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PREPARATION OF BITUMINOUS CONCRETE MIXES BY USING CONSTRUCTION AND DEMOLISHED CONCRETE

[1] V.SANDEEP, [2] P.KEERTHI, [3] NAZMINA YASMIN, [4] M.NIKITHA, [5] P.ARPITHA, [6] V.ANKITHA

[1] Assistant Professor, Department Of Civil Engineering, Princeton Institute of Engineering & Technology for Women, Hyderabad, India

[2,3,4,5,6] B.Tech Students , Department of Civil Engineering , Princeton Institute of Engineering & Technology for Women, Hyderabad, India

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Abstract:

The construction industry is one of the largest consumers of natural resources, especially natural aggregates, for the production of concrete and bituminous mixes. At the same time, it is also one of the largest producers of waste, generating millions of tons of construction and demolition (C&D) debris each year. Traditionally, these wastes have been disposed of in landfills or used in low-grade applications, thereby exerting additional pressure on natural aggregate sources and contributing to environmental degradation. To address these challenges, the recycling of construction and demolished concrete into aggregates for use in pavement construction offers an effective and sustainable solution. This research focuses on the preparation of bituminous concrete mixes using aggregates derived from demolished concrete. The study involves partial and complete replacement of natural aggregates with recycled concrete aggregates (RCA) obtained from C&D waste. Laboratory investigations such as Marshall Stability, flow value, bulk density, air voids, voids in mineral aggregates (VMA), and voids filled with bitumen (VFB) are carried out to evaluate the performance of these mixes. The results are compared with conventional mixes to determine the suitability of RCA in flexible pavements. The findings demonstrate that recycled aggregates, despite having slightly higher porosity and absorption than natural aggregates, can be successfully incorporated into bituminous mixes. Their angular texture improves aggregate–binder bonding and interlocking, while adjustments in bitumen content

compensate for higher absorption. The use of recycled aggregates not only ensures sustainable utilization of C&D waste but also conserves natural resources, reduces construction costs, minimizes environmental impact, and aligns with the principles of circular economy and green highway initiatives.

I.INTRODUCTION

Bituminous concrete is one of the most widely used surfacing materials in flexible pavement construction due to its ability to withstand heavy traffic loads, resist weathering, and provide durable and smooth riding surfaces. Conventionally, high-quality natural aggregates are used in bituminous concrete along with bitumen as a binder. However, rapid urbanization, infrastructure expansion, and industrial growth have led to the overexploitation of natural aggregate resources, creating shortages, escalating costs, and causing serious environmental degradation through quarrying and mining activities.

Parallel to this, the problem of construction and demolition (C&D) waste generation is becoming increasingly severe. With the replacement of old buildings, bridges, and infrastructure, large volumes of C&D debris—comprising mostly concrete rubble, bricks, and mortar—are generated annually. According to estimates, C&D waste constitutes around 30–40% of total solid waste in urban areas worldwide, with concrete accounting for nearly 50–60% of it. In India alone, more than 150 million tons of C&D waste is generated each year, of which only a fraction is recycled. Much of it is dumped into landfills or open areas, leading to environmental pollution, loss of land, and public health hazards.

The recycling of demolished concrete into aggregates offers a practical solution to these twin challenges of aggregate scarcity and waste management. Recycled concrete aggregates (RCA) are produced by crushing, screening, and processing C&D debris. They generally have rougher textures, more angular shapes, and slightly higher water absorption compared to natural aggregates. These characteristics can be both advantageous and challenging: while roughness and angularity enhance interlocking and binder adhesion, higher absorption requires careful mix design adjustments to maintain workability and durability.

Using RCA in bituminous concrete mixes addresses multiple objectives. It conserves finite natural resources, reduces the energy consumption and emissions associated with quarrying, lowers construction costs by utilizing locally available waste, and prevents the indiscriminate disposal of C&D debris. Furthermore, it aligns with national and global sustainability policies such as the Indian Roads Congress (IRC) guidelines, the Ministry of Road Transport and Highways (MoRTH) specifications, and the United Nations' Sustainable Development Goals (SDGs). Thus, integrating C&D waste into pavement construction is not just an engineering necessity but also an environmental and social responsibility.

