A CRITICAL REVIEW OF CHARACTERIZATION AND PERFORMANCE EVALUATION OF RECLAIMED ASPHALT PAVEMENT (RAP) IN ROAD CONSTRUCTION

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ABSTRACT

Removed and / or reprocessed pavement materials containing asphalt and aggregate are termed as Reclaimed Asphalt Pavement (RAP). These materials are generated when asphalt pavements are removed for reconstruction and/or resurfacing of bituminous roads. When scraped or removed RAP properly screened and crushed, it consists of high quality well graded aggregate coated by asphalt cement. Recycling of asphalt pavement makes both environmental and economic profits. Presently use of recycled asphalt pavement has grown worldwide, reducing use of virgin materials thus becoming Technique of Sustainable Development. The objective of this review is to understand the scenario of using RAP in road construction basically in reference to India; learning from developed countries and other nations where use of RAP is in Advance stage.

Key Words: Reclaimed Asphalt Pavement (RAP) Recycling, Road construction, GSB, Base, Wearing surface, Aggregate, Bitumen.

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1. INTRODUCTION

Recycling is defined as “the reuse, usually after some processing, of a material that already has served its first-intended purpose”. 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.

**Figure 1:** Field Conditions of Wastage of RAP

**Figure 2:** Availability of Huge Quantity of RAP

1.1. **Back Ground:**

Pavement recycling came in discussion in USA in 1st time. In USA presently the asphalt pavement industry recycles huge quantity of RAP material annually, which is more than twice the combined total for recycled paper, glass, plastic & aluminum in USA. Bituminous pavement recycling technology is not yet a popular in India and other developing countries because there is no sufficient guidelines and standards available. However in advance countries bituminous material is the most recycled material in the construction industry. For example, in USA, 73 million tons of RAP 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 0.84 million tons in Sweden, 7.3 million tons in Netherlands. In the year 1995, 20 million tons of recycled hot mix was produced in Japan, which constituted 30% of the total hot mix production. whereas in 2015 i.e. after 20 years study shows that in Japan there are about 1150 asphalt plant serving more than 90% of the Country and producing about 55 million tons HMA, out of which about 42 million tons contain recycled HMA.

There are four major asphalt production cost categories including materials, plant production, trucking, and field construction (lay down). In general, the materials are the most expensive.
category, in many cases up to about 70% of the cost to produce HMA mixtures (Figure 3). The binder in any mix is the most expensive material. Therefore, the use of RAP in the intermediate and surface layers of flexible pavements replacing a portion of the binder is the most cost effective methods of constructing the nation's pavements.

Figure 3: Production Cost Categories (%) for a Typical Construction Project

1.2. Material:
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:

1. RAP
   (i) Crushing
   (ii) Screening
   (iii) Stock Pilling
2. Bitumen
3. Rejuvenators
4. Virgin aggregates

1.3. Recycling Methodologies:
Pavement Recycling (PR) Classification could be based on the depth of the old pavement removed.

1. Surface Recycling (SR)
   If the top layers of pavement fail, then the upper layers are removed and laid again. This process is known as surface recycling.
2. Full Depth Reclamation (FDR)
If base failure occurs then the pavement layers up to base layer is removed and constructed again. This process is known as full depth reclamation.

Base on the process adopted in recycling the bituminous mix, it can be broadly classified as

1. Central Plant Recycling
   (i) Hot process (HCPR)
   (ii) Cold process (CCPR)
2. In-Situ/ In Place Recycling
   (i) Hot process (HIPR)
   (ii) Cold process (CIPR)

![Figure 4: Methodologies of Recycling of Asphalt Pavement](image)

2. ADVANTAGES
Pavement recycling technique is an excellent way of rehabilitation of deteriorated pavements. With reference to Indian context. RAP may use to overcome problem of:-

(a) Depleting natural resources.
(b) Unwanted increases of road elevation due to periodical overlay (especially with the city roads),
(c) Disposal problem with the RAP.

