Enhancing intermediate temperature fracture resistance of stone matrix asphalt with untreated recycled concrete aggregate - Experimental dataset

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Data Article

Enhancing intermediate temperature fracture resistance of stone matrix asphalt with untreated recycled concrete aggregate—Experimental dataset

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ABSTRACT

This data article presents details on the assessment of fracture parameters of laboratory asphalt mixtures produced using both natural and recycled concrete aggregates. The gap-graded stone matrix asphalt (SMA) is created by incorporating Trinidad Lake Asphalt (TLA) binder with carefully calibrated mixtures of recycled concrete aggregates (0 %, 10 %, 35 %, and 50 %) and natural aggregates (limestone and dust filler). The dataset variables were chosen based on the specifications of the single-edge notched beam (SENB) and semi-circular bending (SCB) tests, which are currently used for quality control and assurance (QC & QA) assessment of asphalt concrete mixtures. The data parameters provided include air void content, voids in mineral aggregates, voids filled with asphalt, density, Marshall Stability, Flow, test temperature, peak loads, RCA content, and notch depths. The fracture resistance of the mixes was studied by analysing the fracture energy, tensile strength, and fracture toughness for the collected dataset. The data shows that incorporating up to 10 % of RCA into SMA mixes, similar fracture properties can be achieved compared to traditional SMA mixtures. This presents a sustainable and environmentally advantageous op-

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tion, however, it is important to exercise caution as the RCA content increases.

Specifications Table

Subject	Engineering
Specific subject area	Fracture resistance of recycled construction aggregate used as sustainable pavement materials in road infrastructure.
Type of data	Table, Image, Figure, Raw, Analysed
Data collection	The compositions of asphalt concrete were derived from those samples that were prepared in the laboratory. The Marshall mix design and fracture evaluation methodologies were utilised to create and manufacture the asphalt concrete samples. The samples were made up of stone matrix asphalt, and each of them contained four different compositions of recycled concrete aggregate content. The Marshall test procedure was utilised to determine the volumetric properties. On the other hand, the results for the fracture behaviour were obtained by the utilisation of the Single-edge notched beam (SENB) and the semi-circular bending (SCB) tests, as indicated in Fig. 2. Before being subjected to testing, the fracture test was carried out on mixtures that had been prepared for a minimum of three days and conditioned for a minimum of three hours in the environmental chamber at the temperatures that were being tested.
Data source location	Primary data sources: University of the West Indies, Trinidad and Tobago.
Data accessibility	Repository name: Mendeley Data Data identification number: 10.17632/zc4t3×8w59.1 Direct URL to data: https://data.mendeley.com/datasets/zc4t3×8w59/1
Related research article	Leon, L.P., Smith, J. and Frank, A. (2023) Intermediate Temperature Fracture Resistance of Stone Matrix Asphalt Containing Untreated Recycled Concrete Aggregate. Baltic Journal of Road and Bridge Engineering, 18(1): pp.94–121, 10.7250/bjrbe.2023-18.590

1. Value of the Data

Data assessing the fracture resistance of stone matrix asphalt (SMA) with untreated recycled concrete aggregate (RCA) is important across different fields. The dataset serves as a fundamental resource for creating predictive models or computational tools that forecast the intermediate temperature fracture resistance of SMA with untreated RCA. These models can utilise statistical analysis, machine learning methods, or mathematical formulations. Researchers can use the dataset to study the impact of adding untreated RCA to SMA on fracture resistance at moderate temperatures. This aids in the progress of sustainable construction methods and materials engineering.

The dataset assists in quality assurance procedures by offering insights on the performance of SMA blends with untreated RCA, aiding engineers and agencies in verifying compliance with durability and performance criteria. Assessing the fracture resistance of Shape Memory Alloy (SMA) with untreated Recycled Concrete Aggregate (RCA) promotes sustainable construction methods through the utilisation of construction waste materials. This minimises the environmental footprint of construction activities and preserves natural resources. It is essential to have precise evaluations of fracture resistance at intermediate temperatures to create long-lasting and strong pavement systems. This knowledge assists engineers in choosing suitable materials and mixture designs to improve the durability of infrastructure. Studying the impact of untreated RCA on SMA fracture resistance helps in creating cost-effective pavement designs by maximising material efficiency and reducing maintenance and repair costs during the infrastructure's lifespan.

Civil engineers with expertise in pavement design, building, and maintenance would use the dataset to create durable Stone Mastic Asphalt mixtures that include untreated Recycled Concrete Aggregate to guarantee long-lasting performance and sustainability. Materials science and engineering experts in asphalt technologies and sustainable materials can use the dataset for research and development to improve the mechanical qualities and durability of SMA mixtures. Organisations in charge of infrastructure planning, standards creation, and regulatory compliance can use these datasets to create recommendations and specifications for integrating recycled materials into asphalt mixtures while ensuring that performance and safety criteria are maintained. Contractors in the construction industry, particularly road building projects, can utilise the dataset to enhance material selection, mixing designs, and quality control methods, resulting in cost-effective and long-lasting pavement solutions.

A thorough dataset on the use of recycled elements in asphalt and their impact on fracture analysis is an essential resource for the scientific community. It promotes environmental sustainability, enhances economic efficiency, encourages material innovation, improves infrastructure performance, and facilitates informed policymaking. This dataset enables researchers and industry professionals to make informed decisions that improve the sustainability and resilience of transportation infrastructure by providing a comprehensive understanding of how recycled materials affect the properties and performance of asphalt, especially in terms of fracture resistance. This essential dataset in assessing the intermediate temperature fracture resistance of SMA with untreated RCA is also very crucial for advancing sustainable construction practices, ensuring infrastructure durability, and informing decision-making for civil engineers, materials scientists, government agencies, and construction industry stakeholders.

2. Background

The life cycle approach in road engineering consists of the stages such as production, construction, utilization, end-of-life, and recycling [1]. As a result, several studies have explored composite pavement, recycling pavements, and the use of waste materials as aggregate in asphalt mixes [2,3]. Common material substitutions for constructing sustainable pavements include recycled asphalt pavement (RAP), polymers, rubber, steel slag, and recycled concrete aggregate (RCA). Recycled concrete aggregate is an aggregate made from concrete construction and demolition debris that can replace conventional natural aggregates partially or entirely [4]. Whether utilising conventional natural aggregate or a mixture of recycled aggregate, asphaltic concrete may experience pavement degradation due to substandard design or insufficient durability throughout its lifespan. Pavement distress appears in various forms, primarily through cracking; however, there is an inadequate understanding of the characteristics related to how cracks start and spread within the asphalt [5]. The fracture energy of asphalt represents the energy needed to create a new crack surface, whereas fracture toughness measures the energy absorption until failure [6]. Comprehending the initiation and propagation stages of the cracking process is crucial, as failure occurs when the available fracture energy is surpassed. Temperature changes can cause brittle and ductile material breakdown [7]. This research utilised the work-of-fracture method to ascertain the fracture energy of asphalt concrete, chosen for its established background and testing simplicity. SENB and SCB tests have been introduced to analyse the fracture properties of asphalt mixes. The study aims to examine how adding RCA affects the fracture behaviour of SMA. Comparing stone matrix asphalt with recycled concrete aggregates to stone matrix asphalt with only traditional natural aggregates is important in fracture mechanics and behaviour assessment, especially in specific climatic conditions like tropical climates with temperatures consistently exceeding 15 °C throughout the year.

3. Data Description

As can be seen in Table 1, the experimental findings of the TLA straight-run asphalt binder are reflected in the dataset. These values include penetration, specific gravity flash point, and viscosity. As highlighted in Table 2, Specific Gravity, Water Absorption, Sand Equivalent, Soundness, LA Abrasion, and Unit Weight measures are some of the properties of the aggregates included in this category. The data set contained four gap-graded mixtures that were accomplished through the use of stone matrix asphalt (SMA). These combinations were given the designations SMA0, SMA10, SMA35, and SMA50, respectively. In the SMA mixtures, the natural aggregate replacement represented by the numeric designation is the recycled concrete aggregate (RCA), which is expressed as a percentage of the total mass of the natural aggregate replacement. The SMA mixtures are not only distinct from one another in terms of their RCA content (which ranges from 0 %, 10 %, 35 %, to 50 %, respectively), but they also differ in terms of the gradation specifications that they possess, as demonstrated in Graph 1 and Table 4. The aggregate quantities and combinations used in the construction of asphalt concrete mixes are detailed in Table 3,

Table 1
Characteristic of the locally used asphalt binder (60/75 TLA).

Property	Value
Specific gravity @ 25 °C (g/cm^3)	1.012
Penetration @ 25 °C (mm-10)	72
Softening Point (°C)	52
Flash Point (°C)	283
Kinematic Viscosity @ 135 °C (Pa.s)	0.414

Table 2
Properties the study aggregates.

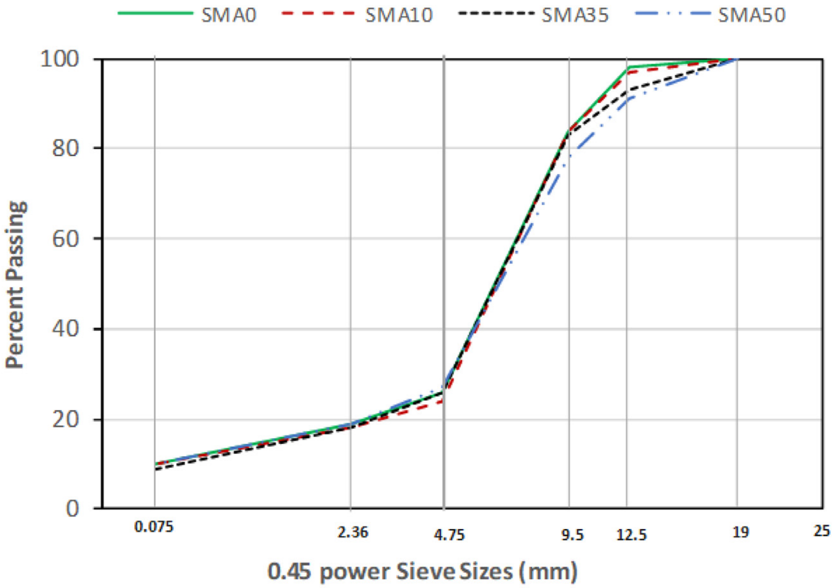
Aggregate property	Limestone	RCA
Specific Gravity	2.629	2.266
Water Absorption (%)	1.2	7.7
pH	7.95	10.88
Aggregate impact value	26.7	36.0
Aggregate crushing value	28.4	32.7
LA Abrasion	33	43

Table 3
Mix Design aggregate percentage proportions for the SMA mixtures.

Mix Type / Aggregate	SMA0	SMA10	SMA35	SMA50
12.5 mm Limestone	27	21	4	0
9.5 mm Limestone	49	49	43	34
Limestone Dust	15	10	9	5
Filler	9	10	9	11
RCA	0	10	35	50

Table 4
Particles sizes and gradation of the SMA mixes.

Mixture / Sieve Sizes (mm)	SMA0	SMA10	SMA35	SMA50
19	100	100	100	100
12.5	98	97	93	91
9.5	84	84	83	78
4.75	26	24	26	27
2.36	19	18	18	19
0.075	10	10	9	10



Graph 1. Gradation of SMA asphalt concrete mixtures.

which describes these elements. The dataset is archived in the Mendeley Data repository in the form of Excel files, which are formatted in the following manner and are explained as follows:

- The initial file contains data pertaining to mix parameters, Single-edge notched beam (SENB), and semi-circular bending (SCB) testing. The two test procedures are categorised based on the specific testing temperatures of 5, 15, and 25 °Celsius, respectively.
- The second file has a comprehensive dataset consisting of several parameters (peak load, notch length, temperature, fracture characteristics) organised into distinct Excel worksheets according to the testing methodology used (SCB and SENB).

Table 5 provides Marshall's volumetric and strength properties for the SMA mixture.

Table 5
Description of the average volumetric and strength properties of the SMA mixtures at 4 % air voids.

Properties	SMA0	SMA10	SMA35	SMA50
Optimum binder content - OBC (%)	5.1	5.4	5.8	6.4
Voids in mineral aggregates – VMA (%)	13.5	13.6	13.6	15.1
Voids filled with asphalt - VFA (%)	72	68	67	58
Density (kg/m^3)	2390	2358	2280	2204
Stability (kN)	8.5	8.2	10.5	7.5
Flow (mm)	2.7	3.2	3.3	4.4

4. Experimental Design, Materials and Methods

The bitumen component was acquired from Trinidad Lake Asphalt and the municipal road agency in Trinidad. The National Quarries Company Ltd., a publicly owned government quarry in Trinidad, provided the natural mineral aggregates used in the creation of asphalt concrete mixes. The recycled concrete aggregate was sourced from a concrete cube extracted from a nearby building site, with a claimed design strength of 30 MPa. The cubes were pulverised with a sledgehammer and then further processed in a jaw crusher to attain the desired maximum aggregate size of ½".

The SMA asphalt concrete compositions were produced in the highway and transportation laboratory situated at the Department of Civil and Environmental Engineering at the University of the West Indies in Trinidad and Tobago. The Marshall Mix Design methodology was employed to design the mixture. The samples consisted of blends created from four separate types of combinations. The combinations included Stone Mastic Asphalt (SMA) blends that were composed of four varying levels of Recycled Concrete Aggregate (RCA) content: 0 %, 15 %, 35 %, and 50 %.

To prepare the SENB samples, the asphalt mix was compressed into a flat shape using a mechanical roller compactor (Fig. 1). The mould was altered to produce slabs of 300 mm × 300 mm × 75 mm. Next, a damp masonry saw was employed to fashion narrow beams from the slab, each measuring around 25 mm in width. The ends of these beams were subsequently discarded. The beam samples were notched at heights of 10 mm, 15 mm, and 20 mm. This process was iterated for every mix design until an adequate number of samples were collected, ensuring three samples for each test temperature and notch length. The dimensions and weights of the beam samples (Fig. 1) were measured and recorded for the purpose of estimating bulk-specific gravity and for further examination. The SCB samples were compacted using a Superpave gyratory compactor, like the method used for the SENB samples, as depicted in Fig. 1. A 150 mm diameter mould was utilised in the preparation of the sample for the SCB test. Every sample was prepared following the appropriate mix design. After the cylindrical sample was extruded and cooled, it was then sliced into circular pieces with a thickness of 25 mm. Each circle was subsequently divided into a semi-circle, as depicted in Fig. 1, and the outermost parts were removed. Notches

Fig. 1. Sample preparation setup (a) roller compactor (b) gyratory compactor (c) SENB (d) SCB.

Table 6
Geometric properties of the SCB test samples.

Property	Density (kg/m^3)	Air Voids (%)	Temperature, T (°C)	Thickness, B (mm)	Height, r (mm)	Notch length, a (mm)	Ligament Area, A_{lig} (mm^2)
SMA0							
Min	2368.5	1.2	5.0	24.0	69.0	15.0	2836.8
Average	2432.0	3.0	15.0	29.5	72.5	24.1	3714.2
Max	2456.9	5.0	25.0	32.0	76.0	31.8	4320.0
Std. Dev.	23.8	1.2	8.3	2.4	2.6	7.1	377.6
Skewness	−1.3	0.3	0.0	−0.8	0.0	−0.3	−0.5
Kurtosis	1.9	−1.5	−1.6	−0.6	−1.9	−1.6	0.2
SMA10							
Min	2405.6	1.1	5.0	27.0	68.0	15.0	3191.4
Average	2425.2	2.9	15.0	29.6	72.4	24.1	3724.0
Max	2449.0	5.6	25.0	32.0	77.0	31.8	4320.0
Std. Dev.	12.5	1.4	8.3	2.0	2.9	7.1	355.9
Skewness	0.2	0.7	0.0	−0.3	0.1	−0.3	0.2
Kurtosis	−0.9	−0.8	−1.6	−1.7	−1.6	−1.6	−0.8
SMA35							
Min	2301.6	1.7	5.0	21.5	68.0	15.0	2902.5
Average	2353.2	3.1	15.0	28.9	72.2	24.1	3635.7
Max	2389.2	5.2	25.0	32.0	76.0	31.8	4185.0
Std. Dev.	27.4	1.1	8.3	2.5	2.9	7.1	358.4
Skewness	0.0	0.1	0.0	−1.1	0.0	−0.3	−0.3
Kurtosis	−1.4	−1.4	−1.6	1.2	−1.8	−1.6	−0.7
SMA50							
Min	2249.0	2.1	5.0	23.0	69.0	15.0	2836.8
Average	2291.1	3.2	15.0	25.4	71.9	24.1	3193.3
Max	2319.8	5.0	25.0	28.0	76.0	31.8	3645.0
Std. Dev.	23.5	0.9	8.3	1.4	2.1	7.1	231.4
Skewness	−0.6	0.6	0.0	0.3	0.3	−0.3	0.1
Kurtosis	−0.7	−0.8	−1.6	−0.9	−1.3	−1.6	−0.8

measuring 15 mm, 25.4 mm, and 31.8 mm were identified and made in different samples. Each sample had a notch width of 1.75 mm because the same saw blade was used to notch every sample.

The sample densities and test temperatures, together with the geometric parameters such as thickness (t or B), height (W or r), notch length (a), and ligament area (A_{lig}), were all documented and can be found in Tables 6 and 7. The SCB and SENB test setup, as shown in Fig. 2, was conducted using a universal testing machine (UTM) and the load (in newtons) displacement (in mm) curves were recorded separately for each tested sample. The test outputs were used to collect values of peak load, work of fracture (area under the curve), fracture energy, and fracture toughness. These measurements are provided in Tables 8 and 9. The dataset's statistical charac-

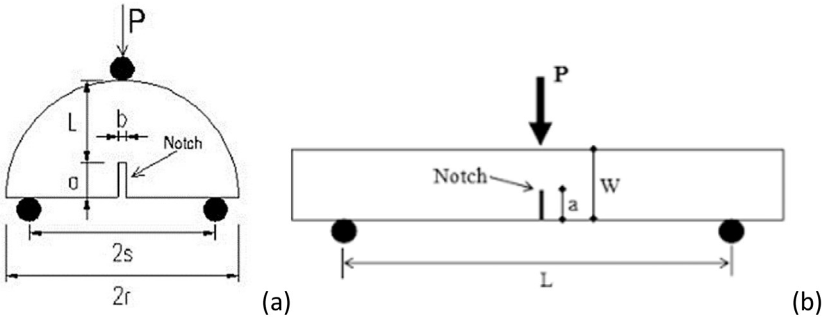


Fig. 2. Setup of the (a) SCB and (b) SENB tests.

Table 7
Geometric properties of the SENB test samples.

Property	Density (kg/m^3)	Air Voids (%)	Temperature, T (°C)	Thickness, t (mm)	Height, W (mm)	Notch length, a (mm)	Ligament Area, A_{lig} (mm^2)
SMA0							
Min	2177.4	1.6	5.0	45.0	23.0	10.0	5850.0
Average	2378.3	4.1	15.0	46.7	26.1	15.0	6305.0
Max	2435.7	8.0	25.0	48.0	33.0	20.0	6720.0
Std. Dev.	49.5	1.8	8.3	0.8	3.5	4.2	220.8
Skewness	−2.6	0.8	0.0	0.1	0.9	0.0	0.1
Kurtosis	10.3	0.5	−1.6	−0.4	−1.0	−1.6	−0.3
SMA10							
Min	2273.5	3.2	5.0	46.0	22.0	10.0	5980.0
Average	2336.6	4.8	15.0	47.8	23.9	15.0	6450.6
Max	2386.2	7.1	25.0	51.0	25.0	20.0	7140.0
Std. Dev.	29.5	1.0	8.3	1.1	0.8	4.2	266.3
Skewness	−0.3	0.6	0.0	1.0	−0.6	0.0	0.8
Kurtosis	−0.8	−0.6	−1.6	1.6	0.2	−1.6	0.9
SMA35							
Min	1846.2	4.0	5.0	43.0	21.0	10.0	5805.0
Average	2260.8	4.8	15.0	45.6	23.9	15.0	6155.2
Max	2328.2	8.2	25.0	49.0	26.0	20.0	6860.0
Std. Dev.	89.5	1.1	8.3	1.5	1.1	4.2	286.5
Skewness	−4.1	1.6	0.0	0.7	−0.8	0.0	0.9
Kurtosis	19.1	2.3	−1.6	0.4	0.9	−1.6	−0.1
SMA50							
Min	2169.5	3.0	5.0	43.0	21.0	10.0	5720.0
Average	2231.3	4.7	15.0	45.0	23.6	15.0	6080.4
Max	2280.1	6.8	25.0	47.0	26.0	20.0	6440.0
Std. Dev.	30.1	1.1	8.3	0.8	1.1	4.2	227.8
Skewness	−0.3	0.3	0.0	−0.1	−0.3	0.0	0.2
Kurtosis	−0.4	−0.6	−1.6	1.3	0.3	−1.6	−1.4

Table 8
Fracture properties for the SCB - SMA mixtures.

Property	Peak Load, P (N)	Work of Fracture (N.mm)	Fracture Energy, G_f (kJ/m^2)	Fracture Toughness, K_{IC}
SMA0				
Min	469.0	777.9	0.3	0.1
Average	1829.2	2673.8	0.7	0.2
Max	3384.0	5854.7	1.4	0.4
Std. Dev.	885.5	1453.0	0.3	0.1
Skewness	−0.03	0.63	0.42	−0.26
Kurtosis	−1.19	−0.17	−0.82	−1.54
SMA10				
Min	367.6	797.5	0.2	0.1
Average	1863.8	2384.6	0.6	0.2
Max	4335.0	5314.0	1.2	0.5
Std. Dev.	1189.3	1262.2	0.3	0.1
Skewness	0.60	0.82	0.48	0.51
Kurtosis	−0.75	−0.01	−0.93	0.41
SMA35				
Min	389.2	788.6	0.2	0.1
Average	1639.7	1969.6	0.5	0.2
Max	3392.0	4674.4	1.2	0.4
Std. Dev.	854.9	853.3	0.2	0.1
Skewness	0.34	1.48	1.17	−0.05
Kurtosis	−0.93	2.77	1.85	−1.35
SMA50				
Min	300.8	521.2	0.2	0.0
Average	1383.0	1930.5	0.6	0.2
Max	3580.0	4648.0	1.5	0.4
Std. Dev.	855.4	1050.2	0.3	0.1
Skewness	0.88	0.95	0.99	−0.08
Kurtosis	1.16	0.65	0.71	−1.40

Table 9
Fracture properties for the SENB - SMA mixtures.

Property	Peak Load, P (N)	Work of Fracture (N.mm)	Fracture Energy, G_f (kJ/m^2)	Fracture Toughness, K_{IC}
SMA0				
Min	13.3	73.3	0.0	0.0
Average	166.9	597.6	0.1	0.1
Max	422.5	1245.1	0.2	0.2
Std. Dev.	126.3	314.3	0.0	0.1
Skewness	0.62	0.35	0.31	0.49
Kurtosis	−0.79	−0.75	−0.70	−1.13
SMA10				
Min	18.3	96.9	0.0	0.0
Average	153.8	534.8	0.1	0.1
Max	390.0	991.0	0.1	0.1
Std. Dev.	98.9	249.2	0.0	0.0
Skewness	0.88	0.13	0.10	0.69
Kurtosis	0.02	−1.13	−1.19	−0.69
SMA35				
Min	24.3	94.0	0.0	0.0
Average	168.5	366.9	0.1	0.1
Max	410.0	623.1	0.1	0.1
Std. Dev.	100.9	164.0	0.0	0.0
Skewness	0.90	−0.04	−0.08	0.38
Kurtosis	0.58	−1.20	−1.20	−0.73
SMA50				
Min	39.3	151.6	0.0	0.0
Average	150.2	447.6	0.1	0.1
Max	332.4	743.8	0.1	0.1
Std. Dev.	91.0	187.2	0.0	0.0
Skewness	0.52	0.03	−0.05	0.46
Kurtosis	−0.81	−1.32	−1.36	−1.22

teristics, including the minimum, average, maximum, standard deviation, skewness, and kurtosis, were computed using Minitab software version 21.

Limitations

None

Ethics Statement

The proposed data does not involve any human subjects, animal experiments, or data collected from social media platforms.

Data Availability

Intermediate temperature fracture resistance of stone matrix asphalt containing untreated recycled concrete aggregate (Original data) (Mendeley Data)

CRediT Author Statement

Lee P. Leon: Conceptualization, Methodology, Software, Writing – original draft, Investigation; **Jovanca Smith:** Conceptualization, Methodology, Validation; **Hector Martin:** Validation, Writing – review & editing.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

[1] D.P.P. Meddage, A. