RESILIENT MODULUS OF GEOSYNTHETIC REINFORCED RECYCLED AGGREGATES

Project Reference No.: *47S_BE_4298*

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Keywords:

Resilient Modulus, Recycled aggregates, Conventional aggregates, Geogrid, Geo textile

Introduction:

Highways is the integral part of infrastructure development, playing a crucial role in facilitating socio-economic progress by enhancing connectivity and accessibility. However, traditional highway construction methods heavily depend on natural resources, raising significant concerns about resource depletion and environmental sustainability. This has prompted researchers to explore alternative materials and methodologies to enhance sustainability in infrastructure projects.

Among these alternatives, recycled aggregates have garnered considerable attention as a viable solution for highway construction. These materials not only alleviate the depletion of natural resources but also address critical waste management issues. Numerous studies by esteemed researchers, including Cardoso et al. (2016), Thacker et al. (2019), Mantlana and Maoela (2020), and Ullah et al. (2022), have highlighted the potential of recycled aggregates to significantly enhance the sustainability of highway projects.

To further address the challenges of durability and load-bearing capacity, the integration of geosynthetic materials such as geotextiles, geogrids, and geocells has been proposed. These materials serve as stabilizing agents, improving the mechanical properties of pavement layers and enhancing their performance under various loading conditions. By incorporating geosynthetics into the pavement structure, infrastructure can endure higher loads with reduced deformation, thus increasing its durability and extending its service life.

The current study focuses on the resilient modulus of geosynthetic-reinforced recycled aggregates, particularly their application in highway construction. The primary objective is to examine how the inclusion of geosynthetics in pavement layers enhances the resilient modulus of recycled aggregates, thereby improving the overall performance of highway pavements. This research aims to provide valuable insights into the design and implementation of sustainable and resilient highway infrastructure by exploring the synergistic effects of geosynthetics and recycled aggregates.

In conclusion, the integration of geosynthetic reinforcement within subgrade layers offers a promising approach to enhance the resilient modulus of pavement materials, ensuring the long-term performance and sustainability of highway infrastructure. This innovative approach not only supports environmental sustainability but also contributes to the development of robust and enduring infrastructure systems.

Objectives:

- ***Determination of Resilient Modulus for Conventional and Recycled Aggregates:*** Assess and compare the resilient modulus values of conventional aggregates and recycled aggregates to understand their performance characteristics in highway construction.
- ***Investigation of Suitability of Geo-synthetic Reinforcement:*** Explore the effectiveness of geosynthetic materials in enhancing the resilient modulus of both conventional and recycled aggregates, aiming to improve the overall stability and durability of pavement structures.
- ***Determination of the Damage Ratio Using KENPAVE:*** Utilize the KENPAVE software to calculate and compare the damage ratios for pavements constructed with conventional and recycled aggregates, both with and without geosynthetic reinforcement, to evaluate their long-term performance and sustainability.

Methodology:

Materials

- ***Aggregates:***
- **Conventional Aggregates**: Natural aggregates typically used in highway construction.
- **Recycled Aggregate**s: Aggregates sourced from construction and demolition waste.

- **Geo synthetic Materials**: Geo textiles and Geo grids: Selected for their reinforcement capabilities in pavement structures.

Methods

- ***Material Preparation:***
- **Sieve Analysis:** Materials were sieved using different sieves to achieve the desired gradation as per the Ministry of Surface Transport standards. This ensured the materials conformed to specified gradation requirements.
- **Proportioning:** The aggregates were proportioned so that the maximum aggregate size was 1/5 of the specimen diameter (20 mm for 100 mm diameter specimens).

- ***Specimen Preparation:***
- **Triaxial Specimens:** Prepared with a diameter of 100 mm and a height of 200 mm for resilient modulus testing.

- **Geosynthetic Reinforced Specimens:** Reinforced specimens were prepared with single, double, and triple layers of geosynthetics embedded within the triaxial specimens as shown below fig.

