To Study Experimental Analysis of Replacement of Aggregate with Recycled Concrete Aggregate in Bituminous Concrete

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Abstract: ***Nowadays, there is a noticeable decline in the availability of natural aggregate resources, both fine and coarse. Consequently, there is a growing emphasis on the recycling of aggregate, specifically through the repurposing of concrete as a replacement for aggregate in certain proportions. Recycling dismantled building concrete aggregate not only offers environmental benefits but also holds economic advantages. In my thesis, I present an experimental study focused on the practicality of utilizing recycled concrete aggregate (RCA) as a partial substitute for aggregate in bituminous macadam (BM). By employing the Marshall Mix design method, I assessed the engineering properties of BM mixtures incorporating various percentages of RCA. The test results indicated that the performance of BM mixtures is influenced by the presence of RCA, primarily due to its higher porosity and absorption characteristics compared to granite aggregates. However, the engineering properties of BM containing a specific amount of RCA displayed acceptable trends and were able to meet standard requirements. Nonetheless, it is crucial to exercise caution and carefully consider the properties of BM mixtures containing RCA in order to achieve desired performance characteristics.***

Keywords: Recycled concrete aggregate (RCA), Hot mix asphalt (HMA), Marshall stability, Air void

1. Introduction

The extensive use of natural aggregates in road construction and the simultaneous increase in solid waste generation have prompted researchers in the pavement industry to explore the feasibility of utilizing certain waste materials in pavement construction. Construction and demolition wastes, including Recycled Construction Aggregate (RCA), make up a significant portion of municipal solid waste. The incorporation of RCA in asphalt mixtures generally offers notable economic and environmental benefits. However, despite its promising potential, the limited availability of sufficient and conclusive data on the engineering properties of RCA has hindered the establishment of reliable design specifications. Addressing this knowledge gap, the purpose of this paper is to investigate the viability of using RCA in asphalt mixtures. As the suitability of aggregates for asphalt mixtures is determined by their characteristics, an experimental program has been devised to evaluate the physical and mechanical properties of RCA. This comprehensive laboratory investigation includes the measurement of various parameters, such as RCA compressive strength, particle shape, water absorption, flakiness index, crushing value, weak particles, wet/dry strength variation, and particle density. The research findings indicate that RCA exhibits a lower presence of flaky and misshapen particles compared to basalt, suggesting that asphalt mixtures incorporating RCA in certain proportions can possess improved workability, deformation resistance, and compaction. However, the test results also reveal higher water absorption and wet/dry strength variation for RCA when compared to natural materials, emphasizing the importance of an appropriate mix design. Aggregate materials constitute a significant proportion, accounting for up to 90-95% of the weight of asphalt mixtures, thereby playing a crucial role in the strength, stiffness, and overall performance of the asphalt surface layer. Considering the significance of aggregates in the properties of asphalt mixtures, including load-bearing capacity and strength characteristics, a thorough understanding of aggregate characteristics is essential for selecting suitable materials to optimize asphalt mixtures and subsequently enhance pavement performance by providing sufficient resistance to permanent deformation and cracking. Therefore, precise evaluation of aggregate properties becomes imperative. The use of natural aggregates (NA) in asphalt mixtures for pavement construction requires large quantities, leading to significant environmental impacts and depletion of natural resources. To mitigate these concerns, researchers have investigated the feasibility of using alternative materials derived from construction and demolition waste (CDW) as substitutes for NA. One such material is recycled concrete aggregates (RCA), which have shown potential for reducing environmental impacts. However, the characteristics of RCA vary widely due to the heterogeneity of the original concrete sources, making it challenging to establish consistent behavior patterns. Various studies have explored the environmental aspects, benefits, and limitations of using RCA as replacements for NA in asphalt mixtures, particularly in low-volume roads. RCA is primarily obtained from the demolition of concrete structures in civil construction projects. The composition of RCA includes approximately 65%-70% NA and 30%-35% cement. This makes RCA a valuable source of construction material. RCA exhibits high heterogeneity, as evidenced by high variation coefficients and standard deviations. Factors such as extraction sources, aggregate types, quantities, mortar, and coating contribute to this heterogeneity.

2. Materials and Method

- **Coarse aggregate**

Coarse aggregates refer to irregular and granular materials such as sand, gravel, or crushed stone, and are used for making concrete. In most cases, Coarse is naturally occurring and can be obtained by blasting quarries or crushing them by hand or crushers. It is imperative to wash them before using them for producing concrete. Their angularity and strength affect the concrete in numerous ways. Needless to say, the selection of these aggregates is a very important process. Materials that are large enough to be retained on the 4.7mm sieve size usually constitute coarse aggregates.

