2 Application and Performance of RAP in Highway Construction: A Literature Review

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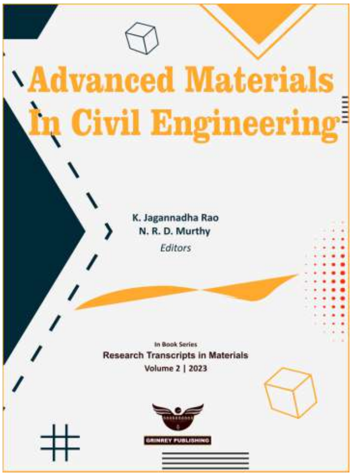

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Abstract

Reclaimed Asphalt Pavement (RAP) is degraded asphalt that has been removed from damaged flexible pavement. The second-largest road network in the world, with a length of more than 63.72 lakh km, is found in India, according to the MoRTH's annual report for 2021–2022. Large quantities of RAP are produced each year during highway maintenance and construction. When the flexible pavements are removed for reconstruction or resurfacing, they are dumped in landfills, posing serious environmental concerns. Recycling overcomes the exploitation of natural resources, reduces the unwanted increase of road elevation due to periodical overlays, and disposal of RAP generated from pavement construction. An overview of the application of RAP is provided in this publication, to understand its importance and performance in highway construction when mixed with different materials viz. rejuvenators, nanomaterials, WMA additives, reinforcement with polymer or bamboo, fly ash – lime, etc. The use of recycled asphalt pavement is progressively expanding in India for road building, which meets the overall goal of sustainable development by lowering the consumption of natural resources, the emission of hazardous gases, the cost and energy of disposal, and landfill utilization.

1. Introduction

The bituminous mix is composed of 5% bitumen binder and 95% stone aggregates. The bituminous paving layers which are removed due to distress in the flexible pavement are known as Reclaimed Asphalt Pavement (RAP) [1]. According to the Ministry of Road Transport and Highway's annual report (2021-2022), the second-largest road network in the world, with 63.72 lakh km, is found in India. This includes Expressways, National Highways (NH), State Highways (SH), Major District Roads (MDR), Other District Roads (ODR), and Village Roads (VR). The majority of these roads are with bituminous pavements requiring continuous regular maintenance. When the flexible pavements are taken out to be rebuilt or resurfaced, they are dumped in landfills posing serious environmental concerns [2]. Due to a lack of understanding of the degree of interaction between old and new asphalt binders, manufacturing techniques, and mix design criteria, the usage of RAP has not attracted much attention in developing nations like India. During the review, the use of RAP as a substitute for virgin aggregates has been encountered for maximum utilization. With the recent developments in technology, the use of RAP is expected to have a good scope and has been included in the construction by many researchers which lead to its popularity in the pavement industry. Therefore, the basic objective of sustainable development through resource conservation in a developing country like India can be aligned with the reuse of RAP in road construction. The benefits of using RAP include a decrease in the consumption of natural resources, landfill usage, emission, saving dumping charges, and energy [1].

1.1 Reclaimed Asphalt Pavement

When Hot Mix Asphalt (HMA) is recycled, a reusable material mixture known as Reclaimed Asphalt Pavement is created. This mixture is made up of aged aggregates and bitumen binders [3]. The aged materials still maintain a considerable value, hence, in the design phase, it is vital to take the aged materials into mind. RAP aggregates are usually finer than virgin aggregates and their quality varies from one pavement to another. The extent of damage to an old pavement leads to doubt in quality when used to produce a new mix [4]. RAP is made of well-graded aggregates 1that are covered with an old binder. Due to the coating with the binder, they are found to reduce water absorption. When the RAP materials are collected, crushed properly, and screened, then they can serve as an alternative to natural aggregates [5]. The RAP content in the bituminous mix depends on the source and properties of RAP, manufacturing process, paving technology, mix design, blending process, and rejuvenators [6]. High RAP content is not commonly used in practice. The maximum use of RAP percentage ranges between 10 to 50% [3].

