A Comprehensive Review on the Replacement of Virgin Material using Reclaimed Asphalt Pavement (RAP) Material in Flexible Pavements

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Abstract. With increased demand and limited aggregate and binder supply brings the use of Reclaimed Asphalt Pavement (RAP) as a valuable component in Hot Mix Asphalt(HMA) since 1970’s in US. Later on, the use of RAP has evolved into a regular practice in many countries around the world and use of these materials in the past has proven to be economically and environmentally sound. Mixing of RAP in virgin materials has been greatly favored over virgin materials because of increase in cost of asphalt, scarcity of quality aggregates and asphalt. The use of RAP in pavement design is Recycling the left over Asphalt through crushing and is recycled back into asphalt which performs equal or better than the virgin mixtures. Now-a-days being more environmentally friendly is important and hence, recycling on site can offer real benefits not only through better planning and regulations, but also saving in the waste disposal charges, energy saving which is modified into the strengthen material. The use of RAP is gaining momentum in India at present and there were very limited studies carried out on the use of RAP in Warm Mix Asphalt (WMA) as well. Therefore an ample scope exists inorder to investigate the complete usage of RAP content.

1. Introduction

During the past few decades, Quarrying works have become downturned due to the increase in the emission of many poisonous gases like carbon dioxide, carbon monoxide, nitrogen dioxide etc .This results in the paucity of the origination of coarse aggregates and in the escalation of their cost[2] . In 1970’s, due to Arab Oil Embargo, the petroleum and binder prices were skyrocketed. In order to overcome these circumstances, the material which was excavated during the demolition of roads can be reused.

Owing to the upsurge in the traffic conditions and perpetual mobility of vehicles, roads are getting deteriorated. So there is a need in the excavation of roads either by full depth reclamation or by surface reclamation [7]. The material which was procured during this process is called Reclaimed Asphalt Pavement. To make the project more economical, to reduce the adverse effects on the environment and also to optimize the resources the reuse of the material which was reclined on the sides of roads as a waste material through excavation can be entertained [3].

Reclaimed Asphalt Pavement, which on crushing gives aggregates and binder, in olden days was excavated into big boulders through excavators. But with the discovery of millers and
bulldozers the pulverizing of RAP into nominal grade aggregates has become evident. After crushing, mixing of RAP with virgin aggregates should be done. During the past years, aged pavement was taken off and thrown away in landfills [6]. As land filling these materials has become less practical and more expensive and also the procurement of quality virgin material reduces, mixing of RAP to virgin materials has become widespread. Because the addition of RAP increases the stiffness and brittleness of pavement materials which gives high potential for cracking [16]. RAP performs better or equal to virgin aggregates [2][11]. The usage of RAP has been increasing now-a-days considering to the environmental and the economical conditions.

This article completely discuss about different works carried out by various research people and stated that the usage of RAP makes the project more economical and reduces the production of waste[5]. And also by reusing the recycled road aggregates which are generated at the same site the cost can be reduced up to 25 to 30% [4].

2. State of art for recycling of asphalt pavements

An extensive literature survey was carried out on recycling of asphalt pavements. The details regarding various methods of recycling were obtained and the laboratory conclusions which were drawn to ascertain the properties of RAP were presented below:

Brian Hill (2011) stated that the WMA technologies increase moisture and rutting susceptibility whereas RAP increases stiffness of resulting mixture. The laboratory tests conducted were Brookfield Rotational Viscometer Test, Bending Beam Rheometer Test, Hamburg Wheel Tracking Test, AASHTO T-283 Moisture Sensitivity Test , Disk-Shaped Compact Tension (DC(T)) Test. The main objective of this paper is to design virgin and high RAP HMA mixtures which satisfy super pave mix design criteria [5].

Jashanjot Singh and A.K Duggal (2015) determined the optimization of the use of RAP in surface courses such as Bituminous concrete. The usage of RAP makes the project more economical and reduces the production of waste. Several laboratory tests were conducted in order to obtain the physical and engineering properties of RAP as well as Virgin aggregates. The tests results concluded that RAP performs better or equal to Virgin aggregates and the results obtained were within the MORTH specifications [10].

Abhishek Verma et al.(2017) stated that the aggregates which are obtained from various rocks have gained more demand as construction materials for flexible pavements. Due to increase in the cost of virgin aggregates due to environmental constraints there is a need in the reuse of the material called Reclaimed Asphalt Pavement which was deteriorated. During the conduction of laboratory tests like Marshall Stability test, California Bearing Ratio test, Unconfined Compression test the stabilizers like fly ash and cement were added and concluded that the results obtained were satisfactory [1].

