POTENTIAL OF RECYCLED MATERIALS AS A REPLACEMENT OF CONVENTIONAL AGGREGATE FOR BASE OR SUB-BASE CONSTRUCTION

Md. Mohayminul Islam[1] and Md. Sakib Hasan[*2]

[1]Lecturer, Department of Civil Engineering, Rajshahi University of Engineering & Technology, Rajshahi, Bangladesh. e-mail: mohayminul.islam37@gmail.com)

[2]Undergrade Student, Department of Civil Engineering, Rajshahi University of Engineering & Technology, Rajshahi, Bangladesh.

***Corresponding Author**

ABSTRACT

The disposal of Construction and Demolition waste has become a matter of great concern nowadays. For this reason, recycling and the reuse of waste materials like recycled concrete aggregate (RCA) and waste ceramic course (WCC) in road pavements may lessen landfill disposal. In this study, the behavior of riverine sand using waste ceramic course (WCC) and recycled concrete aggregate (RCA) for road base or sub-base construction was analyzed. 0%-50% by weight (0%, 10%, 20%, 30%, 40%, and 50%) of WCC and RCA was added to the soil and sample was prepared. Modified Proctor Test was performed for the samples. Due to the increase of RCA and WCC in the sample, the change in Maximum Dry Density (MDD) and Optimum Moisture Content (OMC) values was keenly observed. The MDD value raised from 1.84 gm/cm^3 to 2.12 gm/cm^3 for WCC starting from 0% to 50%. Again, the MDD value increased from 1.84 gm/cm^3 to 2.14 gm/cm^3 for RCA starting from 0% to 50%. So, in this study, the optimum percentage of WCC is 50% and RCA is 50% for MDD. The OMC value decreased from 12.50% to 10.71% for WCC starting from 0% to 50%. Similarly, the OMC value decreased from 12.50% to 10.03% for RCA starting from 0% to 50%. Thus, in this study, the optimum percentage of WCC is 50% and RCA is 50% for OMC. Moreover, the potential of these materials to improve the soil strength parameters was explored. As all the materials used in this study are waste from construction work, these materials might be an alternative solution for the construction of base or sub-base course of flexible pavement.

Keywords: *Modified Proctor test; Optimum Moisture Content; Road subgrade; Recycled Concrete Aggregate; Waste Ceramic Course.*

1. INTRODUCTION

The management of Construction and Demolition waste has emerged as a significant issue in contemporary times. One of the foremost environmental challenges on a global scale pertains to the annual generation of billions of tons of solid trash. The recycling and reuse of waste materials can effectively decrease the utilization of virgin materials sourced from mining operations, mitigate the disposal of garbage into landfills, and lessen the emission of greenhouse gases. The building and ongoing maintenance of roads rely heavily on the performance, durability, and safety of the road paving materials. To fulfil certain purposes, different materials are utilized for different layers of road pavement.

Several researches have been done before using waste materials to the base or sub-base for improving the soil strength parameters. Research was conducted using recycled aggregate concrete (RAC) in pavement construction in 2016. The findings from the analysis of laboratory-cured specimens and cores extracted from pavement sections after a concrete age of 270 days indicated that the recycled aggregate concrete (RAC) mixes exhibited comparable or even superior performance compared to the matching control (normal) concrete mixes. The increased strength and durability properties shown by RAC concrete at later stages of its lifespan indicate its potential use in the building of concrete-based infrastructure, such as pavement. (Nassar & Soroushian, 2016)

A CBR test was performed to evaluate the performance of varying proportions of recycled asphalt pavement (RAP) mix with crushed stone aggregate (CSA), namely at 10% RAP to 50% RAP. Therefore, a financially viable outcome is achieved at a rate of 30%. The replacement rate of the RAP was determined to be 104.20% with a maximum dry density (MDD) of 98%. (Mohammed et al., 2022)

