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Uses of Reclaimed Asphalt Pavement (RAP) in Flexible Pavements

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Abstract: One of the most frequently used waste materials is reclaimed asphalt pavement (RAP). The use of RAP can help reduce the cost of a project and ensure that the project is eco-friendly. Therefore, the aim of this study is to give a detailed description of the production of RAP to ensure that the rehabilitation and maintenance of pavements as well as the construction of pavements are environmentally friendly and cost effective. Previous works have shown the benefits of using RAP with regard to its ability to produce equally good or even superior results compared to the use of virgin or original mixes if they are properly produced and applied. Among the benefits of RAP mixes are good moisture resistance and higher density. This review also demonstrate the critical importance of using RAP in asphalt mixtures.

A well-developed road network is vital for swift economic growth as it links remote areas, provides access to markets, schools, and hospitals, and promotes trade and investment in underdeveloped regions. Roads facilitate inter-modal transport, connecting airports, railway stations, and ports. India's road network spans approximately 4.2 million kilometers, making it the second-largest in the world after the United States. This extensive network handles around 65% of freight traffic and 87% of passenger traffic. National Highways (NH), covering about 70,934 kilometers or just 2% of the total network, carry nearly 40% of the road traffic. State Highways (SH) and Major District Roads (MDR) make up the secondary road transport system, playing a significant role in the rural economy and industrial growth of the country. The traditional method of applying bituminous surfacing on flexible pavements requires a substantial amount of energy, as it involves producing bituminous binder from crude petroleum, drying aggregates, and producing the bituminous mix at a hot mix plant (HMP). Hot mix recycling involves combining reclaimed asphalt pavement materials with new materials, often along with a recycling agent, to create hot mix asphalt mixtures. Properly designed recycled mixtures can perform as well as or better than new conventional hot mix asphalt mixtures. Recycling or rejuvenating agents are organic materials with chemical and physical characteristics chosen to restore aged asphalt properties to desired specifications. The viscosity characteristics of the combined aged asphalt binder and recycling agent determine the choice of recycling agent, which can also be called softening agents, reclaiming agents, modifiers, fluxing oils, extender oils, and aromatic oils. The grade of Recycling Agent (RA) used depends on the amount and hardness of the asphalt in the aged pavement. Lower viscosity RA types can restore aged asphalts with high viscosity, and vice versa. Laboratory studies on asphalt mixes with RAP material and rejuvenating agents compared their performance to virgin asphalt mixes.

Various performance tests, including Retained Stability, Indirect Tensile Strength (ITS), Creep test, beam fatigue test, resilient modulus, and wheel tracking test, have been conducted to compare the performance properties. This paper presents the results of these performance tests on asphalt mixes with RAP and virgin mixes. Laboratory results indicate that asphalt mixes with RAP and rejuvenating agents provide better performance compared to virgin mixes.

Keywords: Moisture resistance, asphalt pavement recycling, reclaimed asphalt, RAP

I. INTRODUCTION

At present, recycled materials are frequently used in the base layers of asphalt pavements. This method is used for the shoulder of rural and urban road pavements via cold or hot-in place recycling. It involves the addition of a very small amount of additive material to the asphalts. According to the Federal Highway Administration (FHWA) up to 100 million tons of hot-mix asphalt are milled annually. The primary reason for using RAP is to eliminate the need to use aggregates and asphalt in the existing pavements. The materials are categorized after the removal of asphalt pavements for rehabilitation and maintenance. RAP consists of high-quality, well-graded aggregates coated with asphalt cement with high moisture content.

The properties of RAP makes it an excellent substitute for virgin resources and thus is able to reduce the need to use virgin aggregates. This makes RAP an eco-friendly and cost-effective alternative for virgin aggregates. The use of RAP also help to reduce the amount of overpriced new asphalt binders used in asphalt paving mixtures. The three primary advantages of using reclaimed asphalt pavements are its eco-friendliness, cost-effectiveness and good performance.