- **Fine aggregate**

In construction, aggregate refers to the particulate materials used in making concrete and fine aggregate refers to aggregate with particles so small that they may pass through a sieve with a mesh size of 4.75 millimetres. Fine aggregate, which may be granular material or crushed stone, is a fundamental component of concrete. The quality of the fine aggregate and the density of the fine aggregate both have a significant impact on the hardened qualities of the concrete.

- **Filler**

The mixture of bitumen and filler is called asphalt mastic. These asphalt mastics are responsible for providing the mixes of sufficient viscosity so that it facilitates coating, easy paving and compaction for more durable mixes. Fillers are thus the finer material (finer than 75μ, as per ASTM D242 minimum of 70% passes through No. 200 sieve) when with the bitumen acts as binder and together fill the voids present in the mixes to produce denser, water resistant (entrance to the water) and durable asphalt concrete.

- **Recycled concrete aggregate (RCA)**

The subject of concrete recycling is regarded as very important in the general attempt for sustainable development in our times. In a parallel manner, it is directly connected with (a) increase of demolition structures past out of performance time, (b) demand for new structures and (c) results of destruction by natural phenomena (earthquakes, etc.). We use RCA as aggregate in bituminous concrete in 0%, 5%, 10%, 15%, 20% in our practical.

- **Bitumen**

The term bitumen refers to a substance produced through the distillation of crude oil. Bitumen is known for its waterproofing and adhesive properties and is commonly used in the construction industry, notably for roads and highways. Production occurs through distillation, which removes lighter crude oil components like gasoline and diesel, leaving the heavier bitumen behind. Deposits can also occur naturally at the bottom of ancient lakes, where prehistoric organisms have decayed and been subjected to heat and pressure.

Table 1: Properties of aggregate

Test	Normal aggregate	Recycled concrete aggregate (RCA)
1) Impact Value Test	11.5	10.88
2) Los Angeles Abration Test	10.8	12.16
3) Specific Gravity	2.9	2.77
4) Water Absorption (%)	0.9	2

Table 2: Bitumen tests results

Test	Values
1) Ductility	65.33
2) Kinematic Viscosity	3965
3) Penetration	65cm
4) Specific Gravity	1.1

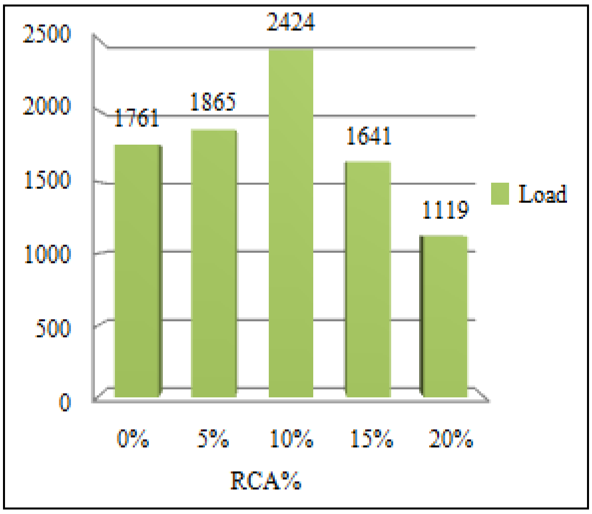
Marshall Test

- The Marshall test method is widely used for the design and control of asphaltic concrete and hot rolled asphalt materials, it cannot be applied to open textured materials such as bitumen macadam. Materials containing aggregate sizes larger than 20 mm, are liable to give erratic results. The full Marshall method is a method of bituminous mix design in addition to being a quality control test.
- The details given below related mainly to its use as a quality control test. The suitability of materials for the design of Marshall asphalt requires that a numbers of tests are performed on the materials.
- The basic Marshall test consists essentially of crushing a cylinder of bituminous material between two semi-circular test heads and recording the maximum load achieved (i.e. the stability) and the deflection at which the maximum load occurs (i.e. the flow). In common with many other tests, the bulk of the work is involved in preparing the samples for testing.