Krupa S Sharma, Ashok Pates(2017)determines the objective of this paper was to reuse the material which was recycled as filling material without any analysis & tests in submerged areas. To investigate the recycling mix after carrying out Marshall Stability tests. The methodology used for investigation of the materials is Marshall Stability test. It concludes that as a result of the analysis the RAP added bituminous mix given competitive as compared with fresh bituminous mix[13].

T.Anil Pradyumma and Abhishek Mittal(2013) explains that the objective of this is to study on mechanistic evaluation of hot recycle mixes with and without utilization of recycling agents and to increase performance properties of mixes. The tests like Resilience modulus test, moisture susceptibility test, Dynamic creep test, Rutting test were conducted. Based on laboratory tests conducted on fresh mixes and mixes which are having the percentage of RAP as 20 it was found that by adding RAP all the properties of bituminous mixes can be improved and RAP with 20% would behave better compare to virgin materials under same conditions[22].

Anil Kumar Yadava and Dr.Syed Aqeel Ahmad (2019) The Bituminous pavement recycling was not yet popular in India and other developing countries due to sufficient guidelines and the lack of availability of the equipment to extract the material. Different types of recycling techniques were
mentioned and Hot in plant recycling technique was adopted by considering 70-100% RAP. Based on the tests conducted and mix design, analysis for future enhancement was made [2].

![Fig.1 Classification of recycling methods based on Processes](image)

Brajesh Mishra(2015) By reusing the recycled road aggregates which are generated at the same site the cost can be reduced up to 25 to 30%. The materials which are recycled frequently are Reclaimed Asphalt Pavements (RAP) and Recycled concrete aggregates (RCA). Consumption of natural aggregates and binder can be made less in mixes containing asphalt by using RAP materials. The main objective is used to use RAP materials after blending in base and sub base course of materials. The laboratory tests were conducted by considering 0% RAP, 10% RAP, 20% RAP, 30% RAP, 40% RAP and 100% RAP. The usage of RAP up to 30% can be feasible and its characteristics are equal to virgin aggregates and the RAP material up to 50% is used as a replacement of granular sub base [4].

Rohan Pawar et al.(2017) The RAP material was collected and is recycled into the nominal aggregates by milling process. The objective is to determine the recycling of RAP content by the central mix plant & hot mix plant. The tests were conducted on virgin aggregates, RAP & Bitumen. All the collected materials were mixed in specified quantities and temperatures based on the requirement and conducted Marshall Stability test. It concludes that according to the Marshall Stability test conducted the values increases for 30% RAP in comparison with the conventional mixes & then reduced for 40% placement of RAP [12].

Siksha Swaroopa Kar, et al. (2018) determines that the aim of this article was to study the effects which are caused by RAP & its components on the mechanical behavior of Foamed Bituminous mixtures. The laboratory tests conducted are Indirect tensile strength, resilience modulus test. The results from the study of the Foamed Bituminous mixtures following to Indian standard conditions were analysed. The foaming qualities of fresh bitumen are used for optimum water content & the foaming temperature[21].

Imad L.AI Qadi et al.(2007) Recycling WMA material results in a mixture of the aggregates which can be reusable and asphalt binder which is called as RAP. Rutting performance typically improves by the use of RAP whereas fatigue and thermal performance has become inconsistent. The objective is to evolve the relationship between old and fresh asphalt binders in RAP[9].

Umesh Kamariya et al.(2018)determines that the objective is to determine the necessity of the mixes with and without added any admixtures and also to increase the properties of RAP materials by increasing the mixing of RAP percentages. The recycling process can be done either by hot or
cold recycling process. The tests they conducted are moisture susceptibility test and rutting resistance test. It concludes that as compared to fresh mixes RAP is stiffer and brittle material and the results shows that the RAP led to increase permanent deformation and moisture damage[23].

Feipeng Xiao and Serji N. Amirkhanian (2007) explains that the objective is to measure the performance of the pavements in several design methods. The crumb rubber was mixed to the fresh binder. The purpose of this is to improve the rutting resistance properties of the rubberized asphalt mixtures. The indirect tensile strength test and rutting susceptibility test were also conducted to rubberize each material. It concludes that the admixture which was added along with RAP increases the resistance against deformation and creep stiffness[7].

Fawaz Kaseer et al. (2019) proposed a technique to ascertain the percentage of vigorous RAP binder and to know the factors which effects the RAP material. The methodology adopted was Resilience Modulus test and the Marshall stability test. Finally the virgin binder content is mixed with recycled binder mixes as they provide a reasonable estimate of the RAP binder [6].

D. Stephen lane et al. (2015) stated that the use of RAP fits the global objective to continual development by the use of the natural resources. It was initiated to explore the potential alternatives of RAP in the higher quantities for base and sub-base. The tests conducted were Resilience modulus test which describes the material response to traffic loading. As the content of the RAP increases, the shear strength of the blend reduced below the level which is required[19].