RAP has been used in asphalt mixes since 1915 and this is especially important for environmental and economic reasons [11]. The introduction of the Superpave system provides a foundation for the development of RAP in an effort to enhance the Superpave guidelines. The use of reclaimed asphalt pavement (RAP) was particularly attractive during the 1970s, especially with the rising oil price during the Arab oil restriction. As a consequence asphalt-paving technologists were forced to develop recycling methods that are able reduce the demand for asphalt binder, thereby reducing the cost of asphalt paving mixtures. Most of the methods developed during this period are still being used today, especially for routine pavement rehabilitation and construction.
The relevance of RAP usage are following:

- The use of RAP has considerable environmental benefits.
- The use of recycled materials in highway construction has economic benefits and is able to improve pavement performance.

Reclaimed asphalt is mixed with aggregates and old asphalt to the same degree as before to create new asphalt mixtures. The use of recycled asphalted material as a foundation, filling or basis of the harvested aggregate and bitumen is known as reuse asphalt as a lesser function than in the original use. One of the most widely used waste products (RAP) is asphalt pavement. RAP will guarantee a project's environmentally friendly development while assisting in cost reduction. Therefore, this study aims to provide a thorough review of RAP development to guarantee both economic and environmental viability. Pavement construction, restoration, and repair. In well-thought-out and executed prior studies, RAP can produce outcomes that are on par with or superior to virgin or first mixes. RAP mixes have two advantages: improved density and efficient moisture resistance. This investigation goes farther in demonstrating the benefits of RAP asphalt blends. Because of its qualities, RAP can be used as an acceptable alternative to virgin materials, reducing the need for virgin aggregate. RAP is therefore a cost-effective and environmentally friendly substitute for fresh aggregates. RAP frequently reduces the quantity of expensive new asphalt binders used in asphalt paving mixtures. The three primary benefits of recycled asphalt liners are their great performance, affordability, and environmental friendliness. Because of these advantages, the FHWA has set goals to encourage asphalt pavement recycling. The usage of RAP has significant environmental advantages. In addition to saving money, using recycled materials in road construction improves the surface appearance. As disposable materials, sand, rubber, and even glass is currently used in pavement design. Recycled asphalt pavement (RAP) is the most often utilized recycled material in pavement design. According to the National Asphalt Paving Association (NAPA). Rejuvenating bitumen involves replacing the oils lost during the aging process and rebalancing the bitumen composition to restore its flexibility. However, the use of rejuvenators is discouraged or even prohibited in some US states due to concerns about the rutting properties of recycled mixtures containing these agents. The percentage of rejuvenator added is crucial for the properties of blended aged asphalt. Proper application ensures improved low-temperature properties without adversely affecting high-temperature properties. Additionally, rejuvenators can penetrate pavement voids, filling them and minimizing binder oxidation. Various commercial rejuvenators and warm mix asphalt (WMA) technologies have been used in previous asphalt recycling works. Oliveira utilized used motor oil, and the results indicated that a 100% recycled mixture outperformed a conventional mixture. This study aims to examine the sustainability of roads constructed and rehabilitated with 100% recycled asphalt materials.

II. LITERATURE REVIEW

To purpose and defend the research work, a number of research papers are analyzed. Following are the excerpts from the different research work performed by number of academicians and researchers.
Gonzalo Valdés et al (2011) RAP rates between 10% and 30% are commonly used in hot recycled bituminous mixes. According to several studies, with these rates bituminous mixtures perform similarly to conventional mixtures. The aim of this work is to analyse the behaviour of mixtures with large RAP contents (specifically, 40% and 60%) and compare it with that of conventional mixtures. These percentages were selected based on the Spanish General Technical Specifications for Highway Rehabilitation, which define and specify the design requirements of recycled mixtures with RAP contents between 10% and 50%. Therefore, the mixture with 40% RAP is within the specified acceptable range while the mixture with 60% RAP is outside this range. The selected project consisted in rehabilitating the pavement of a section of highway A-140, located in Huesca, Spain. The section was 5.9 km long and the annual average daily traffic was 6980 with 8.5% of heavy vehicles. The top 80 mm of the asphalt mix was milled from the damaged pavement, and an 80 mm asphalt layer of S-20 recycled mixture containing 60% RAP (S20R60) was then laid. On top of this course, a 50 mm intermediate course of S-12 recycled mixture containing 40% RAP (S12R40) was placed. Mechanical properties of laboratory specimens: The analysis of stiffness modulus and indirect tensile strength in laboratory specimens has a behavior closer to that of a high modulus mixture and higher values than that of the conventional mixture with 60/70 penetration grade bitumen. Similar conclusions can be drawn from the analysis of dynamic modulus (fatigue tests).

