Quest Journals
Journal of Architecture and Civil Engineering
Volume 9 ~ Issue 3 (2024) pp: 10-20
ISSN(Online) : 2321-8193
www.questjournals.org

Research Paper

Use of Reclaimed Asphalt Pavement in Road construction: a study on Recycling pavement method and its Advantages

Shukdev R. Shiyani
Shekhar H. Parmar , Bonny Bhut
Dr. Subhash University Junagadh
Gujarat, India

ABSTRACT
Today environmental and ecology concern has become a global issue and almost every industry is putting emphasis on environmental friendliness use of material of technology etc. Construction industry is also one of them as we all know, day by day the queries are disappearing with the extensive mining work and as a result of it, we are in crisis of quarry material. Recycling is one of the option by which one can reduce the requirement of fresh material and thereby serving the environmental purpose. Many industries are successfully of effectively using the recycling. The same can be utilized in construction industry and that too in road construction too.

***R**eceived 09 Mar., 2024; **R**evised 20 Mar., 2024; **A**ccepted 22 Mar., 2024 © The author(s) 2024.*
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I. Introduction

There are five broad categories have been defined by ARRA (asphalt recycling and reclamation association). The various asphalt recycling methods categories are:

1. Cold planning (CP)
2. Hot Recycling
3. Hot in-place Recycling (HIR)
4. Cold Recycling (CR)
5. FULL Depth Recycling (FDR)

Within these five broad categories of asphalt recycling, there a under of sub-categories which further define asphalt recycling.

Hot in place Recycling (HIR)
- Surface Recycling (Resurfacing)
- Remixing
- Repaving

Cold Recycling (CR)
- Cold in Place Recycling (CIR)
- Cold central plant Recycling (CCPR)

Full Depth Reclamation (FDR)
- Pulverization
- Mechanical Stabilization
- Bituminous Stabilization
- Chemical Stabilization

Asphalt recycling methods can be used in conjunction with one another on some roadway rehabilization projects. For instance an existing roadway could have an upper portion removed through cold planning (CP) and the resulting Reclaimed asphalt pavement (RAP) could be stock piled of the asphalt plant. The cold planned surface once prepared could be over laid with hot mix asphalt (HMA) containing the RAP from the milled off layer alternatively prior to the placement of the recycled mix the exposed CP surface could have been HIR, CIR or FDR in order to mitigate or eliminate the effects of reflective cracking.

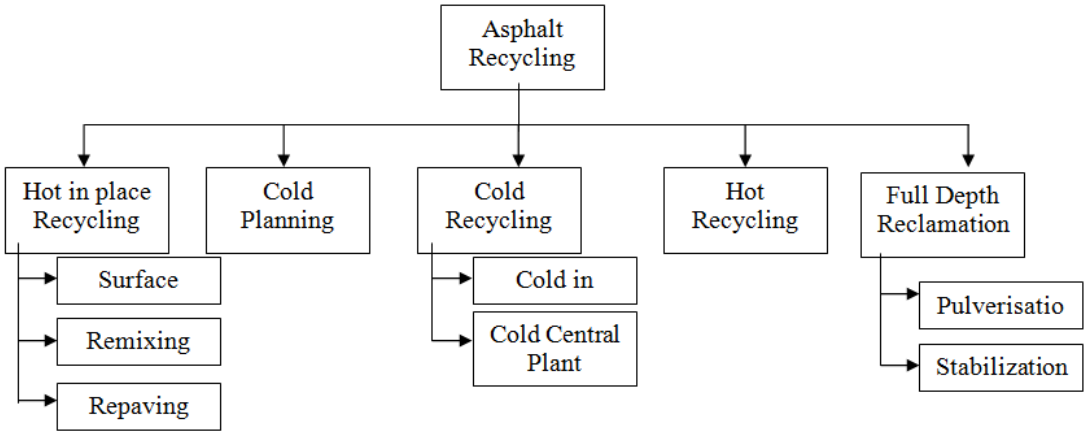

Figure Flow diagram of types of Asphalt Recycling

Overview Of Reclamation And Asphalt Of Recycling

The reclamation of asphalt material can be done using hot or cold process hot process reclamation is applicable only in hot in place recycling (HIR) while cold process reclamation the existing pavement is heated by radiation and then milled or scarified as the hot bituminous surface is soft due to heating. Thus, the reclaimed material is used in place.