3. Results

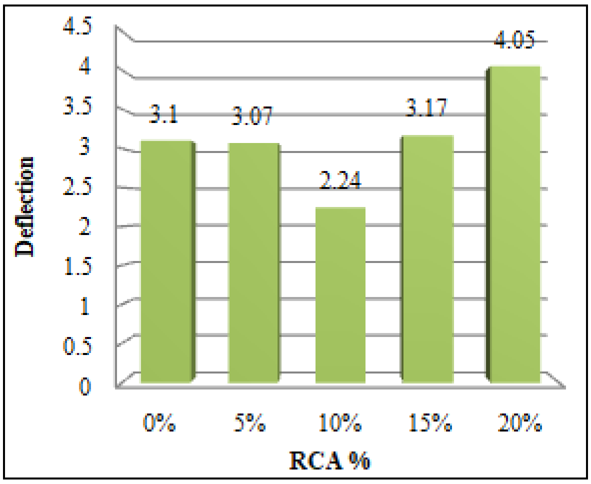
- **Marshall Stability**

Marshall stability of a test specimen is the maximum load required to produce failure when the specimen is preheated to a prescribed temperature placed in a special test head and the load is applied at a constant strain (5 cm per minute). While the stability test is in progress dial gauge is used to measure the vertical deformation of the specimen. The graph is potted between Load and RCA percent.



- **Marshall Flow**

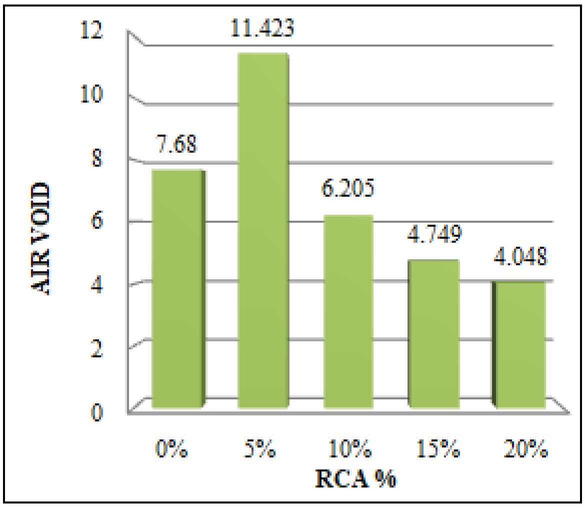
Marshall flow refers to the deformation or displacement of a bituminous mixture specimen during the Marshall stability test. It is the vertical movement or flow of the specimen at the point of failure when subjected to a specific load. During the Marshall stability test, a load is applied at a constant rate of strain (typically 5 cm per minute) to the specimen. As the load is increased, the specimen undergoes deformation or flow. The flow is measured using a dial gauge or other suitable measuring device. The flow value is typically expressed in units of 0.25 mm and represents the amount of vertical displacement or deformation of the specimen at failure.



- **Air voids**

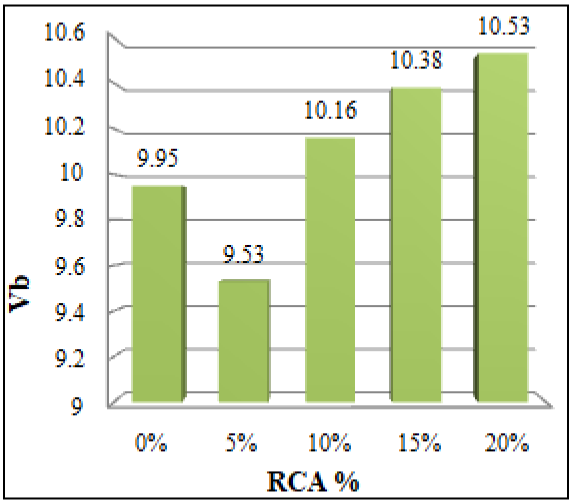
Air voids, also known as air void content or air voids percentage, refer to the volume of air voids or air pockets within a compacted asphalt mixture. In asphalt pavement construction, it is desirable to have a certain percentage of air voids in the mixture to provide flexibility, improve durability, and enhance resistance to moisture damage. The air voids in asphalt mixtures are created during the compaction process when the hot mixture is compacted by rollers. The compaction process causes the aggregates and asphalt binder to rearrange, resulting in the displacement of air and the formation of air voids.

Although a conclusion may review the main points of the paper, do not replicate the abstract as the conclusion. A conclusion might elaborate on the importance of the work or suggest applications and extensions. Authors are strongly encouraged not to call out multiple figures or tables in the conclusion these should be referenced in the body of the paper.