Some other advantages associated with pavement recycling are :-

(i) Less user delay
(ii) Conservation of energy
(iii)Preservation of environment
(iv)Reduced cost of construction
(v) Conservation of aggregate and binder
(vi)Preservation of existing pavement geometrics etc.

3. LITERATURE REVIEW:
3.1 Ahmad M. Abu Abdol summaries that RAP was used for the first time in 1973, however, with low percentage due to the lack of understanding of the effect on the performance of asphalt mixes. Currently higher percentage (e.g. >50%) are being utilized to
reduce costs and natural resources and make use of demolished old asphalt pavements. The main concern of combining RAP in new asphalt mixes is how it will affect the resistance of these mixes to permanent deformation (rutting), fatigue cracks and thermal cracks, which are the main distress that affect the performance of asphalt mixes.

3.2 Albert M. Bleakley find innovative ways to incorporate reclaimed asphalt pavement (RAP) into highway Base Course applications will provide both environmental and economic benefits by allowing in situ recycling materials for projects such as widening or shoulder addition. RAP is a well-drained granular material however 100% RAP has low bearing strength and creeps under load.

3.3 Animesh Das et al illustrates that 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.

3.4 Edward J. Hoppe et al concludes that RAP has been successfully incorporated in bound pavement layers for many years with few concerns about potential environmental contamination. Although the use of RAP as an unbound base layer is not as extensive, the lack of experience has been offset by recent studies examining the leaching potential, indicating no environmental issues of concern. The research result related to the use of stabilizing agents with RAP, however, is not as conclusive. As different stabilization methods begin to be used to a greater extent, undoubtedly more will be learned about additional methods to limit potential contamination concerns.

3.5 Eric J. McGarrah noted that every year Hot Mix Asphalt (HMA) roadways are rehabilitated by milling the existing roadway and replacing the milled portion with new HMA. As a result of this practice a tremendous amount of reclaimed asphalt pavement (RAP) is created. The Federal Highway Administration estimates that 100 million tons of HMA is milled each year. The Washington State Department of Transportation (WSDOT) currently allows RAP to be recycled into new HMA, but only 20% of the RAP may be used in the new material. Thus, a large portion of the milled asphalt ends up at contractor’s pits or landfills. Due to the possible reduction in product and construction cost by using RAP as a base course in addition with increasing requests by contractors to do so, WSDOT is investigating the possibility of blending RAP with virgin material for use as a Base Course material.

3.6 Mansour Solaimanian state that placing Reclaimed Asphalt Pavement (RAP) back on the roadway is a common and popular technique in the paving industry. There are always challenges associated with this type of recycling, especially when the RAP content in the newly paved asphalt mix exceeds 20-30 percent by mass of total mix.

3.7 M. Amaranatha Reddy et al admits that recycling of pavements is a relatively new technique in India and gaining popularity in recent times due to several merits over conventional pavement rehabilitation technique. The first recycling work of flexible pavements was undertaken about fifteen years back and since then milling and recycling of pavements has been adopted in many urban and high volume roads in India. However there have been little research studies reported on these works.

3.8 Mukhtar Abukhetta concludes that depending on the attributes of the characteristics of the recycled materials, the inclusion varies. Some recycled materials have been proven to process preferable properties over the other and have performed satisfactorily in the field. However, there are numerous concerns regarding such incorporation based on both laboratory, experimental and field observations; which have turned out to be essence for further in-depth studies.
3.9 Mustaque Hossain et al found that a recent rise in asphalt binders prices has led state agencies and contractors to use higher quantities of Reclaimed Asphalt Pavement (RAP). Besides being economic, sustainable and environmentally friendly, RAP can be replaced for a portion of aggregates in Hot Mix Asphalt (HMA) where quality aggregate are scare.

3.10 Randy C. West illustrates the current best practices for management of Reclaimed Asphalt Pavement (RAP) and Reclaimed Asphalt Shingles (RAS). A disciplined approach to RAP and RAS management –one based on data to manage inventory, processing, uniformity and quality – will maximize the return of investment in materials, equipment and people.

