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Research Article

Evaluation of Waste Ceramic Tiles, Reclaimed Asphalt Pavement and Recycle Concrete Aggregate as Pavement Sub-Base

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Keywords

RCA,
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CBR,
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Sub-base.

Abstract

The use of various reclaimed or recycled materials from ancient structures as a source of construction materials has become common in modern road and pavement engineering procedures due to the shortage of fresh natural aggregate supplies and rising processing prices. Waste ceramic tiles (WCT), reclaimed asphalt pavement (RAP), and recycled concrete aggregate (RCA) have all been used for a long time as aggregates in the construction of pavement. WCT, RAP, and RCA are all thoroughly analyzed in this paper, with a focus on their mechanical, environmental, and physical properties. To evaluate the load-bearing ability, drainage capabilities, and long-term durability of these substitute materials when applied as pavement sub-base, laboratory tests and performance analysis were carried out. Since different mixtures of these materials are created, the maximum California bearing ratio of 25.54% is found. By promoting the usage of recycled materials, eliminating waste, and lowering the carbon footprint associated with conventional construction processes, this initiative helps to sustainably build out transportation infrastructure.

1. Introduction

Many developed countries have massive waste resources such as fly ash, stone dust, plastic, glass, tire rubber, metal swarf, and various types of construction and demolition waste materials. Ceramic materials, such as ceramic tiles and other ceramic items, contribute most of the waste from construction and demolition. Ceramic tiles are being produced at a growing rate across the world, particularly in Turkey, which is the biggest European manufacturer, and China, which is the world leader. Each year, roughly 250,000 t of tiles are worn out, whereas 100 million tiles are utilized for repairs worldwide [1]. Because the housing industry produces so much waste ceramic tiles, stockpiles of these materials create environmental problems. Ceramic tiles are not recycled; the current way of disposing of ceramic tiles is generally landfill owing to a lack of standards as well as a lack of knowledge and experience in using ceramic wastes [2]. RAP is the most recycled material in the United States, according to a recent report by the Federal Highway Administration's (FHWA), with about 73 million tons of it being recovered each year, 62 million tons of which are utilized to build asphalt pavement [3]. The majority of structure and demolition waste—about 54%—come from products made of ceramics. Waste made of ceramic is strong, rigid, and highly resistant to forces of biological, chemical, and physical damage. When specific gravity is taken into consideration, ceramic tile aggregate is hard, has a smooth side and a rough side, and is lighter in weight than ordinary stone aggregates. In addition to being cost-effective, using ceramic tiles as aggregate in concrete will also be beneficial for the environment [4].

Considering the above background, an approach to evaluate the waste ceramic tiles, reclaimed asphalt pavement and recycled concrete aggregate is planned to be executed in this study. Additionally, the effect of using these waste materials as sub-bases is also planned to be investigated.

The significance of adopting sustainable development principles has greatly increased in recent years as a result of the rapid growth in both population and urbanization. These factors have presented obstacles to the preservation and safeguarding of our natural resources. For a number of years now, there has been an increase in the need for novel and environmentally friendly building materials for diverse construction projects.

Highway construction is an important part of the construction sector where the usage of natural resources has become an important concern for the environment [5]. Highways are transportation infrastructures that have a significant carbon footprint because of the procedures required in material sourcing, extraction, and placement, all of which produce a lot of waste materials. Highway pavement sustainability's primary goal is to adopt actions that might increase ecologically friendly and infrastructures that are economically viable and acceptable to the goals for sustainable development, which serve to define sustainable development as the process of making something that satisfies a current need without damaging the following generation's capacity their own requirements [6]. The three main factors that influence the application of sustainable development principles are the environment, the economy, and society [7-8].

More specifically, the high cost of aggregates is a result of the obstacles to constructing new quarries. Currently, operating quarries are also situated in remote places. The transportation of aggregates is becoming more expensive than requiring places and plants. Additionally, issues with concrete waste, asphalt waste, and waste ceramic tile disposal have also been noted as landfill waste. Roknuzzaman & Serker (2023) [9] investigated that recycled material structures are widely regarded as sustainable constructions since they minimize the need for the abuse of natural resources and prevent the necessity for landfill space. Because they reduce waste production, enhance environmental friendliness, and protect natural resources, RCA, RAP, and WCT are encouraged by sustainable development principles [8-9]. To support the environmental preservation of natural aggregates, recycled aggregate can be employed widely in current green construction from a sustainability perspective.

The environment is under a lot of pressure from the need for new infrastructure carried on by growing populations and the substantial

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quantity of solid waste produced, primarily by the construction sector. Construction and demolition waste is increasingly being recognized as a potential resource due to a shortage of high-quality materials and the increasing cost of natural aggregate [10-11]. Recycled concrete aggregates (RCA), which make up around 70% of construction waste, have been shown to be particularly helpful in constructing flexible pavements with good performance and durability [12].

This is essential not only for cutting down on construction expenses but also for mitigating the environmental consequences associated with road development. In the United States, reclaimed asphalt pavement (RAP) has been in use for over thirty years [13].

The importance of reusing waste materials in road construction in Bangladesh cannot be emphasized. This technique has numerous advantages for both the environment and the economy. The demand for road infrastructure is increasing as the country's population grows and urbanization accelerates. Waste ceramic tiles (WCT) made from recycled waste materials such as recovered asphalt pavement (RAP) and recycled concrete aggregates (RCA) not only help to conserve natural resources but also lessen the environmental impact of trash disposal. Furthermore, it can significantly reduce building costs, making road development more economically viable. Incorporating these sustainable materials also improves the overall durability and performance of the pavement, resulting in longer lasting and more robust road networks. This approach aligns with Bangladesh's commitment to sustainability and serves as a model for responsible infrastructure development in the face of the pressing challenges posed by urban growth and waste management.

Utilizing waste ceramic tiles to mix different percentages of recycled concrete aggregate and recycled asphalt pavement in order to determine the mix ratio that results in a superior pavement subbase. To establish the mix ratio that produces an improved pavement subbase by mixing waste ceramic tiles to combine various percentages of recycled concrete aggregate and recycled asphalt pavement.

Traditionally, pavement subbase materials have primarily consisted of natural aggregates, such as crushed stone and gravel. These materials have been preferred due to their availability and strength characteristics. However, their removal from quarries has a substantial negative influence on the environment, destroying habitats and requiring greater amounts of energy. Moreover, the transportation of natural aggregates over long distances adds to the carbon footprint of pavement construction [14]. Thus, the drawbacks associated with traditional subbase materials necessitate exploring more sustainable options.

Waste ceramic tiles have gained attention as a potential subbase material due to their mechanical properties and environmental benefits. Studies have shown that waste ceramic tiles can offer adequate compressive strength, stiffness, and durability to meet subbase requirements [15]. Recycling waste tiles reduces landfill waste and conserves raw materials [16]. However, further research is needed to address issues such as the heterogeneity of waste tiles and their long-term performance in subbase applications [15].

Recycled Concrete Aggregate has gained prominence as a sustainable subbase material. RCA is obtained by crushing and processing old concrete structures, reducing the need for virgin aggregates and landfill disposal [17][26}. Research has demonstrated that RCA can meet the mechanical and durability requirements for subbase layers [18]. Additionally, using RCA can significantly reduce the environmental impact associated with concrete disposal [19].

Reclaimed Asphalt Pavement presents another sustainable alternative for subbase construction. RAP is obtained by milling and processing old asphalt pavements, conserving valuable resources and reducing waste [20]. Studies have shown that RAP can offer sufficient bearing capacity and durability for subbase applications. The incorporation of RAP also reduces energy consumption and greenhouse gas emissions in pavement construction [21].

2. Research Methodology

2.1. Collection of materials

At first the materials are collected from the local area. The collection of sample is shown in Figure 1.