II.RELATED WORKS

Extensive research has been carried out worldwide to assess the feasibility of using recycled aggregates from C&D waste in pavement construction.

- Poon et al. (2002) investigated the mechanical properties of asphalt mixes containing recycled aggregates and reported that recycled concrete aggregates performed comparably to natural aggregates when used up to moderate replacement levels. They noted that binder absorption increased slightly, requiring adjustments in mix design.
- Topçu and Sarıdemir (2008) studied the use of recycled concrete aggregates in hot mix asphalt and found that stability, flow, and volumetric properties remained within standard limits for partial replacements of 30–40%. They concluded that the environmental benefits outweighed the minor adjustments needed.
- Huang et al. (2005) carried out laboratory investigations on RCA-based asphalt mixtures and observed that while the mixes exhibited good rutting resistance, moisture susceptibility was slightly higher, which could be addressed with anti-stripping additives.
- Tabsh and Abdelfatah (2009) explored the use of RCA in flexible pavements and concluded that angularity of RCA enhanced load distribution and skid resistance, making it particularly beneficial for surface courses.
- Jain and Jain (2011) emphasized the importance of using C&D waste in Indian road projects. Their findings highlighted cost savings, reduced landfill dependency, and alignment with green building and highway policies.
- Silva et al. (2019) conducted durability studies on RCA-modified asphalt mixes and confirmed that with proper processing and grading, recycled aggregates could achieve mechanical and volumetric properties equivalent to conventional mixes.
- Arulrajah et al. (2021) carried out long-term field performance studies of pavements with recycled aggregates. Their results showed satisfactory durability and service life, proving

that RCA-based pavements can withstand actual traffic and weather conditions.

- Fonseca et al. (2011) analyzed the performance of recycled aggregate asphalt in Europe and concluded that RCA incorporation reduced overall construction costs and improved sustainability indices without significant compromise on quality.
- Behera et al. (2014) stressed that RCA use contributes significantly to sustainable development, reducing carbon footprints, energy consumption, and environmental impacts associated with aggregate quarrying.
- Government agencies and policy-makers have also encouraged the use of recycled aggregates. The Indian Roads Congress (IRC, 2020) and the Ministry of Road Transport and Highways (MoRTH, 2013) recommend the use of recycled materials in bituminous and non-bituminous layers. Internationally, organizations such as the Federal Highway Administration (FHWA, USA) and the European Asphalt Pavement Association (EAPA) have promoted recycled materials in pavements to support circular economy principles.

From these studies, it is evident that the use of construction and demolished concrete aggregates in bituminous mixes is not only technically feasible but also beneficial from economic, environmental, and social perspectives. While slight modifications in binder content and quality control measures are essential, the overall performance and sustainability advantages strongly justify their adoption in modern road construction.

III. MATERIAL USED

The preparation of bituminous concrete using recycled aggregates derived from construction and demolition (C&D) waste requires a careful selection of raw materials to ensure the resulting mixture achieves the required strength, durability, and performance standards. The following materials are primarily used:

1. **Recycled Concrete Aggregates (RCA):**
    - Obtained from the crushing of construction and demolition waste such as broken beams, columns, slabs, and old pavement structures.
    - RCA typically exhibits higher porosity, water absorption, and surface roughness compared to natural aggregates. These properties can enhance the bond between bitumen and aggregates but also require careful pretreatment.
    - Sizes are reduced through mechanical crushing and sieving into required gradations of coarse and fine aggregates.

2. **Natural Aggregates (NA):**
    - Fresh aggregates, usually sourced from quarries, are incorporated alongside RCA to balance the mechanical properties.
    - NA provides strength, stability, and resistance to wear. In this study, NA is used mainly for fine aggregate fractions and partially for coarse aggregates.
3. **Pretreated Recycled Concrete Aggregates (PRCA):**
    - Since untreated RCA may contain adhered mortar and dust particles that affect performance, pretreatment is essential.
    - Pretreatment methods include acid washing, mechanical abrasion, and bitumen coating to improve durability, reduce absorption, and enhance the mechanical performance of RCA.
4. **Bitumen (VG-30 Grade):**
    - Viscosity grade (VG-30) bitumen is selected as the binding material because it provides excellent performance under medium to heavy traffic conditions.
    - It ensures good adhesion with aggregates, flexibility under temperature variations, and resistance to rutting and cracking.
5. **Filler Materials:**
    - Fillers such as **cement, lime, and stone dust** are used to fill voids and increase the density of the mix.
    - They improve the stiffness of the binder-aggregate matrix and enhance the resistance against moisture susceptibility and stripping.
6. **Additives (Optional):**
    - Certain chemical admixtures or anti-stripping agents may be used to further improve the moisture resistance of the mix.
    - Polymers or fibers may also be added in advanced studies to improve fatigue life and deformation resistance.

IV. BITUMINOUS CONCRETE MIXES

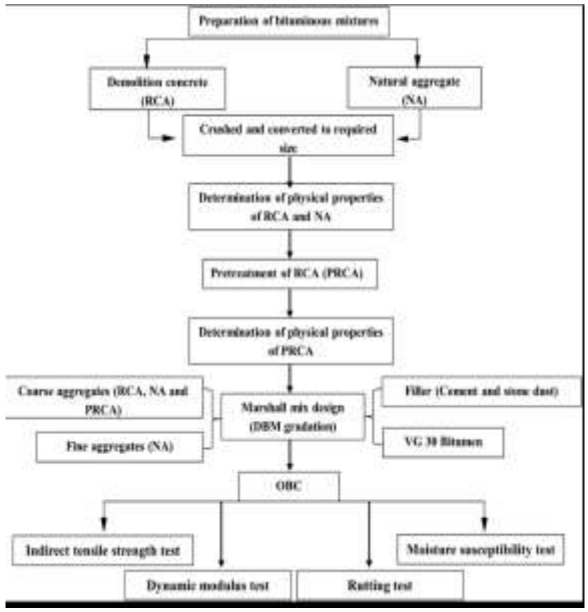

Fig 4.1 Bituminous Concrete Mixes

The preparation of bituminous concrete mixtures using both natural aggregates (NA) and recycled concrete aggregates (RCA) involves a systematic process to ensure the quality, durability, and performance of the final mix. The process begins with the collection of demolition concrete, which is crushed and converted into the required aggregate size, similar to the natural aggregate used. Both RCA and NA are then subjected to a detailed determination of their physical properties, such as specific gravity, water absorption, impact value, and abrasion value, in order to assess their suitability for bituminous concrete production.

Since recycled aggregates generally exhibit higher porosity and absorption, they are pretreated to improve their properties, resulting in pretreated recycled concrete aggregates (PRCA). This pretreatment step may include washing, coating, or mechanical refinement to reduce dust, enhance surface texture, and minimize water absorption. Following pretreatment, the physical properties of PRCA are again determined to confirm improvements and ensure consistency with required specifications.

Once the aggregates are ready, they are categorized into coarse and fine aggregates. A combination of natural aggregates, RCA, and PRCA is used as coarse aggregates, while natural aggregates are generally employed as fine aggregates. Along with aggregates, fillers such as cement and stone dust are incorporated, and VG-30 grade bitumen is selected as the binding material. These ingredients are then proportioned through the Marshall mix design method based on Dense Bituminous Macadam (DBM) gradation to determine the Optimum Binder Content (OBC).

The designed bituminous mixtures are then subjected to a series of laboratory tests to evaluate their performance characteristics. These include the Indirect Tensile Strength (ITS) test, which measures the tensile strength and cracking resistance of the mix; the Dynamic Modulus test, which evaluates stiffness and viscoelastic behavior under different loading and temperature conditions; the Moisture Susceptibility test, which assesses the durability of the mix under moisture-induced damage; and the Rutting test, which determines the resistance of the mix against permanent deformation under repeated loading.

This step-by-step methodology ensures that the prepared bituminous mixes containing recycled concrete aggregates are thoroughly evaluated for structural strength, durability, and sustainability before being considered suitable for flexible pavement construction.