3.11 Sireesh Saride et al say that Reclaimed Asphalt Pavement (RAP) has predominantly been on the global research focus because of its cost effectiveness as well as sustainability. Lack of proper design guidelines being main reasons, a limited amount of research findings are put into practice. In addition, age hardening of the asphalt coating present over the RAP, affect its essential to evaluate the durability and long term performance of RAP mixes besides for their strength and stiffness.

3.12 S.M. Mahlongo examine the use of 100% RAP for sustainable construction and rehabilitation of roads. The characteristics of the recovered material were examined in accordance with the South African specification. The recovered aggregates fall within the envelope for continuously graded mix and the recovered binder is 5.3%.

3.13 V.K. Singh et al say that good practice dedicatates that pavements be maintained and preserved so that major rehabilitation is not needed. For a variety of reason, this does not always happen. Sometimes it is not practical fully rehabilitate a badly deteriorated asphalt pavement. Cracking or other distresses may have progressed to the point that a more aggressive approach is needed. Complete removal and replacement is not necessary; the in-place materials of the old pavement have value and can be reused. Full Depth Reclamation (FDR) is an efficient means of rehabilitating these pavements.

4. SAMPLING, EVALUATION AND CHARACTERIZATION:
The number of cores collected at each location depends on the amount of laboratory testing needed and the type of mix design testing required, the core samples should be examined for different pavement layers, previous surface treatments, and interlayer’s paving fabrics, specialty mixes and evidence of stripping, disintegration or moisture retention.

Representative samples should be tested for:

- Extraction Test/ Asphalt binder content.
- Recovered asphalt binder properties.
- Air void and density properties of the existing mix.
- Moisture content.
- Gradation of the RAP.
- Impact Test.
- Shape Test.
- Stripping Value Test.
- Crushing Test.
- Soundness or Durability Test.
- Water Absorption Test.
- Specific Gravity Test.
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Where full depth Reclamation is being considered, the base and sub base materials also need to be sampled and tested for:

- Moisture content
- Gradation and angularity
- Plasticity index
- Sand equivalency

5. MIX DESIGN CONSIDERATION:
The complexity of a mix design process varies with the level and type of recycling selected. Study reveals that Hot Mix Recycling where 15% or less RAP is blended with new aggregate and virgin asphalt required little change from the mix design procedure used on the virgin mix because the added RAP is not expected to significantly alter the properties of the final mix. However, for higher RAP contents (>25%), a more comprehensive mix design process is needed. Blend charts need to be developed using the asphalt recovered from RAP and virgin asphalt of recycling agent to determine the percentage of RAP that provides the desired binder and mix properties in the final recycled pavement.

The mix design process for hot in-place Recycling is, in many ways, similar to that used for high content RAP Hot Mix Recycling. Hot In-place recycling generally involves the use of 70-100% RAP.

6. IN INDIAN CONDITIONS
Typical X-section of flexible pavement in India is shown below.

![Figure 5: Typical Cross Section of a Flexible Pavement](image)

In India Bituminous layers/mixes available in deteriorated flexible pavements are:-

6.1. Surface Recycling (SR):
(i) Wearing course
   a) Premix Carpet & Seal coat (20mm) – Bitumen 3.5-4.0%
   b) SDBC- (25mm) – Bitumen 5%
   c) BC- (40mm) – Bitumen 5.5%
(ii) Binder Course/Bituminous Base course
   a) BM – (50-75 mm) – Bitumen 3.5 %
   b) DBM – (50-100 mm) – Bitumen 4.5%
At some places bituminous surface dressing (P1&P2) in village roads and few places mastic asphalt layers also available in city roads and bridge approaches and on deck slab as wearing surfaces. At different location due to resurfacing/renewal and special repairs thickness of bituminous layer varies from 50 to 150mm with varying bitumen content and gradation.

