Cement Coating Technique to Improve the Performance of Calicut Tile Aggregates

S. Kishotharan[1], J. Johnkeshanth[2], M. M. M. Kaashif[3] and H. M. C. C. Somarathna[4]
[1,2,3,4]Department of Civil Engineering, Faculty of Engineering, University of Jaffna, Ariviyal Nagar, Kilinochchi, Sri Lanka
[1]kishotharan04@gmail.com

Abstract: Calicut Tile Aggregates (CTA) have demonstrated potential as a sustainable replacement for Natural Coarse Aggregates (NCA) in concrete, with minimal impact on performance even at significant replacement ratios. However, there is potential to further increase the replacement ratio through appropriate treatment. This study aims to enhance CTA properties through a surface treatment technique, specifically using a cement coating. The method involves soaking the crushed CTA in water for 24 hours, applying a cement coating, and curing the coated aggregates for 28 days. An experimental program evaluated the characteristics of NCA, untreated CTA, and treated CTA, revealing minor differences in particle size distribution, bulk density, and specific gravity. Experimental results show that treated CTA exhibits higher water absorption and moisture content. However, the reduction in aggregate crushing value, Los Angeles abrasion value, and aggregate impact value demonstrates the improved mechanical performance of treated CTA. This treatment enhances the physical and mechanical properties of CTA, thereby promoting its use as a sustainable construction aggregate.

Keywords- Calicut tile aggregates, Surface treatment, Cement coating, Sustainable construction.

Introduction

The production of concrete, owing to its extensive application in construction activities, requires careful attention to synthesis as a material that exhibits superior mechanical and physical characteristics [1]. The composition of concrete prominently includes aggregates, which are primarily derived from natural sources [2]. The utilization of such natural materials stands advantageous in minimizing greenhouse gas emissions and curtailing the consumption of natural resources [3]. Furthermore, the adoption of innovative recycling methodologies not only aligns with sustainability objectives but also introduces economic advantages [4]. A pivotal strategy in sustainable concrete production involves the substitution of traditional aggregates with recycled alternatives, aiming to reduce the depletion of natural resources and mitigate environmental degradation [5]. It is critical, when integrating recycled materials into concrete, to study the grade of the concrete and select aggregates that are congruent with the desired properties.

The utilization of broken tiles in concrete mixtures presents an effective solution for addressing waste management challenges and environmental considerations [6]. Clay tiles have been found to offer a feasible alternative to natural aggregates in concrete, with minimal impact on the material's mechanical properties when used as partial substitutes [7]. Extensive research efforts are directed towards enhancing the quality of recycled coarse aggregates [8]. The literature emphasizes the efficacy of various treatment methods in improving the properties of aggregates and, consequently, the resulting concrete. These methods encompass chemical treatments, polymer impregnation, and the application of pozzolanic slurries [9, 10, 11, 12]. Furthermore, immersing recycled aggregates in hydrochloric acid has been identified as a highly effective approach in eliminating adhered debris, such as old mortar, thereby enhancing mechanical properties and bond strength within the cement matrix[4]. Techniques like polymer impregnation and pozzolan slurry soaking have been recognized for their ability to reduce water absorption rates and improve the microstructural homogeneity of the aggregates, thereby resulting in an enhanced surface. Additionally, the use of pozzolanic materials, such as micro-silica and nano-zeolite, in slurries has demonstrated significant improvements in concrete compressive strength and durability [13]. Overall, these surface treatment techniques collectively contribute to the effective utilization of recycled aggregates, thereby promoting sustainability in construction [14]. However, it is important to note that these methods require a high level of technical expertise and financial support. Therefore, there is a need to identify cost-effective and straightforward techniques that can facilitate the sustainable use of recycled aggregates without imposing excessive demands.

This study aims to assess the potential of applying cement coatings to enhance the mechanical properties of Calicut tile aggregates. This research seeks to provide valuable insights into the effectiveness of this coating method in improving the mechanical and physical properties of aggregates as well as concrete. By comprehensively understanding its advantages and limitations, the study aims to promote sustainable and resilient construction practices. The findings of this investigation will support the development of eco-friendly and cost-effective construction materials and techniques.

Materials and Methods

Materials

Ordinary Portland Cement, conforming to the Sri Lanka Standard Specification SLS 107:2008 and classified within the 42.5 N strength category, was employed in this study. The water utilized originated from the standard tap supply at the University of Jaffna's Engineering Faculty, characterized by a pH value of 6.92. For the fine aggregate, river sand locally sourced, exhibiting a specific gravity of 2.50, a fineness modulus of 3.21, a bulk density of $1634.93 kg/m^3$, and particle sizes not exceeding 4.95 mm, was selected. This sand adhered to the ASTM C33 [15] standards, demonstrating a water absorption capacity of 1.77%. As for coarse aggregates, the study incorporated 20 mm downgraded crushed stones, untreated Calicut Tile Aggregates (CTA), and treated CTA. The characteristics of these coarse aggregates will be exhaustively compared within the results and discussion section.