V. METHODOLOGY

The methodology for preparing bituminous concrete mixes with recycled aggregates follows a systematic experimental process. The major steps are described below:

1. Collection and Processing of Materials

- Construction and demolition wastes are collected from demolished structures, construction sites, and old pavements.
- The waste concrete is crushed into smaller pieces using crushers and sieved into required sizes (coarse and fine fractions).
- Dust and unwanted impurities are removed to ensure consistency. Natural aggregates are also sourced from quarries for blending with RCA.

2. Determination of Physical Properties

- Tests such as **specific gravity, aggregate impact value, Los Angeles abrasion value, water absorption, and crushing value** are conducted for both RCA and NA.
- These tests determine the suitability of RCA for use in pavement mixes and provide baseline data for designing the mix.

3. Pretreatment of RCA

- RCA is pretreated to enhance its quality and minimize weaknesses such as high porosity and dust coating.
- Pretreatment may include mechanical abrasion to remove adhered mortar, soaking and drying to stabilize absorption, or coating with bitumen or lime slurry to improve bonding characteristics.
- After pretreatment, the physical properties of PRCA are re-tested to confirm improvements.

4. Mix Design – Marshall Method

- The **Marshall Mix Design Method** is employed using Dense Bituminous Macadam (DBM) gradation.
- Different proportions of RCA, PRCA, and NA are blended as coarse and fine aggregates.
- VG-30 grade bitumen and filler materials are incorporated.
- The optimum binder content (OBC) is determined based on stability, flow value, voids in mineral aggregates (VMA), and air voids.

5. Preparation of Bituminous Concrete Mixes

- The aggregates and filler are heated to the required temperature.
- Bitumen is heated separately to achieve proper viscosity.
- Aggregates and bitumen are thoroughly mixed in the specified proportions.
- Samples are compacted using the Marshall hammer to form test specimens.

6. Laboratory Testing of Mixes

The prepared mixes are evaluated for mechanical and durability properties:

- **Marshall Stability and Flow Test:** Determines load-bearing capacity and deformation resistance.
- **Indirect Tensile Strength (ITS) Test:** Evaluates tensile strength and cracking resistance.

- **Moisture Susceptibility Test (Tensile Strength Ratio):** Assesses durability under wet conditions and resistance against stripping.
- **Dynamic Modulus Test:** Measures stiffness and viscoelastic behavior under repeated loading.
- **Rutting Test:** Evaluates the permanent deformation of the mix under simulated wheel loads.

7. Performance Evaluation and Optimization

- Results are analyzed to compare the performance of RCA, PRCA, and NA mixes.
- The optimum blend ratio of RCA and NA is identified, ensuring a balance between strength, durability, and sustainability.
- Conclusions are drawn regarding the feasibility of using C&D waste in bituminous concrete mixes for pavement construction.

VI.CONCLUSION

The study on the preparation of bituminous concrete mixes using construction and demolition (C&D) waste aggregates highlights the significant potential of recycled materials in sustainable pavement construction. Recycled Concrete Aggregates (RCA) and Pretreated RCA (PRCA) can effectively replace a substantial portion of natural aggregates without compromising the mechanical strength and durability of the mix. The Marshall mix design results confirm that the stability, flow, and volumetric properties of mixes with PRCA fall within acceptable limits for highway applications. Additionally, pretreatment of RCA enhances its performance by reducing water absorption and improving bonding with bitumen, thereby ensuring better resistance against stripping and moisture susceptibility. Performance-based tests such as rutting and indirect tensile strength reveal that PRCA mixes offer competitive results when compared with conventional natural aggregate mixes.

The use of C&D waste in bituminous mixes not only contributes to reducing environmental impacts by minimizing landfill disposal but also conserves natural resources, lowers construction costs, and promotes circular economy practices in infrastructure development. Therefore, incorporating recycled aggregates into bituminous concrete is both an environmentally responsible and technically feasible solution for modern pavement engineering. Future research may focus on large-scale field trials, long-term performance monitoring, and the integration of supplementary additives like polymers, nano-materials, or fibers to further enhance mix performance.

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