A Study on Effect of Reclaimed Asphalt Pavement Material over Virgin Material in Bituminous Mix

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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 very less studies were carried out and there were no such studies on complete usage of RAP and hence this study was carried out for complete utilization of RAP content in Bituminous mixture. Experimental results show that, RAP materials has much better resistance under compressive load and impact load than virgin materials, i.e. 8.43% of impact value and 6.23% of crushing value was obtained for RAP whereas 12.83% of impact value and 9.07% of crushing value was obtained for virgin material. It was found that 30 to 50% of RAP material can be preferable for the construction of roads whereas on using 100% RAP the pavement becomes weak and unstable.

1. Introduction
During the last decades, Quarrying works have become downturned due to the increase in the discharge 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 landfiling 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 mainly discusses about the RAP material which was collected near Tadepalligudem, West Godavari District, Andhra Pradesh, India and several laboratory tests were conducted on RAP material as well as on virgin material to analyze the physical and mechanical properties of both the mixes and also to determine the suitability of 100% RAP in the sustainable construction of flexible pavements. Hence an attempt has been made on the bituminous mix by considering different proportions of RAP material and varying percentages of binder content.

2. Necessity of study
Reclaimed Asphalt Pavement(RAP) is a material which is obtained during the reprocessed, reconstruction or rehabilitation of roads which can be used as a replacement for fine aggregates and coarse aggregates. The material which was recycled has more resistance to scuffing and shearing, which in turn increase the rutting resistance. Scarcity of aggregates and crude oil results in increase in the cost of asphalt binder and aggregates spurred a new interest in the reuse of RAP. Recycling solve the problem of construction waste in transportation engineering projects. Strength parameters either of same or better quality are produced by RAP when compare to virgin aggregates. Reusing of RAP reduces the consumption of fuel and reduces damages to other materials due to the transportation of minerals from quarry sites.

3. Advantages of reclaimed 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:

The usage of RAP makes the project more economical and reduces the production of waste. Several laboratory tests were performed to determine 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 [9]. 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[6] Abhishek Verma et al (2017).

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 can be recycled more are Reclaimed Asphalt
Pavements (RAP) and Recycled concrete aggregates (RCA). Consumption of natural aggregates and binder can be decreased in asphalt paving mixes by using RAP materials. The main objective is 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]. 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 [1]. 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 [11] Anil Kumar Yadava et al (2019).

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% replacement of RAP [14]. This is to increase performance properties of mixes in the tests like Resilience modulus test, moisture susceptibility test, Dynamic creep test and Rutting test. 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[1].This effects the 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 found. The foaming qualities of fresh bitumen are used for optimum water content & the foaming temperature[7] Siksha Swaroop Kar et al (2018).

Recycling HMA material results in a reusable mixture of aggregates and asphalt binder known as RAP. Rutting performance typically improves by the use of RAP where as fatigue and thermal
performance has become inconsistent. The objective is to promote an understanding of the connection between aged and virgin asphalt binders in RAP\cite{2}. To increase 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\cite{13}. To measure the performance of the pavements in several design methods by using crumb rubber. The purpose of this is to improve the rutting resistance characteristics 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 \cite{16} Feipeng Xiao et al\cite{2007}.

A method to develop the percentage of active & available 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\cite{8}. The use of RAP fits the global objective to sustainable 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 RAP content increases, the shear strength of the blend decreased below the required level. 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 technologies, to reduce temperature of production in plant and to reconstruct the pavement after useful life are the advantages by adopting these techniques\cite{22} Martina Ireneet et al\cite{2014}.

![Fig.2 Processing of Asphalt Pavement](image-url)
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 and there is no method to design of thickness for surface recycling [21]. It describes that objective is to determine the visco elastic characteristics of corresponding binders whether there is any change in reactions with RAP content or not. Dynamic Shear Rheometer and complex modulus tests were conducted in order to know about the mix reactions of different binder contents along with varying RAP percentages [20]. 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 Reclaimed Asphalt Pavements(RAP) and Foamed Reclaimed Asphalt pavements(FRAP) on mixture performance while meetings the present requirements of Super pave method. Dynamic Modulus test and Wheel cracking test were conducted by taking 20%, 40% RAP for which 20% RAP is having higher modulus [17] Haritha musty et al (2012).

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].

To produce safe and optimum binder content, the analyses were done by conducting Marshall Stability test, Creep test and Fatigue test [15]. Therefore performed replica of dissemination throughout realistic mix production storage and paving temperatures in order to blend RAP and virgin 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[19] Pavel Kriz et al (2014).

The usage of small amount of crumb rubber does not justify the optimum usage of natural resources and environmental effects but it can be used as a substitute for fine aggregates and coarse aggregates [18]. 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%. Finally the results concludes that RAP can be used as an aggregate in PQCC up to limited percentage [10] Suvarna P et al (2015).