In cold process reclamation the pavement material is reclaimed by cold milling breaking or ripping. In cold milling the pavement surface is milled to required depth the reclaimed material is discharged into a tipper truck and stockpiled of some designated site. The reclaimed materials retrieved are in large chunks, which have to be crushed and then stockpiled. Before stockpiling the materials could be sieved and segregated and stockpiled into various size fraction other reclamation process which is also cold processes may involve ripping and pulverizing the non-bituminous base/ sub base.

There are essentially two types recycling technology (1) In place and (2) In plant each having two variants (a) cold and (b) Hot cold recycling technology has three options. (i) foam bitumen (ii) emulsion (iii) stabilization hot technology has two options depending upon the manner of reclamation by (i) hot process or (ii) cold process.

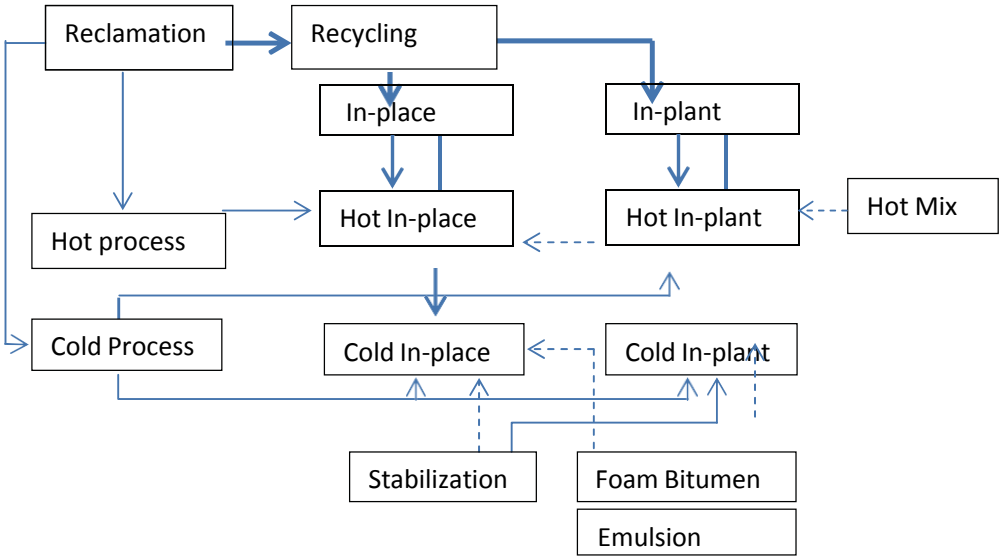

Figure Flow diagram of overview of reclamation and recycling

Aspect of recycling

The following aspects of recycling process as for IRC: 120-2015 are as follows:

1) Hot in place recycling (HIR)
2) Cold in place recycling (CIR)
3) Hot in plant recycling (HIP)
4) Cold in plant recycling (CIP)
5) Full depth reclamation (FDR)

The above different types of recycling aspects and main advantages if recycling are mention below.

1) Hot In place recycling (HIR)

With HIR 100 percent recycling of the existing asphalt pavement is completed on site. Typical treatment depth range ¾ to 2 inches (20 to 50 mm) although same equipment can treat up to 3 inches (75 mm). This processing is a series of equipments that have the ability to perform different functions such as interacted heating of pavement surface to suffer it, milling softened hot pavement surface transferring the milled materials into pug mil mixer of recycling equipments through a belt conveyor, adding fresh mix/ binder/ rejuvenator as per requirements of design into the pug mill, discharging the remixed materials into integrated paving screeds for paving the remixed output, rolling and compaction of the paved material. Three is a limitation on depth of recycling to 50mm (50 mm if softer binder is used)

Figure HIR remixing train

Remixing is the HIR process in which the existing asphalt pavement is heated, softened and scarified and virgin aggregate, new asphalt binder, recycling agent and for new HMA is added (as required) and the resultant thoroughly mixed. Homogeneous recycled mix is placed in one layer, as indicated.

The main advantages of hot in place recycling are mention below

- Conservation of non renewable resources
- Energy conservation compared to other reconstruction methods.
- Reduced truck hauling compared to other rehabilitation methods.
- Eliminates the disposal problems
- Improves riding quality
- Rutting, potholes and raveling are eliminated
- Curb height and overhead clearance can be maintained
- Existing asphalt and aggregate gradation problem can be corrected
- Friction number can be restored
- In place construction reduces traffic disruptions.
- Economic solving are realized

2) Hot in plant recycling (HIP)

This process involves production and laying of hot mix materials but not with virgin aggregate and binder but with a combination of reclaimed stock piled aggregate already coated with binder and additional virgin aggregate and fresh binder to meet the requirements at the design usually, some rejuvenator is used to soften the old hardned binder in the reclaimed aggregates. Heating the reclaimed binder coated aggregate may release unacceptable fumes while feeding them cold directly into the pug mill may reduce the mixing temperature.