Figure 1. Recycled concrete aggregate

Figure 2. Waste ceramic tiles (WCT)

Figure 3. Reclaimed asphalt pavement

2.2. Preparation of sample

The collected RAP, RCA and WCT samples were broken into pieces manually in standard aggregate size. The size of material in sieve analysis was kept as greater than 4.75mm and less than 20 mm, if it had particles bigger than this percentage, it was eliminated after 20 mm of retention. Representative samples were obtained in accordance with AASHTO T-2 recommendations, and a mechanical splitter was made use of to obtain representative samples for each test is shown in 4. AASHTO T-248 contains the specifics of this process. The process of conversion can be carried out in both developed and developing nations because the technology now in use for creating RAP, RCA, and WASTE ceramic tiles through mechanical crushing is available. The procedures used to extract impurities from the main material and produce a usable rating.

Figure 4. Preparation of sample at different ratio

To ascertain the distribution of particle sizes, a sieve test is performed by using different sizes of sieves. The following mixture design is used for the laboratory test shown in Table 1.

Table 1. Different types of mix ratio

Material	RAP (%)	RCA (%)	WCT (%)
Mix A	80	20	0
Mix B	70	25	5
Mix C	60	30	10
Mix D	50	35	15

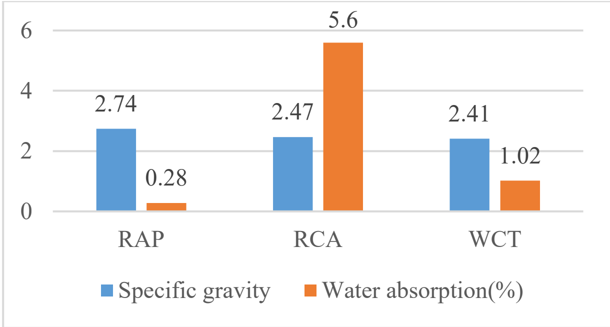

Figure 5. Relationship between unit weight and water absorption for RAP, RCA and WCT

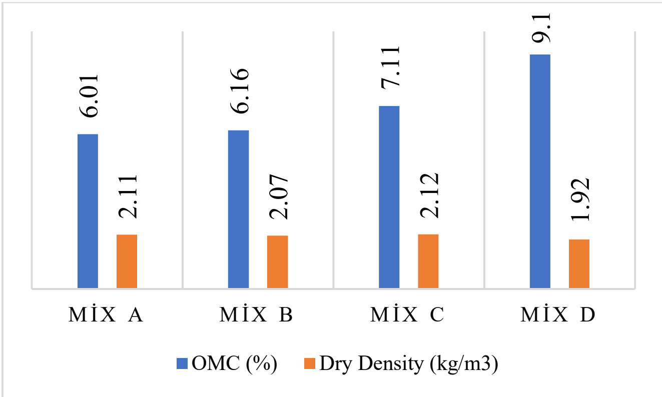

Figure 6. Relationship between dry density and water content for different mixes

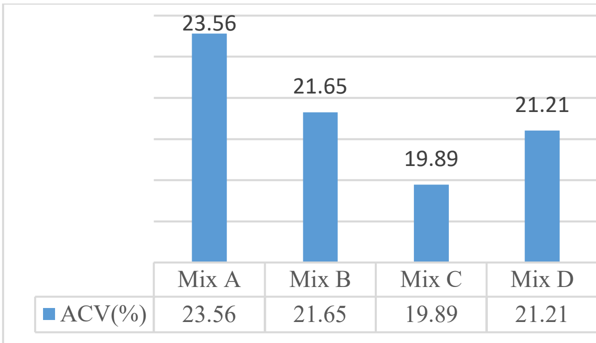

Figure 7. ACV values for different mixes

The CBR test results of different mix ratio are shown in Figure 8.

2.3. Testing of materials

After the test sample was prepared, a few appropriate tests were carried out to ascertain its qualities. To determine the strength and durability of the mix design aggregate, several laboratory tests were executed. The tests that followed included

- Specific gravity and water absorption test (ASTM C127-15 Standard Test Method) [22]
- Aggregate crushing value test (BS 812, Part 110 Standard Test Method) [23]
- Modified proctor test (ASTM D 1557 - Standard Test Methods) [24]
- California bearing ratio test (ASTM D 1883 - Standard Test Methods) [25]

3. Results and Discussion

3.1. Results

Unit weight and water absorption for RAP, RCA and Wct are shown in Figure 5. The optimum moisture content and maximum dry density of each waste mix were determined using ASTM D 1557-Modified Proctor Test methods for laboratory compaction properties of aggregate using standard force (56,000 ft-lbs/ft^3) and volume of mold is 2123 cm^3. The test result is shown in Figure 6. ACV values of different mixes are shown in Figure 7. The findings are summarized below.