Treatment for Calicut tile aggregates

Figure 1: Treated CTA.

Figure 2: Untreated CTA.

Discarded Calicut tiles were collected from a construction site in the Kilinochchi district of Sri Lanka. The tiles were broken down using 2995 g and 1765 g hammers to produce crushed Calicut tiles. The crushed tiles were then sieved through 20 mm and 4.95 mm sieves, yielding CTA particles within this size range. The crushed CTA particles were immersed in water for 24 hours to ensure complete saturation. The soaked CTA particles are then coated with the same type of cement through agitation for even coverage. After coating, the treated aggregates are left to dry at room temperature for 24 hours. Finally, the aggregates undergo a 28-day curing period, during which they are periodically misted with water.

Investigation of aggregate characteristics

The particle size distribution of the coarse aggregates was analyzed following ASTM C 136 [16]. Three 5 kg samples, each with a nominal maximum size of 20 mm, were utilized. After drying and sieving, the mass of each size fraction was measured to determine the percentage passing and retained, thus establishing the particle size distribution.

Specific gravity and water absorption of the coarse aggregates were determined following ASTM C 127 [17]. Samples passing the 4.75 mm sieve were washed, dried, and weighed. The samples were then immersed in water, and their mass in water and under saturated surface-dry conditions were measured for the calculation of specific gravity and water absorption.

The bulk density of the aggregates was determined per ASTM C 29/C 29M [18]. The samples were dried, and the measuring container was calibrated using water. After filling, tamping, and measuring their mass and volume, the bulk density of the aggregates in an oven-dry condition was calculated.

The aggregate moisture content was quantified following the procedures delineated in ASTM C 566 [19], involving the drying of samples within an oven maintained at 105°C until a consistent mass was observed. The total evaporable moisture content was obtained using the initial and terminal masses of the samples.

To assess the resistance to crushing, the Aggregate Crushing Value (ACV) was determined according to BS 812-Part 110 [20]. This involved drying, compacting, crushing under a specific load, and sieving the coarse aggregates, with the ACV calculated as the percentage of material passing a 2.36 mm sieve.

The Los Angeles Abrasion Value (LAAV) was determined per ASTM C 131 [21] by subjecting washed and dried aggregate samples to 500 revolutions in the Los Angeles testing machine at 33 rpm. The loss in mass, calculated as a percentage of the original sample mass, indicates the aggregate's resistance to wear and abrasion. Furthermore, the Aggregate Impact Value (AIV) was determined per BS 812-112 [22] through impact testing on dried aggregate samples. The resulting crushed material was sieved, and the AIV was calculated as the percentage of fines passing through a 2.36 mm sieve, providing insights into the aggregate's resistance to impact.

Results and Discussion

The results of the sieve analysis test were utilized to confirm that the particle size distribution of the aggregates complies with the ASTM C33/C33M [15] standard for concrete production suitability. As depicted in Figure 3, the findings indicate that the aggregates meet the required specifications. Following the application of the coating treatment to the CTA, only minor variations in the size of the coarse aggregates were observed.

Figure 4 depicts the variation in bulk densities of three aggregate types used in this study. The data illustrates that the bulk density of CTA is significantly lower than that of NCA. Additionally, the application of a cement coating results in a slight increase in the bulk density of the treated CTA compared to the untreated CTA.

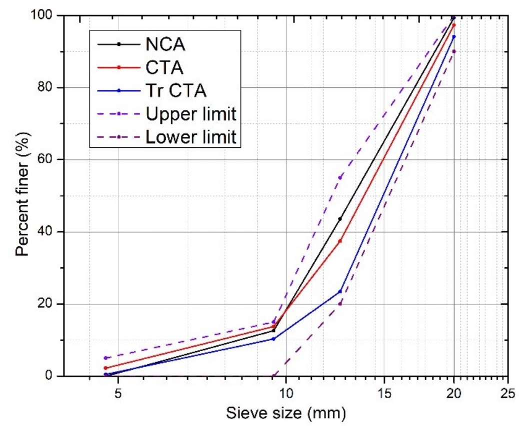

Figure 3: Particle size distribution curve

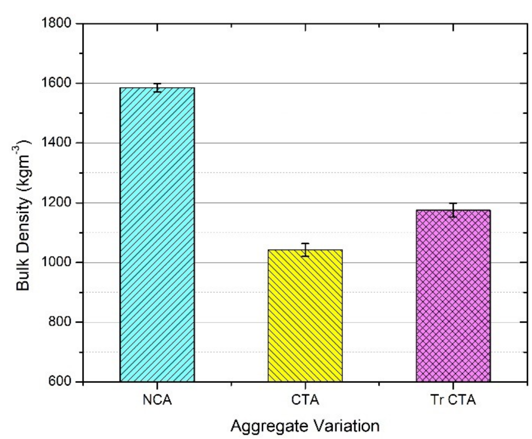

Figure 4: Variation of bulk density

Table 1: Aggregate characteristics of natural coarse aggregates, untreated CTA and treated CTA

Aggregate Characteristics	AggregateType		
	NCA	**Untreated CTA**	**Treated CTA**
Specific gravity	2.72	1.74	1.75
Water absorption (%)	0.90	19.01	18.67
Moisture content (%)	0.09	5.65	9.06

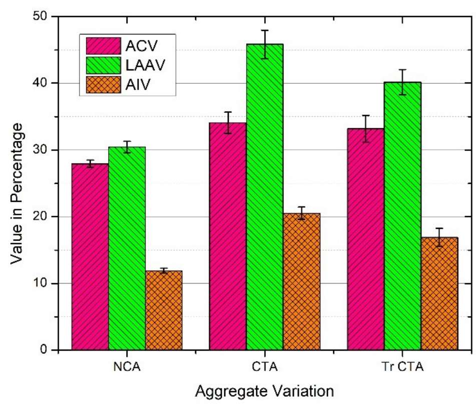

Figure 6: Variation of ACV, LAAV and AIV

Table 1 outlines the variations in aggregate characteristics, including specific gravity, water absorption, and moisture content. The uncoated CTA display a noticeably reduced specific gravity in comparison to the NCA, with a marginal enhancement observed following surface treatment. Owing to its higher porosity, the water absorption rate of CTA significantly exceeds that of NCA. Nevertheless, the application of a surface treatment demonstrates a minor decrement in the water absorption of CTA. Moreover, comparative analyses of moisture content reveal inherently higher moisture retention within CTA relative to NCA, a phenomenon further pronounced upon the application of a cementitious coating as a surface treatment.

The ACV test, as delineated in BS 812-Part 110 [20], serves as a relative gauge of an aggregate's resilience against compressive forces, applied progressively. Initial assessments of CTA reveal an ACV of 34%, highlighting a degree of unsuitability for construction-related applications. After undergoing treatment, the ACV marginally declines to 33%. This minor adjustment suggests the treatment enhances the CTA's potential usability in construction contexts slightly. Furthermore, the LAAV test examines the aggregates' resistance to fragmentation and degradation through processes of attrition and abrasion. Initially, the CTA demonstrates comparatively weak structural integrity, which correlates with a heightened LAAV.

Post-treatment observations note a diminishment in LAAV, a consequence likely

Figure 5: Investigation of aggregate characteristics:(a) Sieve analysis, (b) Bulk density, (c) Specific gravity and water absorption, (d) Moisture content, (e) Aggregate Crushing Value, (f) Aggregate Impact Value, (g) Los Angeles Abrasion Value

attributable to the protective efficacy of the cement coating, which serves to mitigate abrasive forces and, consequentially, lower the measurable value. Within the scope of impact resilience, the AIV test, formalized under BS 812-112 [22], quantifies the aggregate's robustness in the face of abrupt forces or shocks. Prior to treatment, the CTA registers an AIV under 25%, qualifying it as adequate for certain construction applications. Following treatment enhancement, the AIV of CTA decreases to around 17%, signifying an elevated appropriateness for structural assignments.

Conclusions

This study aimed to assess the effectiveness of cement coating as a means of improving the properties of CTA. The application of cement coating did not significantly alter the particle size distribution of the coarse aggregates. The results revealed a slight increase in specific gravity and bulk density for the treated CTA, although these values remained lower than those of NCA. Treated CTA also demonstrated a decrease in water absorption and an increase in moisture content compared to untreated CTA. In terms of resistance to crushing under compressive load, as measured by ACV and AIV, treated CTA exhibited improved properties over untreated CTA, although still inferior to NCA. The findings of this study support the conclusion that cement coating is a viable treatment method for CTA, enhancing its properties compared to untreated aggregates.

Acknowledgment

The authors would like to extend their sincere thanks to the University of Jaffna, with special appreciation to the Department of Civil Engineering for providing essential materials and laboratory facilities.

References

[1] J. N. Farahani, P. Shafigh, and H. Bin Mahmud, "Production of A Green Lightweight Aggregate Concrete by Incorporating High Volume Locally Available Waste Materials," in Procedia Engineering, Elsevier Ltd, 2017, pp. 778-783. doi: 10.1016/j.proeng.2017.04.158.

[2] H. M. S. C. H. Bandara, G. Thushanth, H. M. C. C. Somarathna, D. H. G. A. E. Jayasinghe, and S. N. Raman, "Feasible techniques for valorisation of construction and demolition waste for concreting applications," International Journal of Environmental Science and Technology, vol. 20, no. 1, pp. 521-536, Jan. 2023, doi: 10.1007/s13762-022-04015-z.

[3] J. J. Bolden, "Innovative uses of Recycled and Waste Materials in Construction Application," Greensboro, North Carolina, 2013.

[4] H. K. A. Al-Bayati, P. K. Das, S. L. Tighe, and H. Baaj, "Evaluation of various treatment methods for enhancing the physical and morphological properties of coarse recycled concrete aggregate," Constr Build Mater, vol. 112, pp. 284-298, Jun. 2016, doi: 10.1016/j.conbuildmat.2016.02.176.

[5] A. B. Ceesay and S. Miyazawa, "Strength development and durability of concrete containing recycled roof tile aggregate,"

Recycling, vol. 4, no. 3, 2019, doi: 10.3390/recycling4030029.

[6] B. R. K. C. Dembatapitiya, W. D. S. H. Dissanayake, and T. M. Pallewatta, "Calicut Tile Waste as an Alternative Coarse Aggregate for Lower Grade Concretes," Journal of Engineering and Technology of The Open University of Sri Lanka (JET-OUSL), vol. 1, no. 1, 2013.

[7] D. A. B. P. M. Jayasekara, S. T. N. Jayathilaka, and H. M. C. C. Somarathna, "Feasibility of Waste Calicut Tiles as Aggregates in Structural Concrete," International Conference on Engineering - 2022, Aug. 2022. [Online]. Available: https://www.researchgate.net/publication/363153145

[8] H. Dilbas, Cakir, and C. D. Atis, "Experimental investigation on properties of recycled aggregate concrete with optimized Ball Milling Method," Constr Build Mater, vol. 212, pp. 716-726, Jul. 2019, doi: 10.1016/j.conbuildmat.2019.04.007.

[9] S. Rajasekaran and S. Saha, "Efficient Algorithms for Sequence Assembly 1," 2011.

[10] F. Moghadas Nejad, M. Arabani, G. H. Hamedi, and A. R. Azarhoosh, "Influence of using polymeric aggregate treatment on moisture damage in hot mix asphalt," Constr Build Mater, vol. 47, pp. 1523-1527, 2013, doi: 10.1016/j.conbuildmat.2013.06.060.

[11 M. Pettinari, G. Dondi, C. Sangiorgi, and O. Hededal, "The effect of Cryogenic Crumb Rubber in cold recycled mixes for road pavements," Constr Build Mater, vol. 63, pp. 249-256, Jul. 2014, doi: 10.1016/j.conbuildmat.2014.04.060.

[12] S. N. Abbas, M. I. Qureshi, M. Abid, M. A. U. R. Tariq, and A. W. M. Ng, "An Investigation of Mechanical Properties of Concrete by Applying Sand Coating on Recycled High-Density Polyethylene (HDPE) and Electronic-Wastes (E-Wastes) Used as a Partial Replacement of Natural Coarse Aggregates," Sustainability (Switzerland), vol. 14, no. 7, Apr. 2022, doi: 10.3390/su14074087.

[13] Y. G. Zhu, S. C. Kou, C. S. Poon, J. G. Dai, and Q. Y. Li, "Influence of silane-based water repellent on the durability properties of recycled aggregate concrete," Cem Concr Compos, vol. 35, no. 1, pp. 32-38, Jan. 2013, doi: 10.1016/j.cemconcomp.2012.08.008.

[14] F. Agrela, A. Barbudo, A. RamÃŋrez, J. Ayuso, M. D. Carvajal, and J. R. JimÃl'nez, "Construction of road sections using mixed recycled aggregates treated with cement in Malaga, Spain," Resour Conserv Recycl, vol. 58, pp. 98-106, Jan. 2012, doi: 10.1016/j.resconrec.2011.11.003.

[15] ASTM C33/C33M -23,Standard Specification for Concrete Aggregates 1, 2023. doi:10.1520/C0033-C0033M.

[16] "ASTM C136/C136M -23, Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates 1" 2023.

[17] ASTM C127 - 15, Standard Test Method for Density, Relative Density (Specific Gravity), and Absorption of Coarse Aggregate 1. 2015.

[18] ASTM C29/C29M - 23, Standard Test Method for Bulk Density ("Unit Weight") and Voids in Aggregate 1. 2023.

[19] ASTM C 566 - 04, Standard Test Method for Total Evaporable Moisture Content of Aggregate by Drying 1. 2004. [Online]. Available: www.astm.org

[20] BS 812-Part 110-1990, Methods for determination of aggregate crushing value (ACV). 1990.

[21] ASTM C 131 - 03, Standard Test Method for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine 1. 2003.

[22] BS 812-112-1990, Methods for determination of aggregate impact value (AIV). 1990.