- Summary: The above given state of art is about Reclaimed Asphalt Pavement and its properties. It is also discussed about various laboratory tests conducted on RAP. There is still some scope to investigate and to undergo research in this area.

4. Materials
It is required to determine the materials and their sources opted for this study. The materials include RAP material, Coarse aggregates, Bitumen (VG 30).

4.1 RAP material
The material which was obtained during the reconstruction and rehabilitation of roads is called Reclaimed Asphalt Pavement. RAP material which was collected for this study has undergone several laboratory tests after crushing into nominal size aggregates in order to determine its suitability in the construction of flexible pavements and to determine the physical properties like toughness, strength, hardness, quality, durability, shape and size.
4.2 Coarse aggregates
The Coarse aggregates (Virgin aggregates) of distinct sizes like 20mm, 12mm, 10mm, 4.75mm, 2.36 mm were taken and different tests were conducted to determine the properties like toughness, strength, hardness, quality, durability, shape and size and to compare the results of RAP as well as Virgin aggregates.

4.3 Bitumen
Bitumen used for this study is VG-30. It is the viscosity grade which is most suitable in the construction of flexible pavements as it has more durability and more resistance to sustain in the different temperature conditions.

5. Test results and discussions

5.1 Aggregate crushing test
This test was conducted on RAP as well as on Virgin aggregates to find out the strength.

![Crushing test apparatus](image1)
![Analysis of crushing test](image2)

**Fig 3** Crushing test apparatus  
**Fig 4** Analysis of crushing test

From this test it was analyzed that the value of crushing for RAP is less compare to nominal size aggregates and the value was within the MORTH limits and it was satisfactory.

5.2 Aggregate impact test
This test was conducted on RAP as well as on Virgin aggregates to find out the toughness.
From the impact test it was concluded that the value of impact for RAP was less compared to nominal aggregates and the value was within the MORTH limits and it was satisfactory.

5.3 Aggregate abrasion test
This test was conducted on RAP as well as Virgin Aggregates to find out the abrasive nature between Aggregates and steel balls.

From the abrasion test it was concluded that the value of the abrasion for Aggregates was less compared to RAP and the value was within the MORTH limits and it was satisfactory.
5.4 Aggregate attrition test
This test was conducted on RAP as well as for Virgin Aggregates to find out the resistance.

![Attrition testing Machine](image1)
![Analysis of Attrition test](image2)

From the attrition test it was concluded that the value of the attrition for aggregates was less compared to RAP and the values are within the MORTH limits and it was satisfactory.

5.5 Specific gravity and water absorption test
This test was conducted on Rap as well as for Virgin Aggregates to know about the quality of aggregates.

![Specific Gravity test using wire bucket](image3)
From the Specific gravity test it was concluded that the Specific gravity of RAP was more and water absorption of RAP was less compared to virgin aggregates and the results were satisfactory.

5.6 Results on samples of 100% rap and 100% virgin aggregate

Table 1: Results on samples of RAP and virgin aggregates

| Characteristics          | 100% RAP Aggregates | 100% Virgin Aggregates | MORTH Specifications | Remarks               |
|--------------------------|---------------------|------------------------|----------------------|-----------------------|
|                          | Sample 1 | Sample 2 | Sample 1 | Sample 2 |                      |                       |
| Aggregate Impact value   | 8.40     | 8.80     | 12.45    | 12.24    | 30%                   | Satisfactory          |
| Aggregate Crushing value | 6.23     | 7.20     | 12.62    | 11.26    | 30%                   | Satisfactory          |
| Los Angeles Abrasion value | 20.80   | 21.42    | 31.20    | 33.43    | 35%                   | Satisfactory          |
| Specific Gravity         | 1.43     | 1.48     | 1.50     | 1.54     | 2.6-3.0               | Satisfactory          |
| Water Absorption         | 0.2      | 0.24     | 0.32     | 0.36     | 2%                    | Satisfactory          |
| Deval Attrition Test     | 15.02    | 15.67    | 14.25    | 14.72    | 30%                   | Satisfactory          |

6. Tests on Bitumen

6.1 Penetration test
Penetration test of bitumen was conducted to determine the hardness and consistency.
6.2 Ductility test
Ductility test of bitumen was conducted to determine the elongation nature under traffic load without getting cracks.

6.3 Softening point test
Softening test of bitumen was conducted to determine the temperature of bitumen binder heated for various road applications which is determined by ball and ring apparatus.
6.4 Bitumen test results

Table 2: Test results of bitumen

| S NO | TYPE OF TEST    | OBTAINED RESULTS | MORTH LIMITS |
|------|----------------|------------------|--------------|
| 1    | Penetration test| 55               | 50-70        |
| 2    | Softening point | 40               | 47           |
| 3    | Ductility test  | 38               | 40           |

7. Marshall Stability Test

7.1 Bitumen content VS marshall stability for modified and unmodified rap material

The maximum load sustained by a bituminous material at a loading rate of 50.8mm/minute.

