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STUDY ON PROPERTIES OF RECYCLED CONCRETE AGGREGATE FOR PAVEMENT APPLICATIONS

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ABSTRACT

The rapid expansion of construction activities has significantly increased the demand for natural aggregates, leading to the depletion of natural resources and raising serious environmental concerns. In this context, the utilization of Recycled Concrete Aggregate (RCA), derived from construction and demolition waste, has emerged as a sustainable alternative for pavement construction, particularly in base course applications of flexible pavements. This Study aims to evaluate the engineering properties of RCA and assess its suitability as a partial or full replacement for conventional aggregates. A comprehensive experimental program is conducted, including tests such as specific gravity, water absorption, California Bearing Ratio (CBR), impact value, crushing value flakiness and elongation index, Deval's attrition value and Los Angeles abrasion.The obtained results are systematically compared with the requirements specified in standard pavement design guidelines to determine compliance and performance adequacy. In addition, the study examines the mechanical behaviour and performance characteristics of RCA under loading conditions relevant to pavement applications.

Furthermore, the environmental and economic implications of RCA utilization are analyzed, highlighting its potential in reducing construction and demolition waste, conserving natural aggregate resources, and lowering overall project costs associated with material procurement and transportation.

The study thus demonstrates that the adoption of RCA not only enhances sustainability in pavement engineering but also provides a viable and cost-effective alternative to conventional materials, supporting the transition toward environmentally responsible infrastructure development.

INTRODUCTION:

The rapid growth of infrastructure development and urbanization has significantly increased the demand for construction materials particularly natural aggregates. These aggregates are extensively used in pavement construction, especially in base and sub-base layers of flexible pavements. However, the excessive extraction of natural aggregates has led to the depletion of natural resources, environmental degradation, and increased material costs. Simultaneously, large volumes of construction and demolition waste are generated worldwide, posing serious disposal and environmental challenges. Recycled Concrete Aggregate (RCA), obtained form from construction and demolition waste, has emerged as a sustainable alternative to conventional natural aggregates. RCA typically consists of original aggregate particles coated with adhered mortar, which influences its physical and mechanical properties. Although RCA has been widely used in non-structural applications, its utilization in pavement base layers requires careful evaluation of its engineering properties. The base course layer plays a critical role in distributing traffic loads and providing structural support to the pavement system. Therefore, the materials used must possess adequate strength, durability, and resistance to deformation.

LITERATURE REVIEW:

Study by Merve Akbaş, Bilal Özaslan and Recep İyisan (2023)

This study published in Construction and Building Materials investigated the feasibility of using recycled concrete aggregates (RCA) in flexible pavement base and subbase layers. The RCA materials were obtained from construction and demolition waste produced during urban renewal projects in Istanbul. Laboratory tests were conducted to determine physical, mechanical, and stiffness properties of the RCA samples. The materials were prepared to meet the requirements of American Association of State Highway and Transportation Officials pavement design specifications. The influence of freeze–thaw cycles on stiffness characteristics was also studied using resilient modulus and permanent deformation tests. The results indicated that RCA can provide adequate strength and durability for pavement applications. The study concluded that RCA is a sustainable alternative to natural aggregates in road construction.

Study by Ahmed Hassan and Mohamed Khalid (2020)

This research evaluated the engineering properties of recycled concrete aggregate when used as a base course material in flexible pavements. Laboratory tests such as gradation analysis, compaction, and California Bearing Ratio (CBR) were performed to assess the suitability of RCA. The results showed that RCA exhibited satisfactory load-bearing capacity and compaction characteristics comparable to conventional aggregates. The study also highlighted that the use of RCA can significantly reduce construction costs and environmental impacts. The researchers concluded that RCA can be effectively used in pavement base layers with proper processing and quality control.

Study by Khaled AI-Bayati et al. (2018)

The researchers examined the mechanical performance of recycled concrete aggregates in pavement base layers. Various laboratory tests including resilient modulus, permeability, and shear strength tests were conducted. The findings revealed that RCA demonstrates good drainage characteristics and sufficient structural strength when used in road base layers. However, the presence of adhered mortar slightly increases water absorption compared to natural aggregates. The study recommended proper treatment and gradation control to improve the performance of RCA in pavement applications.

Study by Ali Arulrajah et al. (2013)

This research investigated the geotechnical properties of recycled concrete aggregates for pavement base and subbase applications. Laboratory tests such as compaction, CBR, and shear strength were performed. The results showed that RCA exhibits high shear strength and satisfactory bearing capacity. The study also indicated that RCA materials can meet road authority specifications when properly processed. The researchers concluded that RCA can be successfully used as a sustainable alternative material in pavement construction.