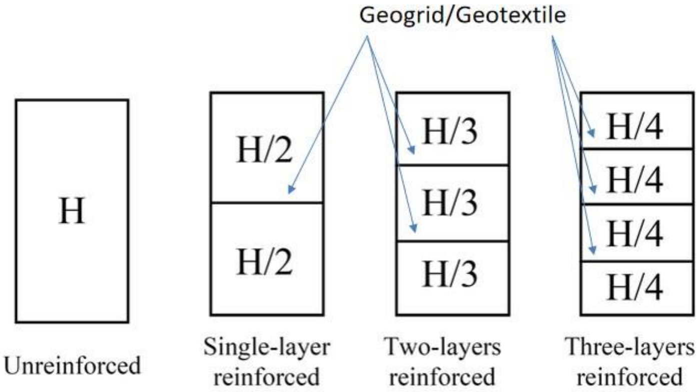

Fig 1: Arrangement of Geo-grid/Geo textile within in Triaxial Specimen

- ***Resilient Modulus Testing:***
- **Testing Protocol:** The prepared specimens were subjected to repeated loading as per the guidelines outlined in AASHTO T 307-99. The loading involved applying axial stress, cyclic stress, and residual stress according to the specified codal guidelines.
- **Data Collection:** Resilient modulus values were measured for both reinforced and unreinforced specimens.

- ***Data Analysis:***
- **Comparison of Results:** The resilient modulus values of reinforced specimens were compared to those of unreinforced specimens to evaluate the effectiveness of geosynthetic reinforcement.
- **KENPAVE Analysis:** The obtained resilient modulus values were input into the KENPAVE software to determine the effect on pavement performance, specifically focusing on rutting and fatigue life.
- **Damage Ratio Calculation:** KENPAVE was used to simulate the damage ratios for both conventional and recycled aggregate pavements with and without geosynthetic reinforcement.

Details of Work Carried Out:

- ***Specimen Preparation:***
- *Aggregates were processed and proportioned to conform to the specified gradation.*
- *Specimens were meticulously prepared in the laboratory, ensuring consistent dimensions and layer placements for geosynthetic reinforcement.*

- ***Reinforcement Layering:***
- Single, double, and triple layers of geotextiles and geogrids were strategically embedded within the triaxial specimens during preparation.
- Precise placement of reinforcement layers at designated heights was maintained to ensure uniformity across specimens.

○ ***Testing and Analysis:***

- Resilient modulus tests were conducted on both reinforced and unreinforced specimens under controlled conditions at IISc soil mechanics laboratory.
- The results were systematically recorded and analyzed.
- The KENPAVE software was used to model the pavement performance, and the outcomes were interpreted to assess the improvements in rutting resistance and fatigue life due to geosynthetic reinforcement.

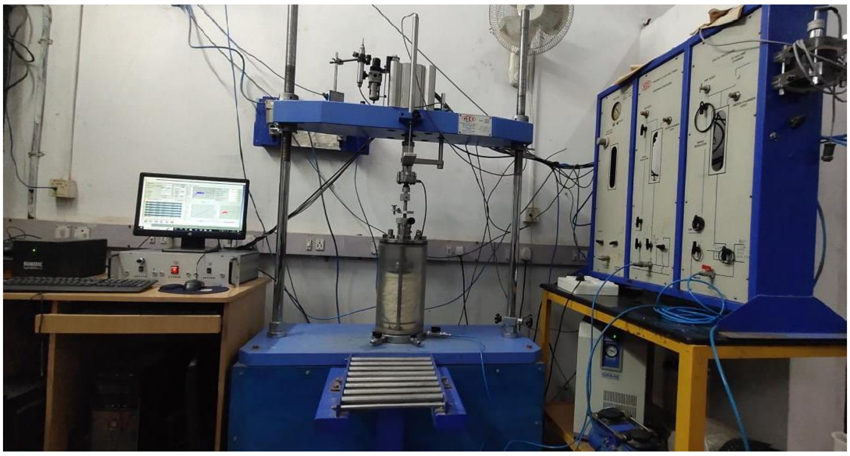

Fig 2: Tri-axial Lab Setup at IISc, Bengaluru

Conclusion:

The study investigated the use of recycled aggregates (RA) reinforced with geosynthetic materials in comparison to conventional aggregates (CA) for flexible pavement construction. Key findings include:

○ ***Resilient Modulus (MR):***

- **Recycled Aggregates (RA):** The MR of RA specimens significantly improved when reinforced with geosynthetics. The highest MR values were observed with double-layer geogrid reinforcement (GR2), indicating superior stiffness and load-bearing capacity.
- **Conventional Aggregates (CA):** CA specimens generally exhibited higher MR values than RA across all reinforcement configurations, demonstrating their inherent superior stiffness and durability.

○ ***Strain Analysis:***

- Both RA and CA showed reductions in tensile and compressive strains with reinforcement. The RA specimens with GR2 reinforcement exhibited the lowest tensile strain, indicating improved deformation resistance.
- The overall strain characteristics of CA were better than those of RA, but the performance gap narrowed with effective reinforcement in RA.

○ ***Damage Ratios****:* CA showed better resistance to fatigue and rutting compared to RA. However, RA with appropriate reinforcement showed substantial improvement, making it a viable alternative.

- ***Environmental and Economic Benefits:***

- The use of RA contributes to sustainability by reducing the need for natural aggregates and managing waste effectively.
- Reinforced RA can provide cost savings in the long term by extending pavement life and reducing maintenance needs.

The study concludes that:

1. ***Geo-synthetic Reinforcement:*** Incorporating geosynthetics, especially geogrids, significantly enhances the mechanical properties of both RA and CA For ratio of 1.5 to 3.0.
2. ***Viability of Recycled Aggregates:*** While CA outperforms RA in raw form, reinforced RA demonstrates substantial improvements, closing the performance gap. This suggests that RA can be a sustainable and cost-effective alternative in pavement construction when adequately reinforced.
3. ***Damage ratio:*** with inclusive of geogrid considerable reduction in Damage Ratio about 98%.
4. ***Sustainability and Practical Implications:*** The findings advocate for the increased use of RA in infrastructure projects to promote environmental sustainability without compromising performance. Proper reinforcement can make RA a competitive option for flexible pavements, contributing to resilient and sustainable road infrastructure.

Scope for future work:

Future research should delve deeper into the long-term performance of geosynthetic -reinforced recycled aggregates under real-world conditions. This involves monitoring the structural integrity and load-bearing capacity of reinforced pavements over extended periods and varying climatic conditions. Additionally, exploring the economic and environmental impacts of large-scale implementation of reinforced recycled aggregates in highway construction could provide valuable insights into cost-efficiency and sustainability benefits.

Investigating the potential of other types of geosynthetic materials, such as geocells and Geo-membranes, could further enhance the performance of recycled aggregates. Comparative studies between different reinforcement configurations, including multi-layered systems, would help in identifying the most effective designs.

Advancements in material science, such as the development of new types of recycled aggregates or the incorporation of additives to improve their mechanical properties, should also be considered. Research could focus on optimizing the mix design of recycled aggregates to maximize their resilient modulus and overall durability.

Furthermore, integrating advanced computational modeling techniques, like finite element analysis, could improve the prediction of pavement behavior and performance. This approach would enable a more precise assessment of the benefits of geosynthetic reinforcement and support the development of more efficient and reliable pavement designs.

Collaboration with industry stakeholders and government agencies is crucial for the practical implementation of research findings. Pilot projects and field trials could demonstrate the feasibility and benefits of using reinforced recycled aggregates in real-world settings, paving the way for widespread adoption.

Lastly, exploring the social and environmental impacts of using recycled materials in construction could provide a holistic understanding of their benefits, contributing to the broader goals of sustainable development and resource conservation. This comprehensive approach will ensure that future infrastructure projects are not only durable and cost-effective but also environmentally responsible and socially beneficial.