According to a study, it is possible to manufacture cement-treated granular materials (CTGM) using construction and demolition waste (CDW) with a range of 0-8 mm recycled aggregates (RA) known as SC20. Furthermore, it has been shown that concrete treated with 75% fine recycled aggregates (FRA) has superior mechanical qualities and dimensional stability compared to concrete treated with coarse recycled aggregates (SC40). (Rey et al., 2015) In 2023, some researchers used demolished concrete as a replacement for the subbase. The use of aged concrete waste aggregates was employed as a substitute for newly sourced materials, with varying proportions ranging from 0% to 100% based on weight. The use of destroyed concrete waste aggregates instead of fresh aggregates resulted in a notable increase in water absorption, rising from 1.58% to 4.65%. This indicates an improvement in the water-cement ratio. The crushing value exhibited an increase from 26.54% to 55.29%, the impact value showed an increase from 27.86% to 58.05%, and the abrasion value saw an increase from 26.96% to 35.58%. According to the findings of this research, it is recommended that the sub-base composition of roads consist of a combination of 50% recycled aggregates and 50% fresh aggregates. The use of concrete debris derived from demolished structures as a sub-base material has the potential to contribute significantly towards the attainment of social, economic, and environmental sustainability objectives (Mazhar et al., 2023, Rashid et al., 2020).

A research study aimed to examine the use of glass waste in conjunction with kilned soil to enhance the properties of weak soil. The soil kilned and mixed with powdered glass waste consists of a composition of 75% expansive soil and 25% glass waste powder. These components are then introduced into expansive soil in varying proportions of 5%, 15%, and 25%. The maximum dry density (MDD) had a significant rise, rising from 1.33 g/cm3 to 1.61 g/cm3. Simultaneously, the optimum moisture content (OMC) underwent a notable reduction, decreasing from 40% to 21.3%. Additionally, the plastic index exhibited a substantial decrease, declining from 58.79% to 19.91%. Lastly, the California bearing ratio (CBR) showed a significant improvement, increasing from 0.95% to 12.08%. (Woldesenbet, 2022) Again an investigation included the selection of waste materials from several building sites, including shredded bricks, crushed waste stone, and crushed old concrete. The stone columns were fabricated with these discarded materials. The findings obtained demonstrated a significant improvement in the settling characteristics of the unconsolidated sand. In summary, the use of locally sourced waste building materials has shown to be an efficient approach for the production of stone columns. (Alnunu & Nalbantoglu, 2021)

The research was conducted using various proportions of crushed rock, recycled concrete aggregate, and crushed glass while maintaining a consistent 1% inclusion of crumb rubber. The coefficient of base reinforcement (CBR) shows a positive correlation with the proportion of glass content. (Saberian et al., 2019) Researchers studied subgrade natural soil by adding waste ceramic tiles. The specimens included tiles in the mixes with dry weight percentages of 0%, 5%, 10%, 15%, 20%, and 30%. The experimental findings indicate that the incorporation of waste ceramic tile into the soil leads to an increase in the California Bearing Ratio (CBR) value. Conversely, the inclusion of waste ceramic tile resulted in a reduction in the Unconfined Compressive Strength (UCS) value of the soil. Additionally, compaction tests revealed that an augmentation in the dry unit weight (γ dry) and a reduction in the associated water content (w) occurred as a result of an increase in the quantity of waste ceramic tile. (Cabalar et al., 2016)

Several researchers have conducted studies on clayey soil. The objective of this study is to investigate the effects of varying proportions of waste ceramic dust and waste plastic strips on the stabilization of clayey gravel. The CBR value was found to be greatest when using waste plastic strips at a concentration of 1% and waste ceramic dust at a concentration of 20%. (Kadhum & Aljumaili, 2020) Recently in 2023, Sharma & and Shrivastava conducted research on recycled brick aggregate (RBA) and RCA. The California Bearing Ratio (CBR) values of lime stabilized (LS) materials show a notable rise when the amount of recycled concrete aggregate (RCA) or recycled brick aggregate (RBA) increases. An increase in the California Bearing Ratio (CBR) values has the potential to immediately decrease the necessary thickness. The topic of discussion is the composition and function of pavement base and sub-base layers. Therefore, the suitability of using Recycled Concrete Aggregate (RCA), Recycled Brick Aggregate (RBA), and their combinations with Lime Stabilization (LS) as subgrade materials. The use of fill material in road and railway embankments may be justified based on their elevated values of California Bearing Ratio (CBR). (Sharma & Shrivastava, 2023)

