as per the state govt. of Jammu and Kashmir rate.
\[1000*7.5*.025 = 187.5\text{cubic meter.} \text{(For 25 mm layer rate given)}\]
We find per meter cubic price:
\[(7500*365) = 2737500\]
\[2737500/187.5 = 14600\text{per cubic meter.}\]
Cost = 14600/cubic meter
375*14600 = 5475000
Total cost = 5475000 Rs
Total maintenance cost for 1 K.M segment = 5992500 Rs
It's approx. 60 Lac.

b) By normal maintenance method time taken for 1 K.M segment:
Total time of project for 1 K.M segment by normal method = 15 days
1. Scarifying of premix damage surface with mechanical means = 5 days
2. Laying WBM (wet mix) for 1 K.M segment. Take 30% potholes. = 5 days
3. Laying premix carpet = 5 days
   Total maintenance cost = 60 Lac.
   Total maintenance time = 15 days.

c) By surface recycling method: - based on the actual job records,
Average operation speed was 3 to 5 meter/min.
Highest speed was over 5.38 meter/min.
Minimum speed = 3 meter/min.
Average operating speed in India = 4.22 meter/min. (Vadodara to Holol project)
For 1 K.M, total time record for surface recycling = maximum 7 hours.
Total cost of surface recycling for 1 K.M is approx. = 36 Lac.
Total time of surface recycling for 1 K.M = 7 to 8 hours.

4.2 RESULT
1. For conventional method (normal method) of maintenance of highway (flexible pavement)
   Total maintenance cost = 60 Lac.
   Total maintenance time = 15 days.
2. For maintenance of highway (flexible pavement) by surface recycling method
   Total cost of surface recycling for 1 K.M is approx. = 36 Lac.
Total time of surface recycling for 1 K.M = 7 to 8 hours.

V. CONCLUSIONS

At present, and for the future, the main concern of any road administration will be that of guaranteeing sustainable quality of the constructed road network, both from the structural and functional point of view, where the environmental impact of any technological solution will need to be increasingly evaluated. In this context, pavement rehabilitation alternatives, which considers the reuse of existing material and recycling of surface, play a decisive role, when compared to the traditional strategy of placing a new overlay, they lead to a clear savings in terms of the technical-economical-environmental impact, for the road administration, users in particular and society in general. Today, many recycling alternatives should be considered in any rehabilitation design. This paper dealt with the analysis of the technical- economical-environmental value of recycling alternatives. Hot in place recycling method is best method compared to other. For the reuse of reclaimed material from an existing pavement, it was concluded that a percentage of at least 40% is feasible which represents an important savings from both the economical and environmental point of view. In terms of future research work, the test trials under real traffic conditions, where those recycling alternatives were constructed, will be followed by monitoring their structural and functional performance evolution. With the results from this research project, in the next few years, it will be possible to improve the reliability of the rehabilitation pavement design, as well as provide guidelines for the technological point of view.

Hence, the conclusion from this thesis is that, as in the case of conventional asphalt pavements, recycled asphalt mixtures must be designed to meet proper specifications, produced with good quality control, and placed properly with no defects or irregularities.

This thesis shows that savings up to 40 and 50 percent can be achieved by using hot mix, hot in-place respectively. These savings are achieved when one of the recycling methods is used in place of conventional method or some other recycling method. In addition to the material and construction cost savings, significant amount of cost savings (in terms of user costs) can be realized by the reduced interruptions in traffic flow when compared with conventional rehabilitation techniques. Recycling can be used to rejuvenate a pavement or correct mix deficiency and conserve material and energy options not available with the conventional paving techniques. A conventional overlay can require upgrading shoulders to maintain the profile, raising guard rails to maintain the minimum safety standard, and restrict overlays below the bridges to maintain underpass height. On the other hand, recycling can effectively be used to maintain the highway geometry and thus resulting in substantial overall savings as well.

India is faced with a challenge of the urgent need to rehabilitate the existing roads as well as to construct new roads under growing concerns with energy prices, aggregate shortages and the global warming. Recently it has eventually successfully finished a highway recycling work of 128 km lane (32km x 4 lanes) of Vadodara Highway, using a Hot In-Place recycler, AR2000 despite of mechanical, operational and new asphalt supply problems and/or difficulties which took place during the operation. The existing road surface of asphalt mix has been 100% reused and recycled with new admix added as designed. This is the first large scale HIR work ever done as a single recycling project in the world as well as in India. The experiences of success, which have overcome such problems and difficulties, will give a good solution to the above challenge.

REFERENCES

[1] D.E. Peterson, “Good Roads Cost Less Pavement Rehabilitation Needs, Benefits, and Costs in Utah”, Report No. UDOT-MR-77-8, Utah DOT, Salt Lake, UT, 1977.
[2] J.A. Epps, D.N. Little, R.J. Holmgreen, R.L. Terrel, “Guidelines for Recycling Pavement Materials”, NCHRP Report 224, TRB, National Research Council, Washington, DC, 1980.
A.J. Peters, R.H. Gietz, J.P. Walter, “Hot-Mix Recycling Evaluation in Washington State”, Report WA-RD-98.1, Washington State Department of Transportation, 1986.

R.G. Maag, G.A. Fager, “Hot and Cold Recycling of K-96 Scott County, Kansas”, Report FHWA-KS-90/1, FHWA, U.S. Department of Transportation, 1990.

L. Stephen, R. Terreland, M. Corbett, “New Developments in Hot In-Place Recycling Technology and Specification”, Proceedings of the 43rd Annual Conference of the Canadian Technical Asphalt Association, Vancouver, Canada, 1998.

Sorensen, Jim, Thomas Siddon, “Advanced HIR Offers a Durable, Cost-Effective Alternative for Roadway Surface Maintenance”, the 24th International Baltic Road Conference, Riga, Latvia, 2000.

Hosokawa, Gomi, Kasahara, “Hot In-Place Recycling of Porous Asphalt Concrete”, Proceedings of 4th International Symposium on Maintenance and Rehabilitation of Pavements and Technological Control, Belfast, Northern Ireland, 2005.

J. Mostafa, M. Kaplun, J. Emery, “Martec’s Approach to Road Maintenance for Sustainable Pavements through Hot In-Place Recycling Technology”, Proceedings of International Symposium on Pavement Recycling, Sao Paulo-SP-Brazil, 2005.

Atsushi Kasahara, “Recycling of Pavement Material and Hot in-Place recycling”, “International Seminar on Innovations in Construction and Maintenance of Flexible Pavements”, Indian Road Conference, Japan, 2015.

S. B. Northboro, “Hot Mix Recycling In Massachusetts”, Project IR 290-5 (054) 101, Project Report, Undated.