T. Anil Pradyumna et al (2013) in this experimental the testing work carried out on virgin mixes and mixes with 20 % RAP, Moisture Susceptibility Values obtained for 20 % RAP mixes are higher as compared to the virgin mixes, which clearly indicates that mix made with RAP is less susceptible to moisture damage as compared to the virgin mixes. Higher viscosity of rejuvenated binder ensures greater affinity of binder with aggregates and renders it less prone to stripping. The results further confirm the increased resistance of RAP mixes towards moisture damage. Dynamic creep tests the accumulated permanent strain at the end of 10000 cycles was found to be less for 20 % RAP mixes compared to the virgin mixes at both the temperatures of 35 C and 45 C. This indicates that mixes with 20 % RAP have more potential to resist permanent deformation compared to the virgin mix. This behaviour is attributed to the hardened bitumen in RAP that possesses higher bitumen viscosity. Rutting test It can be seen from the figure that the rut depth for virgin mix was obtained as 8.20 mm, whereas for 20 % RAP mix, it was 7.6 mm only after 20,000 passes. This indicates that the rut depth for 20 % RAP mix is less compared to the virgin mix. This substantiates that the addition of RAP improves the rutting resistance of the mix. The RAP containing mixes become stiffer compared to the mix without RAP and thus has better resistance to permanent deformation. Fatigue Characteristics Improvement in the fatigue life of BC mix with addition of RAP was observed as compared to the virgin mix. The average percentage increase in fatigue life of the RAP mixes was found to be 67.2% compared to the virgin mix. Therefore, the increased fatigue life implies that the mix prepared with addition of RAP is more durable than the mix without RAP. Resilient modulus Test, MR the resilient modulus test indicates the improvement in the resilient modulus values of bituminous mix on using RAP. This increase in stiffness values might be attributed to the rejuvenation between virgin and RAP binder. As the stiffness of RAP binder is considerably higher than that of virgin VG-30 binder, the specimens with RAP have higher stiffness value.

Arshad Hussain and Qiu Yanjun (2013) et al Effect of Reclaimed Asphalt Pavement on the Properties of Asphalt Binders by in this research conventional and Superpave both methods were used to determine the virgin and residual binder properties. The residual binders obtained from two RAP sources using solvent extraction and abson recovery methods were blended with a virgin binder in different proportions. Ductility, Penetration, dynamic modulus, stiffness and viscosity of the different blends were compared. Viscosity Penetration, and PG grading blending charts were developed based on the corresponding test data. It was concluded that the properties of blends depend on the individual property of the binders. The stiffness of binder is increasing with increasing Reclaimed asphalt pavement binder. This research only pointed to the binder related study so to quantify RAP in asphalt mix design.

S M Mhlongo (2014) et al in this experimental the results of the indirect tensile strength (ITS) and stability tests are presented, as well as the mean of the volumetric properties of the tested specimens. The original asphalt material without additional bitumen i.e. 5.3% bitumen had high relative density (2528 kg/m3) and high air void ratio which is above the specification. The air voids at 5.9% bitumen was slightly higher than the maximum value recommended by specification (3 – 6%). The HMA fabricated with 50/70 bitumen, regardless of the percentage of the bitumen added, exhibited a higher ITS, which is higher than the minimum specified. It can be noticed that the relative density and air voids decreases with the increase in binder content. Revealed that as the bitumen content increases, the workability of the mixtures studied increases and invariably has an influence on the volumetric properties of HMA. The result also demonstrates that the fatigue resistance of the recycled mixtures appears to increases as the bitumen content increases while the bearing capacity decreases. The results obtained in the present study have shown that totally recycled pavement mixtures may be used for wearing course. As shown from ITS, fatigue and volumetric results that the use of 100% RAP with addition of some percentage of bitumen is a very promising solution in terms of economic and environmental factors.