Martina Irene Giani et al. (2014) describes the use of RAP is the other form of the material related technology which reduces the asphalt binder, scarcity of the aggregates thus saves natural resources. The methodology used were Life cycle Assessment (LCA) and Cold In place Recycling (CIR) which analyses and describes its environmental impacts. To understand the environmental benefits which results in the use of RAP techniques, to reduce the temperature of plant production and to reconstruct the road after its usage are the advantages by adopting these techniques[14].

![Processing of Asphalt pavements](image)

Fig.2 Processing of Asphalt pavements
Prithvi S. Kandhal (1997) the existing pavement structures can be strengthened by recycling without adding substantial overlays. The cold planning method was used which describes an automatic method for removal of asphalt pavements because recycling of asphalt surface does not increase the structural capacity of current pavement & there is no other alternative for thickness design of surface recycling[17].

S.Mangiafico et al.(2013) describes that the objective is to determine the visco elastic characteristics of binders and to examine as they amend with RAP content. Dynamic shear Rheometer and complex modulus tests were conducted. There is a necessity for analyzing performance related tests also before finalizing any recycled mix design. The tests were conducted by considering different binder contents along with varying RAP percentages [18].

Haritha Musty et al.(2012) Being economic, sustainable, and environmentally friendly, RAP can be restored for a small amount of aggregates in Hot Mix Asphalt (HMA) where standard aggregates are scare. The objective is to regulate the effects of having higher percentages of RAP and FRAP on mixture performance while meeting the present requirements of Super pave mix design. Dynamic Modulus test and Wheel cracking test were conducted by taking 20%, 40% RAP for which 20% RAP is having higher modulus [8].

Arshad Hussain and QiuYajun (2013) Within the usage of RAP, including the conservation of natural resources the cost of new asphalt mixes can also be reduced. The percentage of RAP is mostly used between 10 to 30 in hot in plant asphalt mixtures. During the construction of a pavement, environmental and financial departments are forcing to place high percentage of RAP. The laboratory tests conducted were DSR testing Rheometer testing. When the RAP binder content increases the viscosity, stiffness and critical temperature of the blend also increases[3].

K. Aravind and Animesh Das (2006) induced to plan a pavement with a hot recycled asphalt surfacing, where on conducting Marshall stability test, Creep test, Fatigue test the mix which was recycled can be finalized through a systematic mix design. The criterion gained are used in the design of pavement. Mix with 5.5% binder content is safe to produce the optimum binder content. The construction cost with recycled mix could be economical compare to virgin mix[11].

Pavel kriz et al.(2014) Performed replica of dissemination throughout realistic mix production storage and paving temperatures in order to blend RAP and fresh aggregates and to make sure pavement resistance to moist damage, Permanent deformation and cracking. 15 to 20% of RAP is commonly used in HMA/WMA in olden days in Canada and up to 40% have been recently used. The main objective is to determine an average diffusion distance or binder film thickness in a typical asphalt mix in order to calibrate the diffusion model[16].

Sara Bressiet al.(2019) explained that the use of recycled materials in bituminous pavements reduce the environmental effects and excessive use of non-renewable resources. The probable environmental effects of asphalt mixes which contains crumb rubber and RAP assuming another binder degree activation of the old binder is evaluated through life cycle analysis. The usage of small amount of crumb rubber does not justfy the optimum usage of natural resources and environmental effects[20].

Munagala Sreenivasulu Reddy and Suvarna P. (2015) proposed that RAP can be used as a substitute for fine aggregates and coarse aggregates. Performance of Pavement Quality Cement Concrete (PQCC) is used as an admixture which is studied by replacing virgin aggregates with RAP and also by conducting experimental tests on RAP. Fine aggregate is replaced with 0%, 15%, 30%, 45%, 60% RAP and coarse aggregates are replaced with RAP by 0%, 15%, 30%, 45% and 60%. [15].

3. Conclusion
An extensive literature survey was carried out on recycling of asphalt pavements under different processes and by different conditions to make the economic conditions favourable and to decrease the adverse effects on the environment. Some of the conclusions drawn from the literature survey are as follows.
- It was inferred that mixes having the percentage of RAP as 20 would behave better compared to virgin mixes under same conditions.
- RAP can be used as aggregate up to concrete replacement of 30%.
- The rheological properties of the binder can be used to analyze the sample and the batch variability and their subsequent impact on the pavement performance.
- The usage of RAP makes the project more economical and reduces the optimum usage of natural resources.
- RAP can be used up to certain limit in the maintenance of roads and as an alternative to overlays.

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