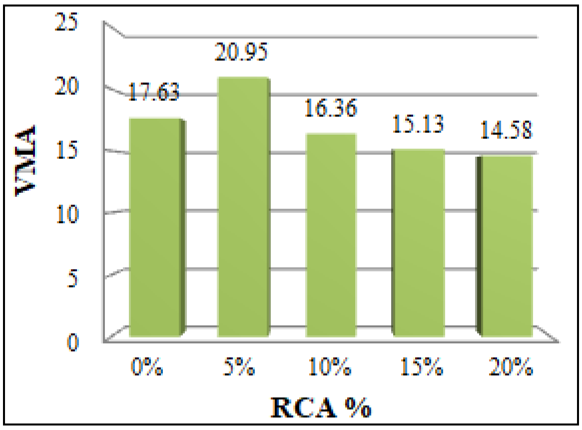
- **The Volume of Bitumen**

The volume of bitumen in a given mixture or sample can be determined by several methods, depending on the specific requirements and available resources. It's important to note that the volume of bitumen may vary depending on factors such as the temperature and compaction level during sample preparation. Additionally, the specific gravity of bitumen can also vary depending on the type and grade of bitumen being used. Therefore, it is recommended to follow standardized testing procedures and consult relevant specifications or guidelines specific to the project or application.



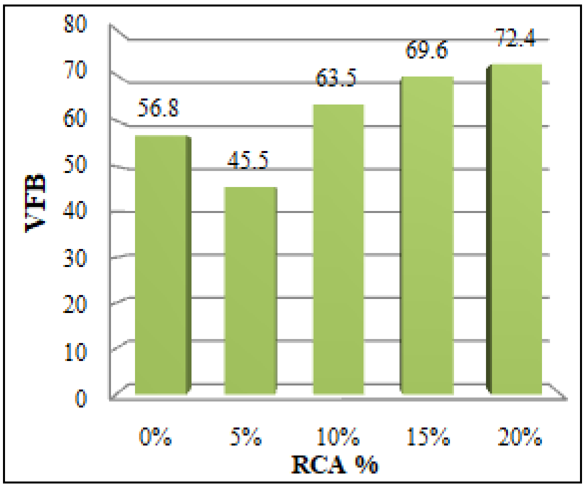
- **Voids in Mineral Aggregates**

The void in mineral aggregate (VMA) refers to the space or voids within the aggregate particles themselves. It represents the volume of air voids within the compacted aggregate mixture. VMA is an important parameter in asphalt mix design and construction, as it affects the durability, stability, and performance of the asphalt pavement. VMA is calculated by subtracting the volume of effective asphalt binder (Vbe) from the total volume of the compacted asphalt mixture (Vt). The effective asphalt binder volume is the volume of asphalt binder that effectively coats the aggregate particles and fills the voids between them.



- **Void Filled With Bitumen**

"Void filled by bitumen" refers to the volume within an asphalt mixture that is occupied by bitumen or asphalt binder. In an asphalt mixture, the aggregates are coated and bound together by the bitumen, filling the spaces or voids between the aggregates. The voids filled by bitumen play a crucial role in providing stability, durability, and flexibility to the asphalt pavement.



4. Conclusion

On the basis of above Marshall Mix test of the RCA is mixed in the bituminous concrete. We can use the RCA as replacement of fresh aggregate in some quantity. In my experiment I use fix quantity of the bitumen and vary the per cent mix of RCA. We use RCA in 0%, 5%, 10%, 15%, 20% and we get above results.

On using fresh aggregate mashall stability is 1761 k.N, marshall flow value is 3.1, and average bulk density is 2.33, air void is 7.68, volume of bitumen is 9.95, void in mineral aggregate is 17.63, void filled by bitumen is 56.8%. These are the average value which is obtain in our practical work.

On using 5% and 15% mashall stability is 1865 and1641 k.N respectively, marshall flow value is 3.07 and 3.17 respectively, and average bulk density is 2.182 and 2.39 respectively, air void is 11.42 and 4.74, volume of bitumen is 9.53 and 10.38 respectively, void in mineral aggregate is 20.95 and 15.13 respectively, void filled by bitumen is 45.5% and 69.6% respectively. On comparing to fresh concrete value of all the value are satisfactory.

On using 10% mashall stability is 2424 k.N, marshall flow value is 2.24, and average bulk density is 2.50, air void is 6.20, volume of bitumen is 10.38, void in mineral aggregate is 16.36, void filled by bitumen is 63.5% which is quite good result on comparing to the fresh concrete.

On conclusion we can use 10% RCA replacement which gives better result and having more marshall stability and low value of marshall flow this means it will work better. On 5% and 15% it is giving satisfactory.

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