Ahmed Ebrahim Abu El Maaty et al (2015) presented the experimental study Characterization of Recycled Asphalt Pavement (RAP) for use in Flexible Pavement the result showed. The mechanical properties include stability; flow and Marshall Quotient are shown where the Marshall mix design of HMA containing RAP and the corresponding optimum binder content (OBC) are illustrated. OBC for each RAP mixture are 4.5%, 4.58%, 4.13%, 4.5% and 5.5% for RAP contents 0.0%, 25%, 50%, 75% and 100% respectively. The results which are average of three samples show that the OBC varies due to the percentage of (RAP) where the lowest OBC value is provided at 50% RAP whereas, the highest value is obtained at 100% RAP. OBC increases by about 2% when RAP content increases from 0% to 25% and by about 22% when RAP content increases from 0% to 100%. The results shown in illustrate that the percentage of RAP plays a significant role in mechanical properties of bituminous mixtures where 100% RAP mixture achieves the maximum stability. For flow value it decreases with increasing the RAP ratio where all flow values are located within the required specifications range (from 2 to 4 mm according to Egyptian Code) except the mixture contains 100% RAP at 4.13 % bitumen content. As shown the Marshall quotient (MQ) of control mixture slightly increases at 3.5 % to 4% bitumen content, after that it slightly decreases at bitumen content up to 5.5%, while MQ of RAP mixtures increases then decreases significantly at a sharp rate by increasing the bitumen content. Based on the Marshall test results discussed previously, an optimum RAP content of 100% is recommended for obtaining the highest stability and Marshall Quotient.

The variations of mechanical properties of RAP mixtures at the optimum bitumen content are shown. It is observed that the addition of 100% RAP has a great impact on the stiffness of the mixture. It can be concluded that there is a significant improvement in the stiffness characteristics of HMA after adding RAP.

P Akhilesh Rao et al (2019) Form the study of literature reviews and preliminary study of the topic there are some remarks are concluded Overall from this study it was concluded that RAP 35% showed results similar to that of virgin bituminous mix and its performance was best amongst other RAP percentages. Also, with the use of RAP 35% the cost of project was reduced by 50 %. The optimum asphalt content is decreased as the Reclaimed asphalt pavement percent increase. Stability of mixes decreases as the recycled aggregate percent increases. This may due to the fatigue of such material by aging. Increasing the recycling aggregate percent in the asphalt mixes decreases the air voids percent which may leads to asphalt bleeding. Increasing of RAP material percent increases the loss of stability of asphalt mix. However, the increasing in loss of stability of asphalt mix is more significant when the percent of Reclaimed asphalt pavement is higher than 30 %. Based on the study analysis and conclusions, the following recommendations are obtained: The RAP is recommended to use in the hot asphalt mixes to save the virgin aggregate for longer time and also to improve the environment. A percent of Reclaimed asphalt pavement may be 30% is suitable to be used in pavement.