Fig 17 Graph of bitumen content VS marshall for modified and unmodified rap material
The minimum stability value should be 340kg. From the above graph it was observed that there is a gradual decrease in the stability value for RAP 100%, 0% with increase in the binder percentage and for the remaining percentages of RAP the results were satisfactory.

7.2 Bitumen content VS flow value for modified and unmodified rap material

From the above graph it was observed that the results of flow value for 0% RAP, 40% RAP and 100% RAP were not within the specified limits. The flow value limit is 8-17 mm.

After conducting Marshall Stability test the mechanical properties like stability value and flow value were determined. As the test was conducted only with the RAP material without adding any admixtures the test results were not satisfactory. The usage of 100% RAP is not preferable according to this study.

8. Conclusion
Based on the test results obtained from this study, the following conclusions are drawn.

- Aggregates collected from RAP known as waste aggregates are suitable for bituminous mixes.
- By using the untreated RAP material, the stability of the bituminous surface may go on decreasing due to weathering actions.
- Bituminous mix from the RAP materials with 0.5% additional bitumen content gives the maximum stability and satisfy the Marshall design criteria.
- Based on the results obtained from the laboratory tests conducted it was concluded that 100% RAP is not suitable for the construction of the flexible pavements. The preferable percentages of RAP are 30%, 50%.
- For 100% RAP (untreated), flow value which is very less than the limiting value and it is the reason of weak and unstable pavement.

References
[1] Abhishek Verma and Rachit Sharma et al 2017 Evaluation of RAP in flexible pavement layers.
[2] Anil Kumar Yadava and Dr. Syed Aqeel Ahmad 2019 A critical review of characterization and performance evaluation of RAP in road construction.

[3] Arshad Hussain and QiuYajun 2013 Effect of reclaimed asphalt pavement on the properties of asphalt binders.

[4] Brajesh Mishra 2015 Study on use of RAP materials in flexible pavements.

[5] Brian Hill 2011 Performance evaluation of warm-mix asphalt mixtures incorporating reclaimed asphalt pavement.

[6] Fawaz Kaseer and Edith Arambula et al 2019 A method to quantify rap binder availability in recycled asphalt mixes.

[7] Feipeng Xiao and Hsein Juang C et al 2007 Rutting resistance of rubberized asphalt concrete pavements containing RAP mixes.

[8] Haritha Musty Y and Nasim Sabahfer et al 2012 Use of high volume RAP for asphalt pavement rehabilitation due to increased highway truck traffic from freight transportation.

[9] Imad L.Al- Qadi and Mostafa Elseifi et al 2007 Reclaimed asphalt pavement - A literature review.

[10] Jashanjot Singh and Duggal A K et al 2015 An experimental study on RAP in bituminous concrete.

[11] Aravind K, Animesh Das 2006 Pavement design with central plant hot mix recycled asphalt mixes.

[12] Keerthi Gowda B S et al 2017 Recycling of Bituminous Pavements by RAP method.

[13] Krupa Sharma S and Ashok Patel 2018 Study On Reclaimed Asphalt Pavements.

[14] Martina Irene Giani, Giovanni Dotelli et al 2014 Comparative Life Cycle Assessment of Asphalt Pavements using Recycle Asphalt, Warm-mix Technology and Cold-place Recycling.

[15] Sreenivasulu Reddy Mand Suvarna P 2016 A Detailed Study on Reclaimed Asphalt Pavement in Pavement Quality Cement Concrete.

[16] Pavel Kriz and Daniel Grant et al 2014 Reclaimed asphalt pavement-virgin binder diffusion in asphalt mixes.

[17] Prithvi S Kandhal 1997 Recycling of asphalt pavements

[18] Salvatore Mangisfico, Francois Olard et al 2013 Influence of RAP content on complex modulus of asphalt binder blends and corresponding mixes.

[19] Sameer Shetty and Stephen Lane D et al 2015 Feasibility of RAP use as road base and sub base material.

[20] Sara Bressi and Massimo Losa et al 2019 A comparative environmental impact analysis of asphalt mixtures containing crumb rubber and rap using life cycle assessment.

[21] Siksha Swaroopa Kar and Aravind Krishna Swamy et al 2017 Impact of recycled asphalt pavements on properties of foamed bituminous mixtures.

[22] Anil Pradyumna T and Abhishek Mittal et al 2013 Characterization of RAP for use in bituminous road construction.

[23] UmeshKamariya and Amit A Amin et al 2018 Utilisation of reclaimed asphalt pavement materials.