A range of 5 to 25% of Feldspar, with increments of 5% by weight of the base and subbase, were included. The laboratory experiments included the performance of the Direct Shear and California Bearing Ratio (CBR) tests, in addition to the determination of water content and dry density. The test results indicate that the California Bearing Ratio (CBR) value of the base material has increased from 30% to 86.40%. Similarly, the CBR value of the subbase material has also shown an increase. The addition of 15% Feldspar resulted in an increase in the range of 21.50% to 87.30%. Based on the available evidence, one may conclude that the inclusion of an aggregation of basic materials has a significant impact. When Feldspar is added as a subbase material, there is a significant improvement in strength. This addition has a positive impact on the overall strengthening of the material. The foundation and subbase layers are essential components in pavement construction. (Rusbintardjo et al., 2019, Shirin et al., 2021)

We can see that several studies have already been done on how to use waste materials to strengthen the flexible pavement layers. Recycled concrete aggregate (RCA) and waste ceramic course (WCC) had not been used with riverine sandy soil as base or sub-base before. Also, Optimum Moisture Content (OMC) and Maximum Dry Density (MDD) were not analyzed using sandy soil, RCA, and WCC altogether.

In this study, different kinds of materials were used to measure the strength parameters of subgrade soil of flexible pavement. In place of the usual materials for the base or sub-base course, recycled concrete aggregate (RCA), waste ceramic course (WCC), and riverine sandy soil were used.
The main objectives of this study are to explore the potential of RCA and WCC to improve the soil strength parameters to be used as a base or sub-base and to find out the optimum percentage of RCA and WCC. Also, the improvement of OMC and MDD values was observed.

2. METHODOLOGY

2.1 Collection of Sample

The riverine soil used in this study was obtained from Balur Ghat, Talaimari, Motihar Thana, Rajshahi. The trash tiles were gathered from a construction site that was in the process of being constructed, situated at Upshahor Cantonment Road, Upshahor, Rajshahi. The sample was taken in consultation with Al-Aksha Developers (Pvt) Ltd. Subsequently, the tiles were fragmented into smaller pieces passing a 19mm sieve. This process resulted in the identification of the appropriate waste ceramic course (WCC). The recycled concrete aggregate (RCA) was obtained from building sites located at RUET. Then the aggregates were sieved. The sample passing 19mm sieve was taken as the RCA sample for the test.

2.1.1 Sand

In this study, sand was used as a fine aggregate, with particle sizes ranging from 0.075 mm (No. 200 sieve) to 4.75 mm in diameter. A collection of sieves, particularly the No. 200 sieve, defines a certain range of sizes by allowing particles smaller than 0.075 millimeters to pass through while retaining particles larger than this threshold.

The presence of sand in a mixture enhances its workability and flow by effectively occupying the spaces between larger coarse aggregate particles. The enhanced workability of the sample facilitates its mixing, transportation, and positioning in the context of construction activities. In this project, river sand obtained from a local provider was used.

2.2 Mixture Preparation for Sample

a. Mix A

Sand (100%) + RCA (0%)

Sand (90%) + RCA (10%)

Sand (80%) + RCA (20%)

Sand (70%) + RCA (30%)

Sand (60%) + RCA (40%)

Sand (50%) + RCA (50%)

b. Mix B

Sand (100%) + WCC (0%)

Sand (90%) + WCC (10%)

Sand (80%) + WCC (20%)

Sand (70%) + WCC (30%)

Sand (60%) + WCC (40%)

Sand (50%) + WCC (50%)

2.3 Compaction Test (Modified Proctor Test)

According to ASTM D 1557, a modified proctor test was conducted using the mold of 10.15 cm diameter and 942.65 cc volume. Approximately 4 kg of air-dried sample of mix A and mix B was prepared sequentially and also the sample was divided into 5 layers. 25 blows of rammer were performed per layer. The optimum moisture content and maximum dry density of each sample mix were obtained.

First of all, the materials were collected from the specific sites. Then the materials were oven dried at approximately 110 ºC +- 5 ºC for 24 hours. Mixes were prepared accordingly starting with 100% sandy soil, following 90% sand and 10% RCA, 80% sand and 20% RCA, and so on. A specific amount of water was mixed with these samples and the samples were put into layer by layer. Rammering was done with 25 blows each layer. After the hammering of 5 layers of the sample, the collar was removed and the extra sample was also removed. Also, the weight of the sample with mold was taken. Some sample was taken to a small can to oven-dry for 24 hours. Again specific amount of water was added to the sample and the same procedure was repeated. The next day the weight of the oven-dry sample was taken and OMC and MDD were obtained from that sample. The same procedure was repeated for all mixes.