Dudhwala Rinkal et al (2021) The results show that each method/technology addresses RAP materials on its own, resulting in a different proportion and content of the proposed components. This enables the problem of waste disposal from RAP to be addressed easily and adverse environmental consequences to be avoided by the use of the RAP materials in light paving construction. A greater proportion of RAP goods have been used today, resulting in considerable costs and material savings, to save capital and natural resources. The addition of RAP to HMA reduced life expectancy. In addition, the lower racking tolerance of HMA-RAP mixtures, with higher RAP percentages. This is the explanation for the effects of the two tests, which are due to the ageing RAP-binding effect on the mixed virgin RAP binder. In previous experiments, higher RAP content was found to increase permeability, thereby reducing the shear strength. The degeneration of the floor and solid modulus in RAP materials were also greater. In addition, the greater RAP percentage decreases shear intensity according to another study. RAP may minimize a substance's bearing capacity unlike virgin aggregates. An improving RAP degeneration and a reduction in CBR value led to an increased RAP. It is also recommended to pair RAP with virgin aggregates such that the weight of the RAP should not exceed 50 percent. WMA-high RAP mixes have less rutting and moisture resistance relative to HMA-high RAP mixtures. Strong RAP-WMA mixtures have greater fatigue resistance, regardless of the surface of pavement or WMA technology used, than low RAP-WMA mixtures. Rutting can therefore also be a problem with high RAP-WMA mixtures, though exhaustion may not be a problem.

Arindam Karmakar et al (2023) in this study it was observed that the physical properties improve. The optimum moisture content was seen to be decreasing and maximum dry density increasing with increase of course materials. The results of the compaction test for different mixture gradations. It is also found that MDD and OMC increase with an increase in cement content. This may be because of better packing of RAP material with cement and the higher specific gravity of cement. Highest MDD was found to be 2.516 gm/cc for gradation. UCS of the samples were seen to be increasing with better grading of the materials. Between the UCS and cement content of various mixes, a linear relationship is found. The samples before and after testing and the results for UCS test for different mixes after 7 days of curing. Gradation 2 has shown better UCS value than gradation 1 and 3 may be because of higher MDD of the mixture. Gradation 4 found to satisfy the minimum 7 days UCS value of 4.5 MPa as specified by IRC:37 (2018) with 5% cement content. This indicates that along with aggregates right quantities of fines are also very important for proper filling of the voids in the sample. Whereas cement acted as the binder providing strength and stiffness to the mixture. This is due to the presence of mortar and improved interlocking between RAP material and cement.

Long-term performance of treated RAP materials is studied through durability test under extreme moisture changes, which are likely to occur during the pavement's service life. The study assessed the average mass loss as a percentage after 12 cycles of wetting and drying, offering valuable insights into the durability of the treated mix under various environmental conditions. The results demonstrated that the average mass loss of the optimized DSFC blend was measured at 3.2%, well below the permissible limit of 14% as given in IRC:37 (2018). Result shows the sample before and after durability test. This finding indicates excellent longevity for the optimized blend, making it highly durable and suitable for long-term usage on pavements.

The use of RAP has become increasingly popular in the asphalt industry and many studies have been conducted on this subject. However, the results of these studies are not as anticipated in that the use of RAP is still very limited, and that RAP has an unfavorable reputation among the pavement community, especially with regard to the use of RAP materials in new asphalt mixes. The incorporation of RAP in HMA resulted in a shorter fatigue life.

Additionally, higher percentages of RAP resulted in reduced racking resistance of HMA-RAP mixtures. The explanation for the findings of the two studies is related to the stiffening effect of the aged RAP binder on the blended virgin-RAP binder within the mixture.

Previous studies have shown that higher RAP content increases permeability and resilient modulus whilst reducing shear strength. RAP materials exhibited a more pronounced pavement degeneration and resilient modulus. Another study found that higher percentages of RAP have the effect of reducing shear strength. Unlike virgin aggregates, RAP can reduce a material's bearing capacity. Increasing the amount of RAP resulted in greater permanent degeneration and smaller CBR value. Thus, it is recommended for the RAP to be mixed with virgin aggregates and that the weight of RAP should not exceed 50%. WMA-high RAP mixtures have reduced rutting and moisture resistance compared to HMA-high RAP mixtures. Regardless of the pavement layer and WMA technology employed, high RAP- WMA mixtures exhibit better fatigue resistance than high RAP-WMA mixtures.