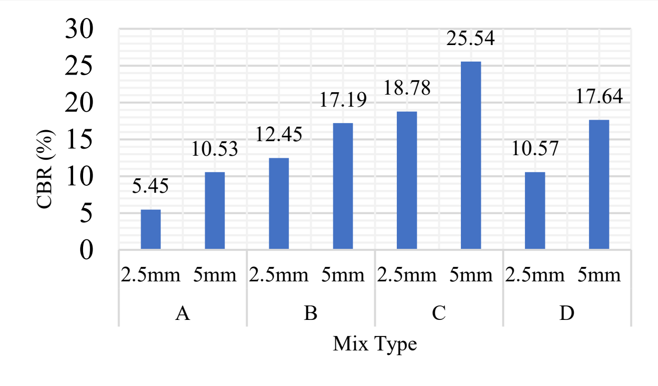

Figure 8. CBR value for different mix

4. Discussion

To The evaluation of recycled concrete aggregate, waste ceramic tiles, and reclaimed asphalt pavement in the pavement subbase was conducted by preliminary laboratory testing and subsequently field testing in a demonstration project. A comprehensive set of lab examinations was taken on four different mixes of RAP, RCA, and WCT.

The use of RAP, RCA and WCT and improved quality of different mixes result in acceptable hardened concrete properties. previous research has shown that RCA and RAP mixtures can have mechanical properties comparable to conventional coarse aggregate. here we use of RAP, RCA and WTC are blend in different ratio as subbase pavement.

This study leads to the following conclusions:

- Mix A, which is free from WCT has low CBR value in unsoaked condition of 10.53 which refers to low strength characteristics. It suggests that the waste needs to be improved if it is to be used as filling material.
- The CBR values for Mix A, B, C and D were 10.53%, 17.19%, 25.54% and 17.64% respectively. the treated sample can be used as subbase pavement.
- The Mix C has a high CBR value of 25.54% and ACV value of 19.89% which refers to high strength characteristics. it suggests that the wastes to be used.

5. Limitations

Following are some limitations of these research:

✓ Permeability of the sub-base materials is not check.
✓ The thickness of the sub-base cannot be evaluated.

Declaration of Conflict of Interests

The authors declare that there is no conflict of interest. They have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

[1.] I. B. Topcu and M. Canbaz, "Utilization of crushed tile as aggregate in concrete.," Iranian Journal of Science Technology, Transaction B, Engineering, vol. 31(B5), p. 561–65, 2007.

[2.] F. Pacheco-Torgal and S. Jalali, "Reusing ceramic wastes in concrete.," *Construction and building materials,* vol. 24(5), pp. 832-838, 2010.

[3.] T. B. Edil, "Characterization of recycled materials for sustainable construction," *Proc. 18th ICSMGE,* 2013.

[4.] G. H. Brundtland, "Our common future—Call for action," *Environmental conservation,* vol. 14, no. 4, pp. 291-294, 1987.

[5.] C. Chon. &. Y. S. Onn, "Greenhouse gas emissions associated with electric vehicle charging: The impact of electricity generation mix in a developing country," *Transportation Research Part D: Transport and Environment,* vol. 64, pp. 15-22, 2018.

[6.] E. O. Fanijo &. K. J. Nwakaire, "Assessing the sustainability of meat transport mode choices in abattoir logistics using the analytic hierarchy process," *ARPN Journal of Engineering and Applied Sciences,* vol. 10, no. 20, pp. 9331-9338, 2015.

[7.] M. Roknuzzaman and N. K. Serker, "PRE-TREATMENT OF RECYCLED AGGREGATES BY REMOVING RESIDUAL MORTAR: A CASE STUDY ON RECYCLED BRICK AGGREGATES FROM A DEMOLISHED COMMERCIAL BUILDING," *技術學刊,* vol. 38, no. 1, pp. 51-64, 2023.