2. Recycling Process of RAP

In industrialised nations, recycling old distressed pavement has been one of the most popular options for pavement restoration. These damaged pavements are removed up to a certain depth through the milling process. According to IRC, there are five methods to recycle RAP. The recycling methods include Reclamation (hot and cold), Hot-in-Place, Cold-in-Place, Hot-in-Plant, and Cold-in-Plant and are briefly explained in Table 1.

2.1 Rejuvenators

Rejuvenators are additives to asphalt that soften hardened, aged asphalt to restore it to its initial viscoelastic form. The addition of rejuvenators can increase RAP content, and its dosage and type have a considerable impact on the effectiveness of asphalt. The amount of asphaltenes enhances the bitumen binder's stiffness and viscosity because of the loss of oil components during construction and service [3]. The microstructural characteristics of RAP with rejuvenators demonstrate that as the rejuvenator dose is increased, the amount of aged asphalt binder layer on RAP increases noticeably. The optimum dosage for the rejuvenation of RAP is found to be 6% and waste vegetable oil is found to perform better than waste engine oil and waste grease [8]. The Fatigue Beam test result highlights date seed oil's potential as a rejuvenator which enhances the mix's fatigue life. 20% RAP mixed with 10% DSO gives a 15% increase in fatigue life which has the longest fatigue life among the mixes taken for the study [9].

Table 1. Recycling Methods [7]

Sr. No.	Recycling Methods	Process
1.	Reclamation	a) Hot - When the surface of heated existing pavement gets soft, it is milled. b) Cold - Pavement is removed by breaking it down and milled to the required depth.
2.	Hot-in-Place Recycling	a) Infrared is used to heat the pavement and the milled materials are transferred into the Pug mill mixer. The amount of fresh binder or rejuvenators is added to the recycling equipment as per the design requirements. b) 100% reclaimed material is utilized. c) Maximum depth of recycling: 50mm
3.	Hot-in-Plant Recycling	a) The reclaimed aggregates coated with an aged binder are mixed with a fresh binder and virgin aggregate as per the design. Rejuvenators are usually added to soften the aged binder. b) 50% reclaimed material is utilized. c) Maximum depth of recycling: 100mm
4.	Cold-in-Place Recycling	a) Milling and mixing occurs simultaneously using foam bitumen and rejuvenator. b) Maximum depth of recycling: 75mm
5.	Cold-in-Plant Recycling	a) Mix is produced using either emulsion or foam bitumen. The hard-aged binder is softened by adding rejuvenator to RAP. b) Reusing RAP is equivalent to cold-in-place recycling. c) Maximum depth of recycling: 100mm

2.2 Blending of RAP and virgin binder

Blending is a process that combines different materials and mixing them to obtain the desired mix. The RAP and virgin binder blend together when being mixed, proving that it does not behave as a black rock (no blending) [3]. RAP aggregates are coated with binder at the outer layer that are softer than inner layer indicating that majority of the old RAP does not mix properly with the new binder [10]. However, further research is required to find out the proportion of RAP that will successfully bind with virgin binder.

3. Bituminous Mixes with RAP

3.1 Hot Mix Asphalt (HMA)

Hot Mix Asphalt is an asphalt mixture prepared with heated aggregates and heated bitumen (150°C-190°C) to form a uniform mix, which is spread and compacted for a smooth, well-consolidated pavement layer. It is the most common type of mix used for bituminous paving. India being a developing country, has been using HMA for ages and will continue to use it as it is the most ideal solution in terms of costs, reliability, and comfort. However, it increases the emission of greenhouse gases, energy consumption, air pollution, low resistance to water and durability, etc. RAP's suitability for usage in the construction of flexible pavement is studied in which Marshall mix design specifications are adopted for 0%, 10%, 20%, 30%, and 40% RAP. The use of RAP in the construction of Bituminous Concrete of the flexible pavement saves almost 41% of virgin binder when 40% RAP is used [5].

3.2 Warm Mix Asphalt (WMA)

Warm Mix Asphalt is the asphalt technology that lowers the asphalt mixture's heating temperature (100°C-140°C). These mixes as compared to Hot Mix Asphalt (150°C-190°C), are produced and applied at lower temperatures [11]. WMA technology can be Foaming technology and Additive technology (natural or chemical additives). Its advantage includes decrease in production temperature, reduction in fuel and energy, and low emission of greenhouse gases. The decrease in temperature results in less hardening of the binder and it is fully compatible to be used with RAP. RAP-WMA mixtures have been found to increase the risk of moisture damage and are not significantly resistant to low-temperature cracking (distress in cold regions) over an extended period of time than

RAP-HMA mixes [12]. Depending on the kind of WMA additive used in the study, the mixture's mechanical characteristics change, for example Sasobit, Kaowax, Zeolite, and PAWMA. The additive Sasobit when incorporated into the RAP-containing asphalt mixture gives the highest increase in the resilient modulus value i.e., 37.8% at 5°C, 63.3% at 25°C, and 14.9% at 40°C. The inclusion of 50% RAP into the WMA mix leads to a considerable improvement in resilient modulus, resistance to the effects of moisture, and flow number. However, the mixture loses flexibility and cracking resistance [13]. The resistance to fracture and moisture damage of HMA and WMA (2% wax additive) of varying RAP percentages (0%, 10%, 20%, 30%, and 40%) are studied. Tests for semi-circular bending and the tensile strength ratio with RAP percentage of 10%, 20%, and 30% have shown higher values than the HMA and WMA with 0% RAP. TSR value is lowered with 40% RAP in HMA mixes as well as WMA mixes [14]. RAP-inclusive Dense Bituminous Macadam (DBM) mixes with WMA additives have considered natural aggregates, 5 years old RAP aggregates, and 15 years old RAP aggregates. The workability of the mixes increases and RAP-WMA is found to maintain its properties more than RAP-HMA mixes even after aging for a long term [15].

3.3 Cold Mix Asphalt (CMA)

CMA is a mix that is produced without heating the aggregates and binders. The binder used here is either cutback bitumen or bitumen emulsion. It is easy to use, environmentally friendly, and cost-effective. In a cold mix, the mixing temperature range is 0 to 40°C. RAP is utilized in the field by using the Cold Mix Technology since it requires less time to cure and is more affordable. Milled RAP is mixed with water, asphalt that has been emulsified or foamed, and additives, if desired. The asphalt mixture is then spread, and compacted. [16]. For maturation of the sample for developing cohesion and stiffness, sufficient curing time is required [17]. However, due to its high void ratio and lesser stability values, it is used for small repair works in places where the temperature is too cold. Many researchers have been working to increase the performance of CMA using additives, fillers, deteriorated materials, and modifiers. Differences in the three types of asphalt mixtures are shown in Table 2.

Table 2. Comparison of different types of bituminous mixes [4], [16]

Sr.	Description	HMA	WMA	CMA
1.	Energy consumption: a) Per ton during production b) Per ton of laid material	275MJ 680MJ	234MJ -	14MJ 453MJ for CMA 136MJ for cold in situ recycling
2.	Greenhouse gas emitted	53.6 Kg per ton CO_2	10 to 15% lesser emission than HMA	36.1 Kg per ton CO_2
3.	Mixing temperature	150-170°C	100-140°C	0-40°C
4.	Suitability at different temperatures	All types of weather	Cold weather	Extremely low temperatures
5.	Service Life	20-25 years	Like HMA with addition of additives	2 years till date
6.	Application	Paving, surface failure, and patching	Paving, surface failure, and patching	Patching or filling up small cracks