Hence, rutting may still be a concern for high RAP-WMA mixtures while fatigue may not present any problem. In addition, with the exception of foamed base WMA mixtures, high RAP-WMA mixtures have an acceptable resistance to moisture. Despite the benefits of asphalt recycling and reclamation as a rehabilitation technique, not all reclamation and pavement and asphalt recycling are suitable for the treatment of different forms of pavement distress. Considering that there are differences between by-products in terms of their properties and form, RAP should be used based on the following principles: 1) mixtures with RAP should be able to meet the requirements set for mixes with virgin materials, and 2) the performance of mixes containing RAP should be equivalent to or exceed the performance of virgin asphalt mixtures.

III. METHODOLOGY

RAP materials are generated when asphalt pavements are removed for resurfacing, reconstruction, or accessing buried utilities. After properly crushing and screening, RAP forms a mixture of well-graded and high-quality aggregates coated by asphalt cement.

The Federal Highway Administration (FHA) of the US Department of Transportation (DOT) mentions the following ways of producing RAP materials for pavements:

1) The asphalt pavement is removed either by milling or full-depth removal at the site. The milling is conducted using a milling machine that can remove the pavement surface up to 50 mm thickness in a single pass. To perform full-depth removal, a rhino horn on a bulldozer or pneumatic pavement breakers are used to rip and break the pavement. These RAP materials are taken to a central processing plant, where they undergo further crushing, screening, conveying, and stacking.

2) Asphalt pavement can also be pulverized at the site using a self-propelled pulverizing machine. These pulverized materials are used with a stabilized base course at the same time.

3) In addition to the above methods, there are hot-in-place and cold-in-place recycling of asphalt pavements.

IV. RAP MIX AND MATERIAL TESTING

There are two types of process to prepare a mix. Asphalt materials can be recycled using either hot or cold processes. Hot-in-place recycling specifically applies to the hot process, while cold-free recycling encompasses all other recycling methods (IRC: SP:120-2015). The existing surface is heated, causing the bituminous material to soften, melt, or become scarified. The recycled material is then reutilized. Cold process recycling involves cooling the paving material, which is then cracked or fractured. The recycled materials must be compressed and stored in large chunks. Before storage, these materials can be separated and divided into different size fractions. Cold recovery methods may include the ripening and sulfurizing of non-bituminous bases or subbases (IRC: SP:120-2015).

Recycling technology can be categorized into two main types:

1. In- Place
2. In- Plant

The Following are the process of Reclaimed Asphalt process (RAP) Mixing.

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)

Application Technique	Evaluation factor			
	Climate	Traffic	Condition Addressed	Contraindication
Cold In-Place Recycling (CIPR)	Remediation performs well in all weather conditions	Very successful in both high- and low-volume roadways	Reconstruction of old pavements	• Long remaining life, • Extend the service life of roadway pavements by 10-15 years
Hot mix asphalt recycling (HMAR)	Dried treatment sealants perform better in warmer climates	Performance is not significantly affected by different ADT or truck levels	Reconstruction of old pavements	• Extend service life of roads for over 12 years
Hot in-place recycling (HIR))	Dried treatment sealants perform better in warmer climates	Performance is not significantly affected by different ADT or truck levels	Correct shallow-depth HMA surface distress.	• Preservation treatment process is expected to extend pavement life by 10-12 years
Full-depth reclamation (FDR)	Remediation performs well in all climate conditions	Higher traffic bearing capacity	Stabilized base course	• Extend the service life of roadway pavements by 10 years

Table 1 Asphalt pavement maintenance and rehabilitation using RAP

V. BENEFITS OF RAP

Asphalt pavements that have reached the end of their life cycle can be removed, reused, and land-filled, or remain in the area where they were originally used to be reused as a backing structure for new pavings. If the asphalt pavement is recycled as it approaches the end of its life cycle, it will be milled to obtain a perfectly reusable reclaimed asphalt pavement (RAP). RAP can be used in new asphalt mixtures. The use of RAP as aggregate replacement for road base layers have shown that the full use of RAP brings considerable economic savings and environmental and engineering benefits.