[8.] R. Jin and Q. Chen, "Investigation of concrete recycling in the US construction industry.," *Procedia Engineering,* vol. 118, pp. 894-901, 2015.

[9.] J. Walls and M. R. Smith, "Life-cycle cost analysis in pavement design: Interim technical bulletin," *(No. FHWA-SA-98-079). United States. Federal Highway Administration,* 1998.

[10.] X. Xu, Y. Luo, A. Sreeram, Q. Wu, G. Chen, S. Cheng and X. Chen, "Potential use of recycled concrete aggregate (RCA) for sustainable asphalt pavements of the future: A state-of-the-art review," *Journal of Cleaner Production,* vol. 344, p. 130893, 2022.

[11.] R. Cardoso, R. V. Silva, J. de Brito and R. Dhir, "Use of recycled aggregates from construction and demolition waste in geotechnical applications: A literature review," *Waste management,* vol. 49, pp. 131-145, 2016.

[12.] H. S. Coban, B. Cetin, T. B. Edil and Q. Sun, "Evaluation of mechanical degradation characteristics of recycled and natural aggregates under gyratory compaction effort," *Transportation Geotechnics,* vol. 34, p. 100743, 2022.

[13.] D. McNichol, "Paving the way: Asphalt in America," *National Asphalt Association, Lanham, Maryland,* 2005.

[14.] G. Guduru&. & K. K Kuna, "Asphalt tops the charts for environmental stewardship-again," *HMAT: Hot Mix Asphalt Technology,* vol. 16, no. 5, 2011.

[15.] P. Singh and R. K. Singla, "Utilization of waste ceramic tiles as coarse aggregate in concrete," *Journal of Multidisciplinary Engineering Science and Technology (JMEST),* vol. 2, pp. 3294-3300, 2015.

[16.] R. Herrador &. R. Garach, "Use of recycled construction and demolition waste aggregate for road course surfacing.," *Journal of transportation engineering,* vol. 138(2), pp. 182-190, 2012.

[17.] Cabalar, A. F., D. I. Hassan and M. D. Abdulnafaa, "Use of waste ceramic tiles for road pavement subgrade.," *Road Materials and Pavement Design,* vol. 18(4), pp. 882-896, 2017.

[18.] Mangalprasad, M. Pooja and H. A. Shahane, "Effect of Tiles Waste and Fly Ash Brick Waste on Permeability and Strength of Lower Granular Subbase Material," *Proceedings of the Indian Geotechnical Conference,* Vols. IGC-2019 Volume II, 2019.

[19.] Deboucha, Sadek, S. m. A. M. Sail and H. Ziani, "Effects of ceramic waste, marble dust, and cement in pavement sub-base layer," *Geotechnical and Geological Engineering,* vol. 38(3), pp. 3331-3340, (2020).

[20.] A. Arul, J. Piratheepan and M. M. Disfani., "Reclaimed asphalt pavement and recycled concrete aggregate blends in pavement subbases," *Laboratory and field evaluation: Journal of Materials in Civil Engineering,* vol. 26(2), pp. 349-357, (2014).

[21.] J. Arachchige, S. Pradeep, C. Gallage and A. Kumar., "Assessment of recycled concrete aggregates as a pavement material," *Geomechanics and Engineering,* vol. 6.3, pp. 235-248., (2014.

[22.] ASTM C127-15. Standard Test Method for Relative Density (Specific Gravity) and Absorption of Coarse Aggregate, ASTM International, West Conshohocken, PA, (2015).

[23.] BSI BS 812. Part 110: Specification for aggregate for crushing value. (2020).

[24.] ASTM D127-15. Standard Test Method for Laboratory Compaction Characteristics of soil using Modified Efforts, ASTM International, West Conshohocken, PA, (2015).

[25.] ASTM D127-15. Standard Test Method for California Bearing Ratio of Laboratory Compacted Soils, ASTM International, West Conshohocken, PA, (2015).

[26.] Sultana, A., Roknuzzaman, M., Afrose, A., and Dev, T., Impact of Multiple Recycling on the Strength of Coarse Aggregate, Civil Engineering Beyond Limits, 1(2021),12-15.

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