Figure Asphalt batch plant with RAP in feed for hot recycling

Therefore the hot mix production process has to be suitably modified it is suggested that not more than 50% of the reclaimed material is to be used, though a widely accepted percentages is only 30% and thickness is 100 mm.

The main advantages of hot in place recycling in list out below:-

- Conservation of non renewable resources.
- Energy conservation compared to other reconstruction methods
- Disposal problems eliminated.
- Problems with existing aggregate gradation can be corrected.
- Curb reveal height and overhead Clearance can be maintained
- Economic saving are realized

(3) Cold in place recycling (CIR)

In this process, milling and mixing are simultaneously process accomplished by a single equipment or a train of equipment capable of milling and conveying the milled material to be fed to a pug mill, with parallel supply line for feeding fresh aggregate also and separate feeding lines to pug mill for bitumen emulsion and rejuvenator where foam bitumen is to be used there has to be separated feeding line for hot bitumen and water to produce the foam bitumen and then feed into the pug mill.

Figure Multi-unit CIR train

The mixed material is discharged into the hopper closely following the recycling equipment or train of equipment then paved and competed. This type of recycling is considered suitable for depth up to 150 mm and the use of reclaimed material is also in same order (typically 30 to 50%) as in HIP another variant at cold in place recycling is (CIR) FULL depth reclaimanation, where the thickness at pavement to be recycled is greater than typically 150 mm.

(4) Cold in-plant recycling (CIP)

This process involves production of the mix in a plant using either emulsion or foam bitumen and laying and compaction is usual manner rejuvenator is to be added in the mixing process to suffer the hard binder in the reclaimed material depth of recycling and use of reclaimed material is same as for cold in place recycling cold in plant recycling.

Figure Cold Central Plant Recycling (CCPR)

The main advantages at cold recycling are:

- Conservation at non-renewable resources
- Energy conservation compared to other reconstruction methods
- Eliminates the disposal problems
- Surface irregularities and cracks are interrupted and filled
- Rutting, potholes and revaling are eliminated
- Base and sub grade material are not disturbed

- Cross slope and profile can be improved
- Existing gradation problem can be corrected
- Riding quality is improved
- Economic saving are realized.

5) FULL depth reclamation (FDR)

FDR is the rehabilization option in which the full thickness of the asphalt pavement and a predetermined portion of the underlying material (base, sub base) is uniformly pulverized and blended to provide an upgraded, homogenous base material. The thickness varies between 100 to 300 mm. It produces, granular pavement layer which can be used as is can have additional granular materials placed over it or can be enhanced with the additional of an additive FDR equipment consist of a reclaimed unit stabilizing additive unit, motor grader and roller.

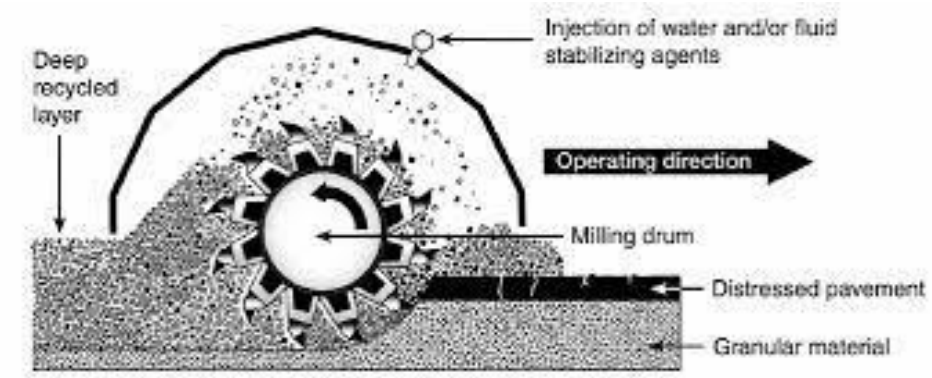

Figure 2.7 Full Depth reclamation

The main advantages of FDR are:-

- Conservation of non-renewable resources
- Energy conservation compared to other reconstruction methods
- Few pieces of equipment required
- Elimination of bumps and dips, rutting potholes patches and cracks
- Sub grade deficiencies can be corrected
- Exiting gradation problem is solved
- Significant structural improvement
- Produces thick bound layers that are homogenous

Sources of Reclaimed Asphalt Pavement (RAP)

RAP may be obtained from several sources. The performance of a RAP mix depends on the source from which it is extracted and the method of extraction. There are many different methods of extraction of RAP as discussed in further section. The most common method is through milling operation, also known as cold planning. Two other common sources of RAP are full depth pavement demolition and asphalt plant waste. The various possible sources of RAP are as follows.