A. *Economic Benefits*

According to Babashamsi *et al*. 2006 the life cycle cost analysis of pavements incorporated with RAP showed that a saving of $58,000/km can be achieved for asphalt mixtures containing 30 to 50% RAP. This saving consists of the savings in material cost due to the replacement of a part of the binders" virgin aggregates with RAP and the lower transportation cost. Conventional crushed stones are generally more expensive than recycled materials. According to Edil [22] a saving of up to 30% was achieved by using RAP as base material for pavements. The most expensive component of asphalt pavement construction is the asphalt binder. The use of RAP material in pavement construction means that less asphalt binder is required. As such, it has been proposed that the most economical use of RAP in asphalt mixtures is in the immediate and surface layers of flexible pavements.

B. *Environmental Benefits*

Amongst the many environmental benefits of using RAP are reduced demand for non-renewable resources; less landfill space is required for the disposal of used pavements; reduced fuel consumption and emissions since the materials do not have to be transported; and less extraction of virgin materials [24]. Previous studies have proven these benefits. For instance, one study has shown that the incorporation of 15% RAP into warm-mix asphalt mixtures was able to reduce the total cumulative energy requirement, climate change and use of fossil fuels by 13 to 14%.

C. *Engineering Benefits*

A survey was carried out in the United States to compare the Long-Term Pavement Performance of virgin mixes and mixes containing RAP. Results show that, in terms of all aspects of pavement performance, the performance of mixes containing a minimum of 30% RAP is equivalent to those containing virgin materials. Another study has shown that the base layers containing RAP have higher strength than those containing conventional aggregates. The use of RAP has also been demonstrated to be suitable for the construction of pavements in areas with low traffic and freezing temperatures; areas with high traffic and non-freezing temperatures; and areas with medium traffic and freezing temperatures as well as low moisture levels.

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VI. SUMMARY AND CONCLUSIONS

A disciplined approach to RAP management — one based on data to manage inventory, processing, uniformity, and quality — will maximize the return on investment in materials, equipment, and people.

Good management of RAP begins with collecting or accepting the materials in ways that ensure the materials are not contaminated. Most RAP is obtained through roadway milling operations. Milling is beneficial to roadway maintenance because it removes distressed layers, helps restore the roadway profile and cross slope, and aids in creating a strong bond with the overlay. An important decision by the highway agency is determining the appropriate milling depth. Leaving a poorly bonded interface or a moisture damaged layer in the pavement structure is a sure way to a short life for the rehabilitation. RAP from multiple sources can be made into a very consistent material with good stockpiling and processing techniques. An inventory analysis is very helpful to make the best decisions on when and how to process. Good stockpiling practices include building in layers to help average out variations, avoiding trucks on top of the stockpiles to minimize compaction, and avoiding pushing material over the edge of the stockpile to minimize segregation.

The goal of processing RAP is to make a uniform material that meets the needs of mix designs that will use RAP as a component. A decision about processing includes setting the crusher top size to balance the need to utilize the material in a range of mix types versus the generation of additional fines. Fractionating RAP should be a contractor's choice, not a specification requirement. Fractionating RAP can be beneficial when the RAP supply exceeds the current rate of usage and the plant is capable of producing higher RAP contents, but mixes are unable to meet volumetric or gradation requirements during mix design or quality assurance testing.

VII. FUTURE SCOPE

The future scope of Reclaimed Asphalt Pavement (RAP) is promising and involves several key areas of focus:

1) Technological Advancements: Continued research and development to improve the processing, mixing, and application techniques for RAP. Innovations in recycling technology will enhance the quality and performance of RAP mixtures.
2) Increased Usage: Expanding the use of RAP in road construction projects, aiming for higher percentages of recycled materials in asphalt mixtures. This will contribute to sustainability and cost savings.
3) Environmental Impact: Reducing the environmental footprint of road construction by minimizing the use of virgin materials and decreasing CO_2 emissions.
4) Global Adoption: Encouraging more countries to adopt RAP in their road construction practices, supported by appropriate guidelines and standards.
5) Life Cycle Assessment: Conducting comprehensive life cycle assessments to evaluate the long-term performance and environmental benefits of using RAP.
6) Sustainable Practices: Promoting sustainable construction practices and integrating RAP into the circular economy to reduce waste and conserve resources
7) Economical: Due to reuse of aggregate it will be economical.