4. Mix Design of RAP with HMA

The process for designing an asphalt mix for RAP mixes is the same as for conventional asphalt mix design. For producing a quality RAP mixture, there should be adequate information on the source of RAP and the mixture's components should all adhere to the requirements as per IRC, ASTM, MoRTH, AASHTO, etc. [4], [6]. There are two standard methods for determining the characteristics of the materials that make up RAP for extraction of aged binder i.e., ignition oven method and solvent extraction method. Physical properties of the extracted RAP binder, virgin binder, RAP aggregates, and virgin aggregates are tested. To produce a high-strength and uniform mix, proper gradation of the aggregates is important. Gradation should be done as per IRC, AASHTO. Then, the required RAP aggregates, virgin aggregates, and binder are mixed using the Marshall Mix Design. The bituminous concrete mix's volumetric characteristics are used to determine the performance of the mixture. This includes Marshall stability value, air voids, optimum binder content, flow value, voids in mineral aggregate and filled with bitumen.

Steps to find out the effective specific gravity and bulk specific gravity:

Step 1: Theoretical maximum specific gravity is calculated.

Step 2: Effective specific gravity of RAP aggregates is calculated using

$$G_{se} = \frac{100 - P_b}{\left(\frac{100}{G_{sm}} - \frac{P_b}{G_b}\right)} \qquad (1)$$

where G_{se} = Effective RAP specific gravity
G_{sm} = RAP's theoretical maximal specific gravity
G_b = RAP binder's specific gravity
P_b = RAP's binder content

Step 3: RAP's bulk specific gravity is then calculated.

$$G_{sb} = \frac{G_{se}}{\left(\frac{G_{se} P_b}{100 G_b} + 1\right)} \qquad (2)$$

where G_{sb} = RAP's bulk specific gravity
P_{ba} = RAP binder absorption
Note: If the RAP source is known, the G_{sb} value for neat aggregate is used to calculate G_{se}. Else, the calculation is done according to the steps given above [6].

For the mix design of Semi Dense Bituminous Macadam (SDBC), two processes are adopted. *Type A:* RAP sample is collected and cleaned. Aged binder and old aggregates are separated using Centrifuge-based

Bitumen Extractor. Then, a homogeneous mix is created by combining the estimated virgin binder with the extracted binder. A recycled mix is created by adding this bitumen mixture to the hot mixture of used and new aggregate. *Type B:* The collected RAP sample is broken down into the desired size using a hammer. It is then added to the virgin aggregate and heated to form a mix. The hot virgin binder is then added to this mix thus producing a recycled mix [18]. The aggregate mix of RAP aggregate and virgin aggregate is prepared as per the specifications of Bituminous Concrete (BC) Grade 1 of MoRTH. 2% lime filler by weight of aggregates is kept constant and the RAP percentages used are 10%, 20%, 30%, and 40%. Then, the heated bitumen as per the requirement is added to the blended aggregate mix [5]. A study for BC mixes consisting of 20% RAP and 10% rejuvenating agent has found that blends containing 20% RAP gives better performance than the conventional mixes. After 20,000 passes, the RAP mix yields a rut depth of 7.6 mm compared to 8.2 mm for the conventional mix, indicating that the RAP mix has increased resilience to long-term deformation [19].

5. Applications of RAP

With the increase in scarcity of virgin materials i.e., aggregates and bitumen, RAP has the potential to partially replace the virgin materials in the mixes. RAP used in the US climbed to 89.2 million tons in 2019 from 76.2 million tons in 2017 [36]. EAPA (European Asphalt Pavement Association) reports that 50 million tons of RAP are recycled throughout all member states of the European Union in its 2020 report [37]. This section presents the applications of RAP and its performance when used as a substitute to the natural materials in a mix.

5.1 RAP in different layers of flexible pavement

5.1.1 Surface Course

The gradation of RAP indicates that the RAP aggregates have an aggregate size between that of the bituminous course and the wearing course [20]. The studies of the potential and stability of coarser and finer fractions of RAP aggregates have found that old (20yrs) RAP aggregates are unsuitable to be used in bituminous mixes and new (2.5yrs) RAP aggregates are suitable for bituminous mixes such as the construction of DBM and BC of flexible pavement [21]. With an increase in RAP ratio, the performance of RAP in surface course improves in terms of fatigue life and high-temperature stability, whereas anti-cracking at low temperature performance declines [22]. The performance of RAP when used as a substitute to natural aggregates in surface and binder courses are shown in Table 3.