Generation from milling of HMA layer

Milling is the controlled removal of an existing pavement to a desired depth, using specially designed equipment having replaceable tungsten carbide cutting teeth mounted on a rotor drum driven by the power supplied by milling machine (IRC: SP:120-2015). Fig 2.8 shows milling machine removes pavement layer. Milling is mostly used followed by cold process. Hence it is commonly known as cold milling, though milling is done following a hot process also in Hot In-place recycling (HIR).

Figure : Milling machine removes asphalt pavement layers as part of pavement rehabilitation.

Important aspects to be considered in cold milling are the depth of milling, appropriate milling tools to govern the size of milled material, control of dust, collection and transportation of milled material (IRC: SP:120-2015). The milling depth is determined based on visual inspection of cores to determine depth of surface cracks and location of weak layer and interfaces. Fig 2.9 shows the different types of milling teeth on rotar. Proper consideration must be done while examining the milling process to ensure that the material is not contaminated with impurities like soil, base material, geotextiles or debris. The maximum limit of deleterious material is recommended as 1% for evaluating the RAP contamination

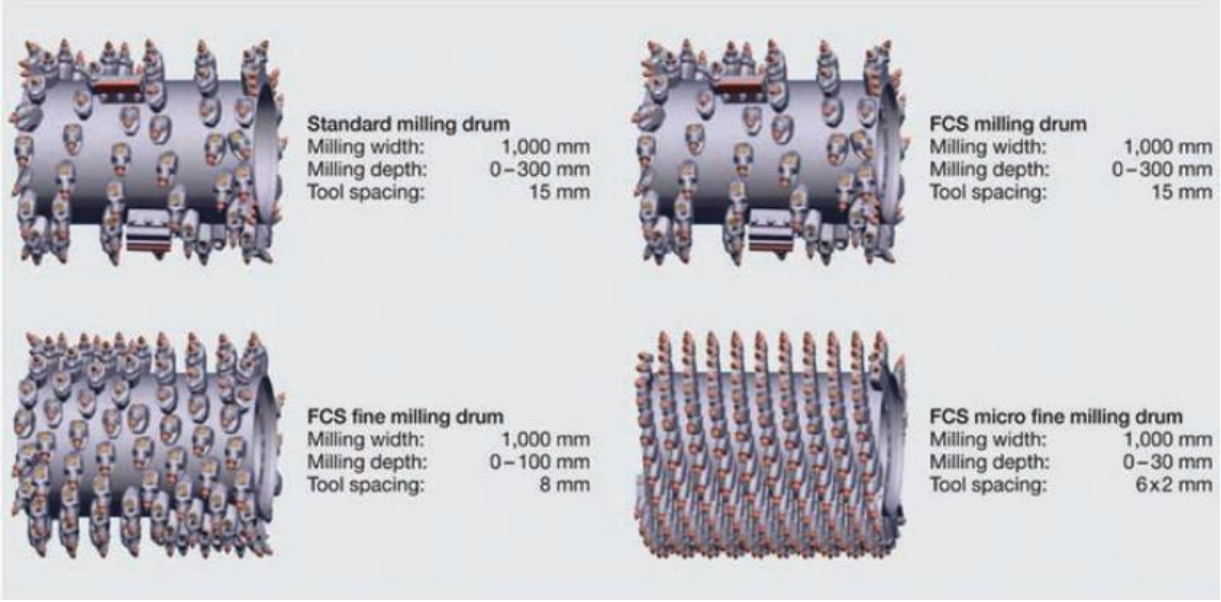

Figure Different types of milling teeth on Rotar

Pavement demolition

The recycling material can also be extracted from complete demolition of an existing pavement. This can be done using some mechanical equipment such as a bulldozer or backhoe. This process is limited to small areas of pavement. This process is slow and results in large chunks of pavement that may be more challenging to process into a useable recycled material. In case if the material is contaminated with soil, the material needs to be crushed and is used as shoulder or base material.