3. RESULT AND DISCUSSIONS

3.1 Maximum Dry Density

Variation in dry density concerning moisture content for different percentages of RCA is shown in Figure 1. Figure 1 shows that as the percentage of water content increased, the dry density increased to a certain level. Then the dry density dropped down. At the maximum dry density, the optimum moisture content was attained. For 100% sand the maximum dry density was the lowest and OMC was the highest. At 10% RCA and 90% soil sample, the MDD value was higher than the 100% soil sample. The MDD value gradually increased to 50% RCA and 50% soil sample. 50% RCA and 50% soil sample gave the highest MDD value and the lowest OMC value. Figure 2 shows a slightly higher MDD value of 10% WCC and 90% soil sample than the value of 100% soil sample. But after that the MDD value gradually increased and the OMC value gradually decreased to 50% WCC and 50% soil sample. At 50% WCC and 50% soil sample the MDD value was found the highest and the OMC value was the lowest.

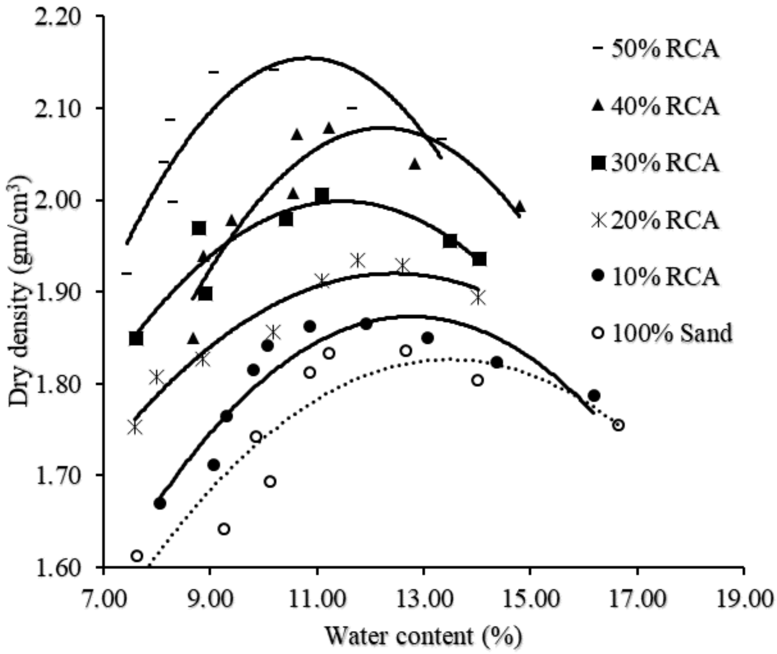

Figure 1: Variation in dry density with respect to moisture content for different percentages of RCA

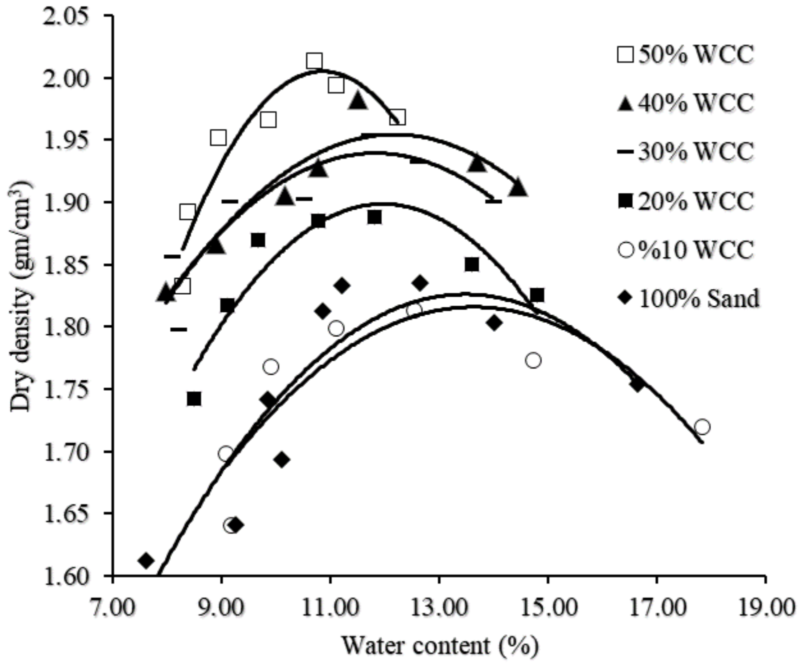

Figure 2: Variation in dry density with respect to moisture content for different percentages of WCC