Table 3. RAP's performance in surface and binder courses

RAP %	Description	Performance	Ref.
20	Using a rejuvenator, the RAP binder's characteristics are restored. 20% RAP does not affect the performance of the surface course	A significant decline in performance can be seen at 30% RAP	[22]
35	DBM with RAP (5 years old RAP aggregates and 15 years old RAP aggregates) inclusive WMA mixes	Can be used without any restoration up to 35%. For post-aging, renovation may be required for increasing workability	[15]
40	10 years old RAP and combinations of modified AK-13 and AC-20 are used as top and middle layers respectively	The value of TSR for RAP mixes is significantly lower (admissible value = 80%), according to the F-T indirect tensile strength test i.e., On the top layer, 73%, and the middle layer, 63.7%	[23]
30, 40	RAP, recycled concrete aggregate, virgin aggregates, and bitumen binder	A modified mixture offers greater resistance to permanent deformation. Performance tests of the mix have found to be improved i.e., Marshall stability value, moisture susceptibility test, etc.	[1]

The quality of RAP will determine the long-term performance of the bituminous mix [4], [6]. Using high RAP (more than 30%) in the laboratory is practical, since the production conditions may be easily maintained. Consequently, research has been carried out to evaluate the pavement performance in the field. Field analyses have been performed on 47 RAP sections subjected to three different environmental situations in

California, and the analysis' findings indicate that long-term RAP performance in all three environmental zones is probably comparable to that of the conventional mix [34]. The National Centre for Asphalt Technology (NCAT) test track of test sections containing no RAP, 20% RAP, and 45% RAP are constructed and the average rut depth for each section after 9.4 million ESALs of traffic at the end of 2 years are 5mm, 8.7mm and 2mm respectively. It is evident that the section containing high RAP performs well [35].

5.1.2 Base Course

The replacement of the conventional WMM base layer by RFL (RAP fly ash-lime) has found that as lime concentration and cure time increases, the Resilient Modulus increases as well. An analysis is done using KENLAYER and IRC 37 (2012) and it is found that RFL2 has a longer service life than traditional WMM by 12% and 47% in fatigue and rutting respectively. RFL2 is found to be more cost advantageous than the conventional WMM [24]. In order to be used as the base or subbase of new pavement, RAP is treated with fly ash. The results of resilient modulus and UCS having 80% RAP, 20% virgin aggregate, and 40% fly ash are found to satisfy the criteria for base/subbase materials required for low-volume roadways. For the replacement technique and addition approach, respectively, there is a rise in Mr and UCS values with 30% and 40% of fly ash [25]. As the base course for the flexible pavement, RAP enhanced with polymer/bamboo is utilised. For uniform load distribution, to prevent non-uniform settling, and to improve performance, this study uses both geogrid and geocell [26]. The performance of RAP as a construction material in base layer is given in Table 4.

5.2 RAP in concrete mix

Concrete mix prepared with RAP after adding crimped steel fibres performed better in compressive strength and tremendous improvement can be seen in split tensile and flexural strength tests [27]. To improve the RAP quality utilised in the concrete mix, a novel method is introduced i.e., the Abrasion and Attrition Technique (AB & AT). By using dirty or unwashed RAP (DRAP), washed RAP (WRAP), and RAP treated with AB & AT, the effects of the new novel method on the fresh, durability, and mechanical qualities of concrete are studied. The mechanical qualities of the concrete mix are shown to be greatly improved when RAP aggregates are beneficiated using the Abrasion & Attrition procedure [28]. The effects of RAP aggregates beneficiated by AB & AT with admixtures on the mechanical, fresh, and durability properties are investigated, and the amount of admixture needed to improve performance is determined. The admixtures are Silica fume (SF), Sugarcane bagasse ash (SCBA), and Fly ash (FA) [29] [41]. RAP can also be used as an alternative material which can be used in place of natural aggregates for preparing a sustainable PCP mix [30]. The performance of RAP when used in concrete mix is given in Table 5.

Table 4. Performance of RAP in the base course

RAP Content	Description	Performance	Ref.
Reinforced RAP and WMM/RAP without reinforcement	RAP reinforced with polymer and bamboo in the form of geogrid and geocell	The load-bearing capacities of RAP reinforced with polymer and bamboo are, respectively, 75.29% and 24.05% more than those of unreinforced WMM.	[26]
70% RAP	The ideal mixture is RFL2 (7.5% lime, 22.5% fly ash, and 70% RAP).	UCS (4.66 MPa) and Resilient Modulus (7 days – 392 MPa and 28 days – 540 MPa) increase as lime concentration and curing time are increased.	[24]
80% RAP	Ideal mixture is 40% fly ash, 20% virgin aggregate and 80% RAP	Resilient modulus and UCS values with 40% of the fly ash and 20% of the RAP are replaced with new aggregates have fulfilled the criteria for base/subbase material for low traffic roadways.	[25]

Table 5. Performance of RAP in concrete mixes

Content	Description	Performance	Ref.
Concrete mix with RAP and admixtures	AB & AT with admixtures viz., Silica fume (SF), Sugarcane bagasse ash (SCBA) and Fly ash (FA).	Maximum improvement in the mechanical properties and durability properties when OPC is replaced by 10% SF, 5% SCBA, and 20% FA (sulphate-free environment).	[29]
Old(20yrs) and new(2.5yrs) flexible pavement	DLC mixes - Old RAP aggregates DBM and BC - New RAP aggregates	Old RAP - 75% coarse NA and 50% fine NA replacement New RAP - 25% coarse and 0 fine replacement	[21]
50% Coarse RAP (exposure to aggressive surroundings) and 100% RAP	Coarse RAP is used to substitute natural aggregate for PCP mixes	Satisfactory values of porosity, compressive strength, and flexural strength. 100% by RAP if binary gradation is performed	[30]
RAP + Crimped steel fibers	1% addition of steel fibers is required without which the concrete performance declines as RAP content increases	Inclusion of steel fibres has increased the concrete mix's flexural, split, and compressive strengths at an average of 10%, 44.9%, and 43.9% respectively. RAP reinforced with fiber increases fatigue strength by 50%-65%	[27]

5.3 RAP with nanomaterials

It has been discovered that bitumen and asphalt mixture behaviour can be improved by the addition of nanomaterials. It has the potential to increase the flexible pavement's service life and boost its durability. The improvement in rutting performance following the addition of RAP has been confirmed by numerous researchers. In the recycling of the binder, 20% RAP binder incorporation is possible with nanomodified binder and 10% RAP binder for unmodified binder [31]. The penetration value of the modified binder drops as the amount of nano silica in the binder rises, increasing the stiffness of the binder in the process. Marshall Stability increases by 32.5% when 4% Nano silica is added to the asphalt mixture having RAP with a reduction in flow value by 21.4%, and ITS value increased by 37.8% [32]. A reduction in stripping and moisture susceptibility is achieved by adding SBS nano-composite, which increases surface free energy and increases bitumen and aggregate adhesion. The addition of 2% of the nanocomposite increased the TSR value considerably [33].

6. Environmental Benefits

Industrialization have exploited the environment which increases the release of greenhouse gases (CO_2, CH_4, N_2O), which in turn increases air pollution. This is due to the various environmental exploitation and excessive use of natural resources. However, in the construction industry, there has been an increase in the reuse and recycling of industrial waste, by-products, or demolished materials like rubber, polymers, fly ash, RAP, and RCA [4, 34-38]. Since hot-mix asphalt requires burning fossil fuels, the effectiveness of WMA and CMA has been improved by numerous studies. The use of RAP is found to partially replace the virgin aggregates and binder, and transportation charges which contribute to lower emission of greenhouse gases. Hence, incorporation of RAP in pavement construction is consistent with the overall goal of energy conservation and reducing CO_2 emission.

7. Life Cycle Cost Analysis

One of the most crucial aspects of pavement maintenance is the optimization of the economic aspect. Research has been done by considering the extraction, production, transportation, and eventually road construction processes. Cost savings of 57% are seen in the RAP manufacturing plant when compared to virgin materials. And, with 20% RAP, the total cost reduction is found to be 14% [39]. Future climatic conditions can also affect the long-term performance of RAP. Hence, life cycle cost analysis of RAP is carried out considering the future climatic conditions for Interstate 95 (I-95) in New Hampshire (NH), USA. For the projected climate between 2020 and 2040, a cost reduction of around 18% is observed [40]. From a financial and environmental perspective, RAP combinations are not always preferable to virgin mixtures unless the relevant cost ratios and service life reach specified limits. In terms of finances, the service life ratio of RAP mixtures to virgin mixtures must be more than the cost ratio of these two materials, and for environmental reasons, the service life of RAP mixtures must be greater than 70% (40% RAP) to 90% (10% RAP) of that of the virgin mixture [41].

8. Conclusion

A well-built road network that accommodates people's travel needs and the movement of commodities is essential to a nation's development. Many studies have revealed that RAP as an alternative material for natural aggregates in the construction industry is beneficial, gives good performance results, decreases the usage of natural aggregates, which are depleting, and addresses the storage and disposal of reclaimed asphalt material. Hence, the use of RAP in India is gaining attention as it is easily available, environmentally friendly, and cost-effective. This chapter presents information on the recycling process of RAP, incorporation of RAP in bituminous mixes, applications, and performance of RAP as a construction material, and its environmental benefits. Based on the reviews, the following are concluded as,

- Asphalt mixtures with RAP can be used up to 30% which performs as good as conventional asphalt mixtures. Like conventional mixes, RAP inclusive mixtures use the same mix design.
- Fly ash, lime, and steel fibres can improve the performance of a base layer with a high RAP concentration.
- WMA and CMA with the incorporation of RAP gives the environment economic benefits. However, performance of the mix depends on the type of WMA additive used.
- Rutting and fatigue performance have improved when RAP is utilised in place of natural aggregates and binders.
- Rejuvenators increase the mix's resistance to moisture degradation in high RAP concentration mixtures.

Nomenclature

G_{se}	:	Effective RAP specific gravity
G_{sm}	:	RAP's theoretical maximum specific gravity
G_b	:	RAP binder's specific gravity
G_{sb}	:	RAP's bulk specific gravity
P_b	:	RAP's binder content
P_{ba}	:	RAP binder absorption
Mr	:	Resilient Modulus
AASHTO	:	American Association of State Highway and Transportation Officials
AB&AT	:	Abrasion and Attrition Technique
APTF	:	Accelerated Pavement Testing Facility
ASTM	:	American Society for Testing and Materials
BC	:	Bituminous Concrete
CMA	:	Cold Mix Asphalt
DBM	:	Dense Bituminous Macadam
DLC	:	Dry Lean Concrete
DSO	:	Date Seed Oil
HMA	:	Hot Mix Asphalt
IRC	:	Indian Road Congress
ITS	:	Indirect Tensile Strength
MoRTH	:	Ministry of Road Transport and Highway
PCP	:	Pervious Concrete Pavement
RAP	:	Reclaimed Asphalt Pavement
RCA	:	Recycled Concrete Aggregate
RFL	:	RAP Fly Ash Lime
SBS	:	Styrene-Butadiene-Styrene
SDBC	:	Semi Dense Bituminous Macadam
TSR	:	Tensile Strength Ratio
UCS	:	Unconfined Compressive Strength
WMA	:	Warm Mix Asphalt
WMM	:	Wet Mix Macadam

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