METHODOLOGY:

GENERAL APPROACH:

This study adopts an experimental laboratory-based approach to evaluate the engineering properties of recycled Concrete Aggregate (RCA) and assess its suitability for use in the base course layer of flexible pavements. The methodology involves systematic material collection, processing, laboratory testing and comparison of obtained results with standard specifications prescribed by the Ministry of Road Transport and Highways.

MATERIAL COLLECTION AND PREPARATION:

Recycled Concrete Aggregate (RCA) was collected from demolished concrete structures. The collected material was processed in the laboratory to obtain aggregates suitable for testing. Recycled Concrete Aggregate (RCA) mainly contains original natural aggregate particles such as crushed stone or gravel that were previously used in concrete, along with hardened cement mortar that remains attached to their surfaces after crushing. The adhered mortar makes RCA more porous and slightly lighter than natural aggregates, resulting in higher water absorption. The adhered mortar is removed by soaking in sulphuric acid.The prepared RCA samples were stored under controlled conditions to maintain uniformity during testing.

LABORATORY TESTING:

The experimental investigation focused on determining the physical and mechanical properties of RCA using standard testing procedures as per Indian Standards.

DATA EVALUATION:

The results obtained from laboratory testing were analyzed and compared with the permissible limits specified by the Ministry of Road Transport and Highways for base course materials in flexible pavements.The evaluation focused on strength characteristics, durability, shape properties and physical properties.

TESTS CONDUCTED:

1. Aggregate crushing value test.
2. Aggregate impact test.
3. Flakiness index test.
4. Elongation test.
5. Deval’s Attrition test.
6. Los Angeles Abrasion test.
7. Specific gravity & water absorption test.
8. Soaked California Bearing ratio (CBR) test.

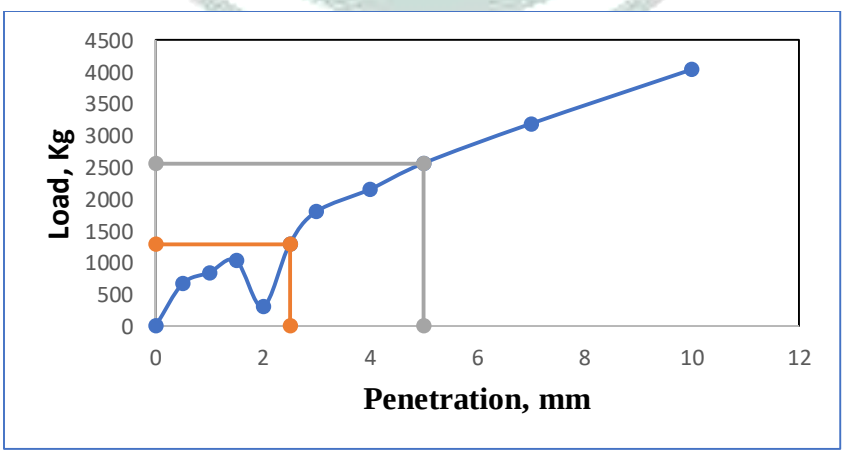
TEST RESULTS:

Aggregate crushing value: 25.62%
Aggregate impact value: 17.89%
Flakiness index: 5.3%
Elongation index: 42.33%
Deval's Attrition value: 2%
Los Angeles Abrasion value: 18%
Water absorption: 2.02%
Specific gravity: 3.0
Soaked CBR at 5.0% with 30% RCA: 126.76%

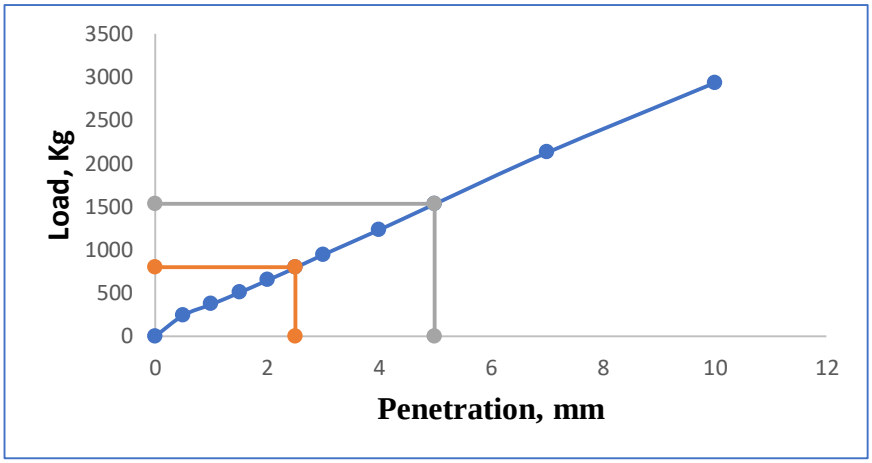
PERMISSIBLE LIMITS SPECIFIED BY MORTH:

The values should not exceed than the follows,
Aggregate crushing value: 40%
Aggregate impact value: 35%
Flakiness index: 25%
Elongation index: 25-30%
Los Angeles Abrasion value: 35%
Water absorption: 2%
Specific gravity: 3.0

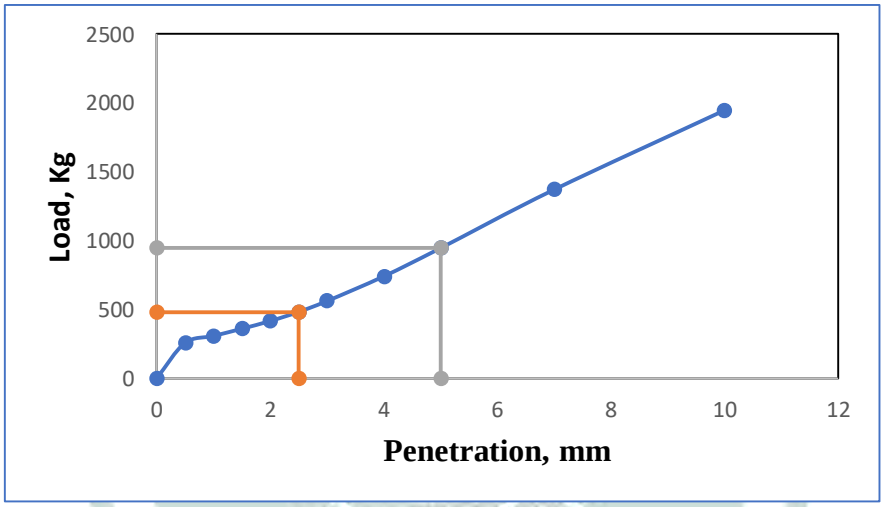
GRAPHICAL REPRESENTATION OF SOAKED CBR TEST RESULTS:



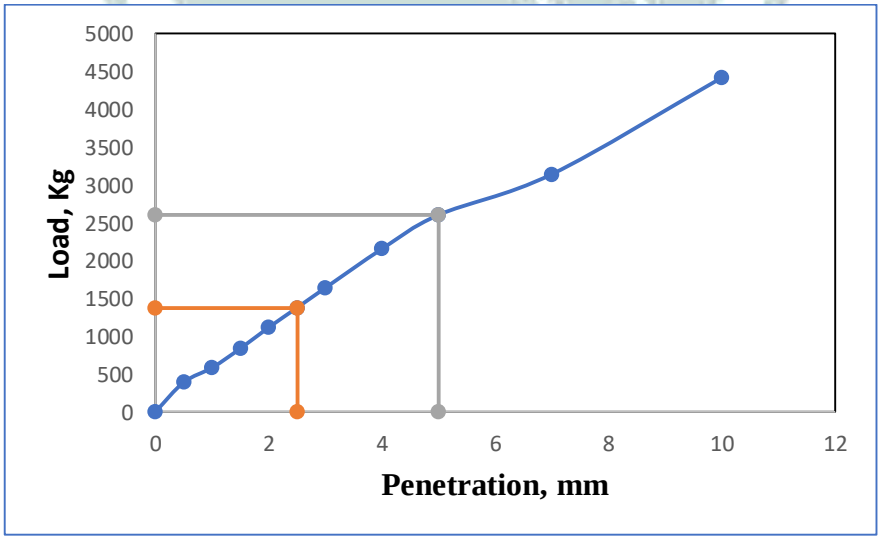
Penetration vs Load for 0% RCA Sample



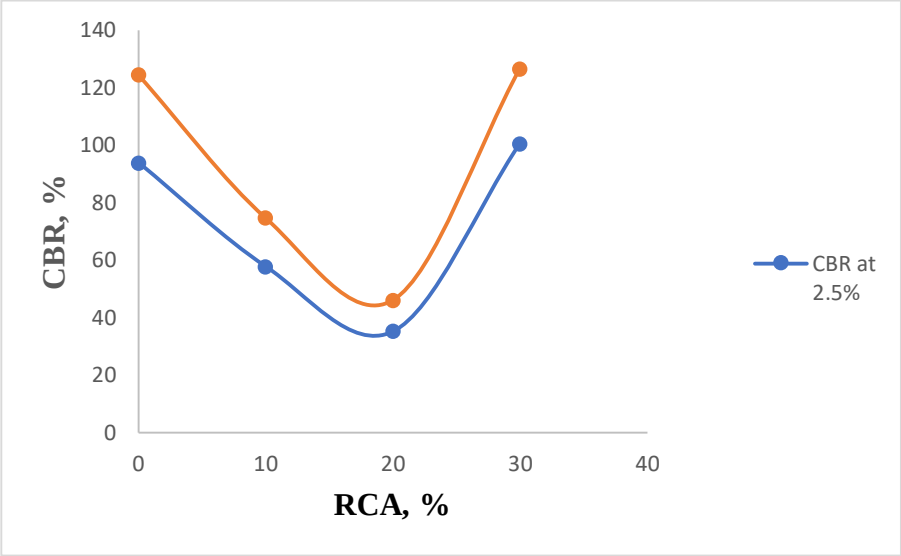
Penetration vs Load for 10%RCA Sample



Penetration vs Load for 20%RCA Sample



Penetration vs Load for 30%RCA Sample



RCA vs CBR

Load vs Penetration Behaviour:

The Load vs Penetration curves for different RCA percentages show a gradual increase in load with increase in penetration for all mixes. The control mix (0% RCA) exhibited a steady and high load-bearing capacity throughout the test.

With the addition of RCA (10% and 20%), a noticeable reduction in load values was observed at corresponding penetrations. This reduction can be attributed to the presence of adhered mortar in RCA, which leads to higher porosity and lower strength compared to natural aggregates.

However, at 30% RCA replacement, the load values increased significantly and were found to be comparable to or even higher than the control mix. This indicates improved interlocking and compaction characteristics at this proportion.

Effect of RCA Content on Strength:

The variation of CBR with RCA percentage shows a non-linear trend,

- Initial addition of RCA weakens the aggregate matrix due to the presence of old mortar and increased water absorption.
- At higher replacement (30%), better particle packing, interlocking, and compaction may have contributed to improved strength.

COMPARISON:

The Aggregate Crushing Value obtained for RCA is 25.62%, which is well below the permissible limit of 40% as per MORTH specifications. This indicates that the RCA possesses adequate resistance to crushing under compressive loads.

The Aggregate Impact Value of RCA is 17.89%, which is significantly lower than the permissible limit of 35%. This shows that the aggregate has good resistance to sudden impact loads.

The flakiness index of RCA is 5.3%, which is well within the permissible limit of 25%, indicating good particle shape and favourable interlocking characteristics.

The elongation index is found to be 42.33%, which exceeds the recommended limit of 25–30%. Higher elongation indicates the presence of elongated particles that may affect compaction and stability. This suggests that RCA may require proper screening or blending with natural aggregates to improve shape characteristics.

The Deval's attrition value of RCA is 2%, which is very low, indicating excellent resistance to wear and abrasion. This suggests that the material is durable and capable of withstanding traffic-induced stresses

The apparent specific gravity of RCA is 3.0, and the bulk specific gravity is 2.82, both of which are relatively high and indicate good density and strength characteristics. Higher specific gravity values generally correspond to stronger and more durable aggregates.

The water absorption value of RCA is 2.02%, which is slightly above the typical permissible limit of 2%. This higher value is due to the presence of adhered mortar on RCA, which increases porosity. Although marginally higher, it can be managed through proper mix design and moisture control during construction.

CONCLUSION:

This study evaluates the properties and suitability of Recycled Concrete Aggregate (RCA) as a sustainable alternative to natural aggregates in pavement construction. RCA, obtained from demolished concrete structures, is processed and reused to reduce construction and demolition waste, conserve natural resources, and minimize environmental impacts associated with quarrying and transportation. Laboratory tests including aggregate impact value, crushing value, specific gravity, water absorption, flakiness index, elongation index, and soaked California Bearing Ratio (CBR) were conducted to assess its physical and mechanical properties. The results indicate that RCA possesses adequate strength and durability required for pavement applications, although slightly higher water absorption is observed due to the presence of adhered mortar. Despite this, its overall performance remains within acceptable standards. The study highlights that proper processing, grading, and proportioning of RCA can ensure satisfactory strength, stability, and durability in pavement layers. Additionally, the use of RCA offers economic benefits by reducing material costs and supports sustainable infrastructure development through efficient resource utilization and waste recycling. Therefore, RCA can be effectively used in pavement construction as an environmentally friendly and economically viable material.

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