3.2 Relationship between OMC and MDD with Different Mix of RCA

Figure 3 shows the OMC for different percentages of RCA. The values showed almost a linear relationship between OMC and RCA. As the percentage of RCA increased in the sample, the value of OMC decreased and the lowest OMC value was gained at 50% RCA and 50% soil mix. MDD for different percentages of RCA is shown in Figure 4. The values hold almost a linear relationship between the MDD and RCA. As the percentage of RCA increased in the mix, the value of MDD also increased and the highest MDD value was obtained for 50% RCA and 50% sand mix.

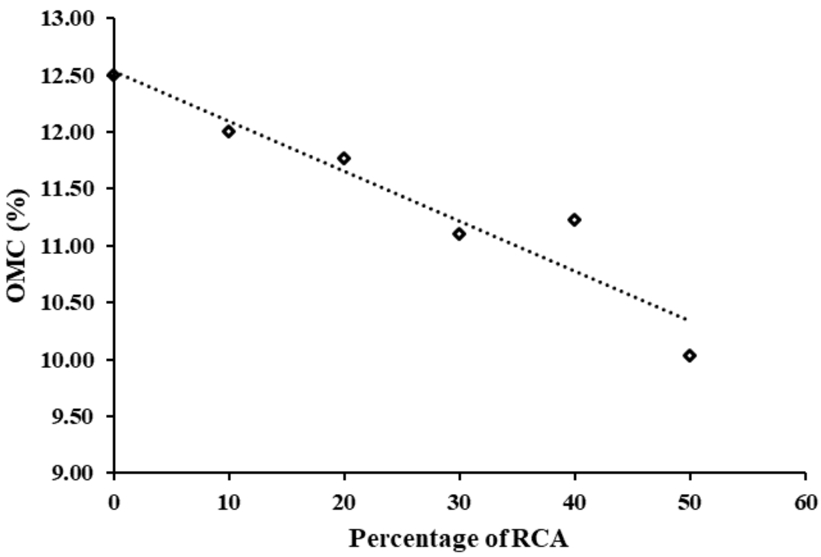

Figure 3: Optimum moisture content for different percentages of RCA

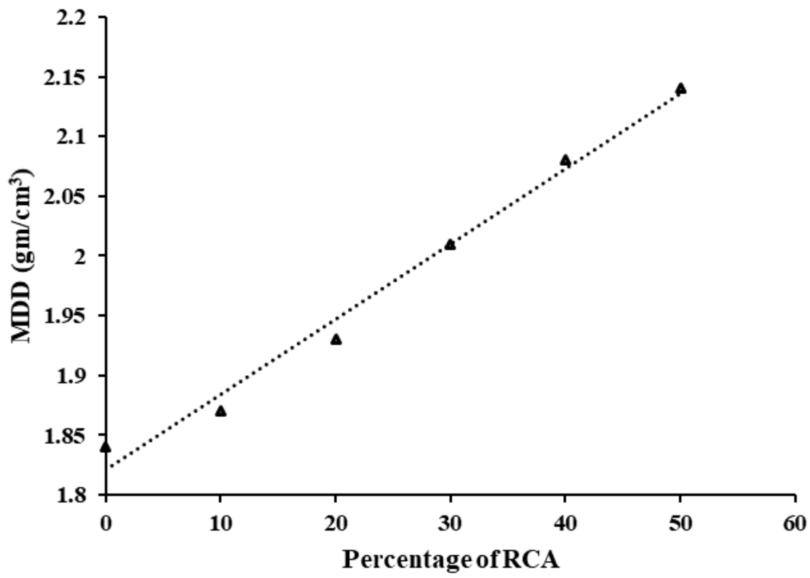

Figure 4: Maximum dry density for different percentages of RCA

3.3 Relationship between OMC and MDD with Different Mix of WCC

Figure 5 shows the OMC for different percentages of WCC. The values showed almost a linear relationship between OMC and WCC. As the percentage of WCC increased the value of OMC decreased and was similar to RCA. The minimum OMC was obtained for 50% WCC and 50% sand mix. MDD for different percentages of WCC is shown in Figure 6. The values hold almost a linear relationship between the MDD and WCC. As the percentage of WCC increased the value of MDD also increased and a maximum value of MDD was found for 50% WCC and 50% sand mix.