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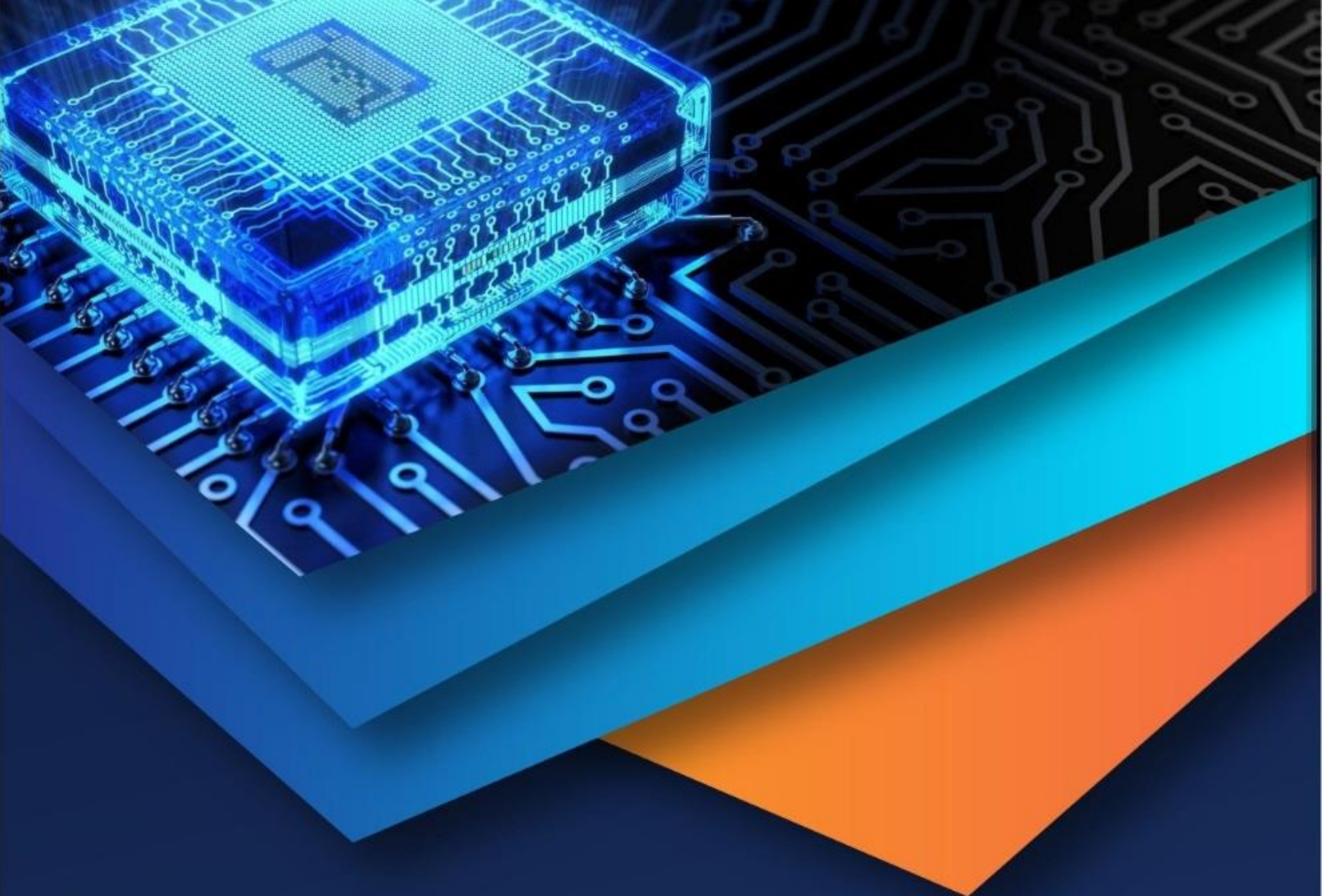

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