6.2. Full Depth Reclaimed (FDR)

(i) WBM
(ii) WMM
(iii) Stabilized Base
(iv) Granular Sub base
(v) Sub grade

In full depth reclamation pavement material may reclaimed up to sub grade and characterized /classified. After FDR Reclaimed material may use with or without stabilization (with lime/fly ash etc.)

7. PERFORMANCE EVALUATION:

Previous research in USA & Japan it can be concluded that using RAP is advantageous as RAP mixes can yield results equal or even higher than fresh mixes. If calculated and introduced appropriately RAP mixes have a constructive effect on various parameters like Marshall Stability, moisture resistance and density. This can be considering as scope of this study and research. Study of use of RAP material in road construction can be dividing in two major groups:

- As Constituent of Flexible Pavements
- As Constituent of Rigid Pavements

7.1. As Constituent of Flexible Pavements:

After characterization of reclaimed asphalt pavements performance material will be planned to check in design mix suitability in laboratories for

(i) Wearing Course (PC,SDBC,BC)
(ii) Binder Course (BM, DBM)
(iii) Base Course (WMM, WBM, CT base)
(iv) Granular Sub Base (GSB)
(v) Stabilization of Subgrade (SOIL)

For use in bituminous mix different percentage of RAP, virgin aggregates, virgin Bitumen and Rejuvenators if required will mix in different proportions and test for

- Marshal Stability
- Stripping Value
- Water Retention
- Density

With RAP innovative techniques such as:-

- Waste Plastic Technology
- Nano Technology
- Cold Mix Technology
May apply to enhance the mix design properties and to overcome environmental issues for different traffic conditions pavement layers.

For use in Sub Base and Base Course gradation of characterized material obtained in FDR modified with mix design using some part of virgin aggregates and if needed stabilization may do with appropriate additives like Cement, Lime, Emulsion or Fly Ash etc. Impact Value of mix aggregate will recheck before design.

7.2. As Constituent of Rigid Pavements:

A typical section of Rigid Pavement in India is Shown below:

![Figure 5: Typical Cross Section of a Flexible Pavement](image)

Recycled asphalt Pavement (RAP) is the reclaimed and reprocessed pavement material containing asphalt and aggregate. Most RAP is recycled back into flexible pavements, and as a result there is a general lack of data pertaining to the mechanical properties for RAP in other applications such as Portland cement concrete for Pavement Quality Concrete (PQC). Study of mechanical properties of Portland cement concrete containing RAP as coarse aggregate should be investigate in the laboratory. Different concrete mixes widely differing water/cement ratios and mix proportions will design using RAP as coarse aggregate. Different additives and admixture and methodology may be try to enhance the properties of PQC produced using RAP, such as

- Fly Ash
- Fibers
- RCCP

The RAP coarse aggregate will consist “asphalt-mortar” (asphalt binder-sand-filler matrix). The properties of produced PQC for rigid pavement by using RAP as coarse aggregate will be tested will include

- Physical properties of RAP aggregate
- Compressive strength
- Flexural strength

8. CONCLUSION

8.1 Bituminous pavement recycling technology is not yet a popular in India and other developing countries because there are no sufficient guidelines and standards available; hence they have to learn and apply.

8.2 Advantages of use of RAP necessitate adoption of pavement recycling techniques in near future. Hence it is a major scope of Characterization and Performance Evaluation of Reclaimed Asphalt Pavements (RAP).
8.3 The information obtained from a materials evaluation is used to help select the type and amount of recycling additive to use as well as to determine the need for additional aggregate to address any deficiencies in the existing pavement structure.

8.4 Test Results will summaries to decide the mix design proportion for Granular and Bituminous mixes with different class of characterized/classified RAP.

8.5 Properties of Pavement Quality Concrete (PQC) obtained with coarse aggregate of RAP material can be evaluated and analyzed. These properties will be compared with those of similar concretes produced by using virgin natural gravel aggregates.

8.6 Properties of RAP and concerning design mix may analyze to develop design charts for further enhancement in technique.

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