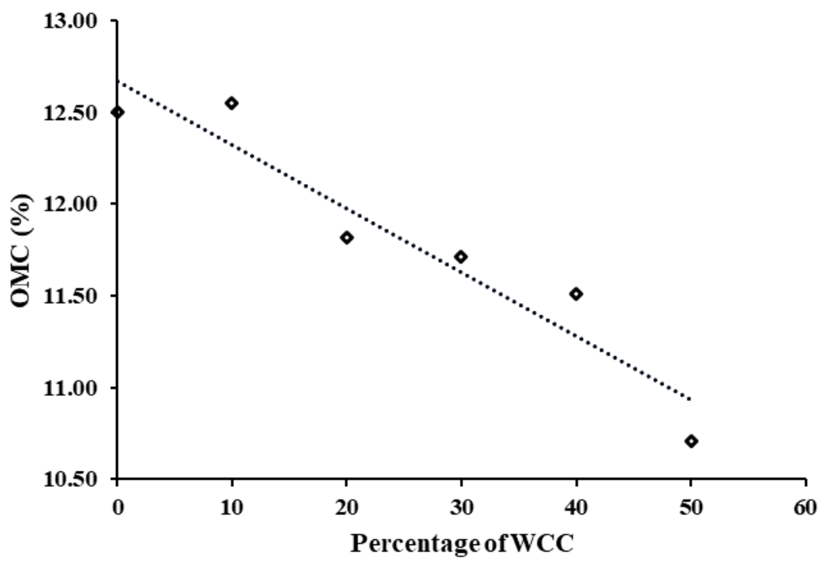

Figure 5: Optimum moisture content for different percentages of WCC

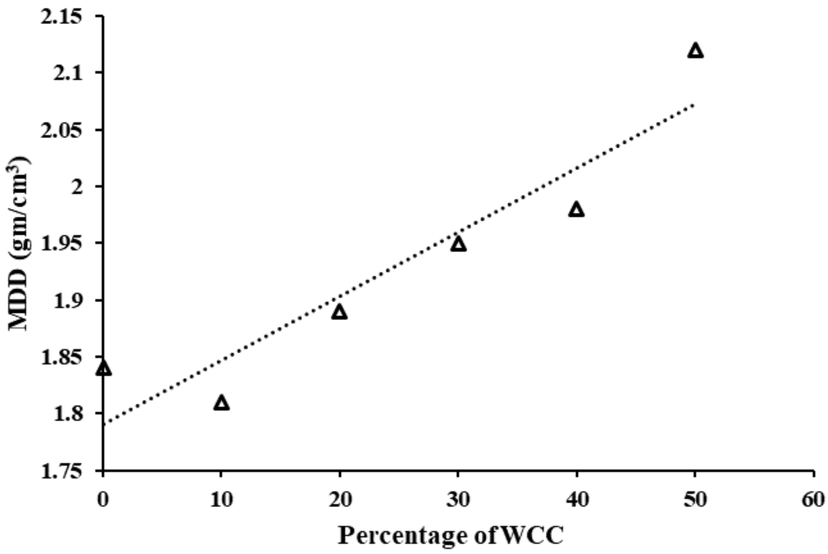

Figure 6: Maximum dry density for different percentages of WCC

4. CONCLUSIONS

According to the study above, the following conclusions may be found:

- As the result shows the improvement of soil strength parameters, RCA and WCC can be used at base or sub-base mixed with sandy soil.
- The optimum percentage of **WCC is 50%** and **RCA is 50%.** However, further tests like the resilient modulus test would give the accurate optimum result but due to some limitations, the tests were not performed in this study.
- The MDD value rose from 1.84 gm/cm^3 to 2.12gm/cm^3 and from 1.84 gm/cm^3 to 2.14 gm/cm^3 for WCC and RCA respectively.
- OMC decreased from 12.50% to 10.71% and from 12.50% to 10.03% for WCC and RCA respectively.