One of the problems associated with use of backhoe loader or excavator is that there is a possibility of damage to the layer below the bituminous layer besides the retrieved materials, being in form of lumps, which cannot be used without re-crushing. While disposal of unusable material is lumps is environmentally damaging,

making them usable by re-crushing is also fraught with some problems as the lumps instead of breaking may tend to become sticker due to presence of bitumen, especially in hot weather .

Full depth reclamation (FDR)

In Full depth reclamation (FDR) all the reclaimed materials of the pavement, with or without fresh materials, is stabilized in-situ with suitable to produce the base course of the pavement to be overlaid by bituminous course(s). Fig 2.10 shown full-depth reclamation. If economically feasible, it is preferable to reclaim the bituminous layer and other granular or bound layers separately to retrieve as much useful and high value bituminous materials as possible.

Figure : Pavement rubble from full-depth demolition of roadway

Waste from HMA generated at plant

During the production all asphalt plant operations generate some waste during plant start-up, transition between mixes, and clean-out. Generally, start-up and shut-down plant wastes have very low asphalt contents. Another form of waste is mix rejected from a project due to incomplete coating or due to the mix temperature being too high or too low for the job. Other situations that may result in wasted mix include trucks loaded with too much mix to finish the job or mix that could not be placed due to inclement weather. These waste materials are often stockpiled for later processing into a recyclable material. Since these waste mixes have not been subjected to environmental aging from years of service, the asphalt binder is less aged than RAP recovered from a road.

Processing of Reclaimed Bituminous (Asphalt) Materials

RAP materials may be obtained from several sources. The most common method is through cold milling operation, also known as cold planning/ milling. Two other sources of RAP materials are obtained from full-depth pavement demolition and bituminous plant waste as discussed in above section. The milled material obtained can be of high quality such that it may not require any processing. However, in some cases it is desirable to screen out some oversize particles to maximize the amount of RAP that can be used in a mix. The RAP particles can also be separated into coarse and fine stockpiles that may be used wherever required. This separation of RAP on the basis of size increases the control over quality and reduces the variability. The basic goals of processing RAP are following :

1. Creating a uniform stockpile of material from a collection of different RAP materials from various sources.
2. Separating or breaking apart large agglomerations of RAP particles to a size that can be efficiently heated and broken apart during mixing with the virgin aggregates.
3. Reducing the maximum aggregate particle size in the RAP so that the RAP can be used in surface mixes (or other small nominal maximum aggregate size mixtures).

Processing Milling Material

The millings obtained from a single source are often consistent in gradation, asphalt properties, and binder properties. But one of the problems associated with increased usage of RAP in asphalt mixture is the dust content in the RAP. Since milled RAP's already contain a large amount of dust therefore further crushing of milled material is not desirable.

Processing RAP from Multiple Sources

RAP materials obtained from multiple sources that have different compositions must be processed to create a uniform material suitable for use in a new asphalt mixture. Blending as a part of processing operations is a key to achieve a consistent RAP from multiple sources. A bulldozer, excavator, or similar equipment should be used to blend materials from different locations in the multiple-source RAP material stockpile as it is fed into the screening and crushing operation.

Stockpiling RAP

In most cases, processed RAP will be moved from the location it is screened or crushed to another location more convenient to feed into the asphalt plant. However there is another opportunity that the material is remixed to improve its consistency. It is done most commonly to prevent or limit the segregation. Arc-shaped, uniformly layered stockpiles are preferred for storing milled or unprocessed RAP material (i.e., material of various sizes). As with fresh aggregate, conical stockpiles or small, low-sloped piles are preferred for storing processed RAP material (Copeland 2011). The advantages and disadvantages of different RAP processing options are listed in Table 2.1 (IRC: 120- 2015).

Table : Advantages and Disadvantages of RAP Processing Options (IRC: 120- 2015)

Process	Possible advantages	Possible disadvantages
Use of millings without further processing	• Avoids further crushing of aggregate in RAP, which may allow higher RAP contents • Lowest cost of RAP processing options	• Requires multiple RAP stockpiles at the plant millings from individual projects are different; therefore, new mix designs are required
Screening RAP before crushing	• Limits crushing of aggregate particles in RAP, Which reduces dust generation	• Few RAP crushing and screening units are set up to pre-screen RAP
Crushing all RAP to a single size	• Allows the processed RAP to be used in many different mix types • Generally , provides good uniformity from RAP material obtained from multiple sources	• Tends to increase the dust content of RAP stockpiles, which may limit how much RAP can be used in mix designs
Fractionating RAP	• Using different sized RAP stockpiles provides greater flexibility in developing mix designs.	• Requires the most space for multiple smaller stockpiles. • May generate an excess of a RAP size if the mix designs are not balanced to the RAP feed

Determination of RAP Percentage and Binder selection

Generally, the contractor decides the percentage of RAP and the selection of binder for meeting the appropriate specifications. The maximum RAP content actually used by contractors is typically about 40% (West et al. 2014). The percentage of RAP used in the mix may be selected by determining the contribution of RAP in the total mix by weight or by determining the contribution of the RAP binder in the total binder in the mix by weight while maintaining volumetric properties requirements (Copeland 2011). When the RAP is limited to a low percentage of the new mixture, 15% or less (as a percentage of the aggregate blend), it is not necessary to determine the properties of the RAP binder (NCHRP Report 673). As the small amount of RAP binder have little effect on properties of mix. However, when higher RAP percentage are used, the stiffness of RAP binder must be considered. This can be done by using a soft grade binder than normally used. A more precise approach involves using a blending chart or a spreadsheet to estimate the grade of the binder formed by blending the RAP binder and the new binder. The binder selection guidelines for the RAP mixtures according to AASHTO M 323 are given in Table 2.2.

Table : Binder selection guidelines for RAP mixtures according to AASHTO M 323

Recommended fresh asphalt binder grade	RAP percent
No change in binder selection	<15
Select fresh binder one grade softer than normal (eg select PG 58-28 If PG 64-22 would normally be used)	15-25
Follow recommendations from blending charts	>25

When a blending chart (or an appropriately designed spreadsheet such as HMA Tools) is used, samples of the RAP binder must be obtained for testing through the use of solvent extraction and subsequent recovery of binder. Based on the desired final blended binder grade, the desired percentage of RAP, and the recovered RAP binder properties, the required properties of the appropriate virgin binder grade can be determined according to blending chart procedures. In another case, if a specific fresh asphalt binder grade is to be used and the desired blended binder grade and recovered RAP properties are known, the allowable percentage of RAP is determined according to blending chart procedures. However, the blending chart process is time-consuming, involves hazardous solvents, and creates disposal issues.

RAP Percentage based on Binder

The primary issue in limiting the high RAP content is the amount of binder replacement available since the use of RAP can reduce the need for virgin binder and impact the binder properties. Thus, RAP content must be satisfied according to percentage binder replacement. The percentage of RAP used in the mix can be selected by determining the contribution of the RAP binder toward the total binder in the mix by weight. The amount of total binder replaced by binder in RAP is computed as follows :

$$\text{Binder Replacement},\% = \frac{A\ x\ B}{C}\ x\ 100$$

Where:
A = RAP percent binder content.
B = RAP percent in mixture.
C= Total percent binder content in mixture.

Once the physical properties and critical temperatures of the recovered RAP binder are known, there are two options for blending as follows:

- Blending at a known RAP percentage.
- Blending with a known virgin binder grade.

Blending at a Known RAP Percentage

In the case where the desired final blended binder grade, the desired percentage of RAP, and the recovered RAP binder properties are known, the required properties of a virgin binder grade can then be determined at each temperature (high, intermediate, and low) separately as follows: T_{blend}- (%RAP TRAP)

$$T_{virgin} = \frac{\text{Tblend} - (\%\text{RAP x T RAP})}{1 - \%\text{RAP}}\ \text{x}\ 100$$

Where:
Tvirgin Critical temperature of virgin asphalt binder (high, intermediate, or low). Talend Critical temperature of blended asphalt binder (final desired) (high, intermediate, or low).
%RAP = Percentage of RAP expressed as a decimal. TRAP = Critical temperature of recovered RAP binder (high, intermediate, or low).

Blending with a Known Virgin Binder Grade

In the case where the final blended binder grade, the virgin asphalt binder grade, and the recovered RAP properties are known, the allowable RAP percentage can be determined as follows:

$$\%\text{RAP} = \frac{\text{Tblend} - \text{Tvirgin}}{\text{TRAP} - \text{Tvirgin}}$$

This should be determined at high, intermediate, and low temperatures. The RAP content or range of contents meeting all three temperature requirements should be selected.

II. Conclusion

This paper is conclude the methods of Recycling of Asphalt Pavement and conclude its advantages. based on this study following points can be covered

Aspect of recycling process and its advantages
Sources of reclaimed Asphalt Pavement
Processing of reclaimed asphalt materials\
Determination of RAP percentage and binder selection

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