REFERENCES

Alnunu, M. Z., & Nalbantoglu, Z. (2021). Performance of loose sand with different waste materials in stone columns in North Cyprus. *Environmental Geotechnics*, *8*(5), 318–323. https://doi.org/10.1680/jenge.18.00079

Cabalar, A. F., Hassan, D. I., & Abdulnafaa, M. D. (2016). Use of waste ceramic tiles for road pavement subgrade. *Road Materials and Pavement Design*, *18*(4), 882–896. https://doi.org/10.1080/14680629.2016.1194884

Rashid, G.M.H., and Islam, M.M., (2020). A Review Paper on: Effect of Different Types of Filler Materials onMarshall Characteristics of Bitumen Hot Mix. International Journal of Materials Science and Applications.Vol. 9, No. 3, pp. 40-46.doi: http://dx.doi.org/10.11648/j.ijmsa.20200903.11

Kadhum, R. K., & Aljumaili, M. A. (2020). Strengthening the clayey gravel and sand soils for Subbase course highway using different waste materials. *IOP Conference Series:Materials Science and Engineering*, *888*(1), 012062. https://doi.org/10.1088/1757-899x/888/1/012062

Mazhar, M. A., Alam, P., Ahmed, S., Khan, M. S., & Adam, F. A. (2023). Sustainable usage of demolished concrete waste as a sub-base material in road pavement. *Frontiers in Sustainability*, *4*. https://doi.org/10.3389/frsus.2023.1060878

Mohammed, K., Gudina, O., Jemal, A., & Geremew, A. (2022). The comparative experimental studies on the suitability of ceramic waste aggregate and recycled asphalt pavement aggregate as an alternative for Base course material. *Journal of Civil Engineering, Science and Technology*, *13*(2), 160–171. https://doi.org/10.33736/jcest.4781.2022

Nassar, R. U. D., & Soroushian, P. (2016). Use of Recycled Aggregate Concrete In Pavement Construction. *The Journal of Solid Waste Technology and Management*, *42*(2), 137–144. https://doi.org/10.5276/jswtm.2016.137

Rey, I.D., Ayuso, J., Barbudo, A., Galvín, A., Agrela, F., & de Brito, J. (2015). Feasibility study of cement-treated 0–8 mm recycled aggregates from construction and demolition waste as road base layer. *Road Materials and Pavement Design*, *17*(3), 678–692. https://doi.org/10.1080/14680629.2015.1108221

Rusbintardjo, G., Fitriyana, L., M. Yusoff, N. I., & Yero, A. S. (2019). Increase the strength of Base and Subbase of Flexible Pavement by adding Feldspar as an additive material. *Journal of Advanced Civil and Environmental Engineering*, *2*(2), 59. https://doi.org/10.30659/jacee.2.2.59-64

Saberian, M., Li, J., & Cameron, D. (2019). Effect of Crushed Glass on Behavior of Crushed Recycled Pavement Materials Together with Crumb Rubber for Making a Clean Green Base and Subbase. *Journal of Materials in Civil Engineering*, *31*(7). https://doi.org/10.1061/(ASCE)mt.1943-5533.0002765

Sharma, A., & Shrivastava, N. (2023). Geotechnical Characterization of Construction and Demolition Waste Material Blended with Sandy Soil. *International Journal of Geosynthetics and Ground Engineering*, *9*(4). https://doi.org/10.1007/s40891-02300458-7

Shirin, M.S., Islam, M.M., Kumruzzaman, M., (2020). Stabilization of Coal Mine Waste and Its PracticalApplication as a Road Subgrade. American Journal of Traffic and Transportation Engineering. Vol. 5, No. 5,pp. 51-56.doi: http://dx.doi.org/10.11648/j.ajtte.20200505.11

Woldesenbet, T.T. (2022). Experimental Study on Stabilized Expansive Soil by Blending Parts of the Soil Kilned and Powdered Glass Wastes. *Advances in Civil Engineering*, *2022*, 1–12. https://doi.org/10.1155/2022/9645589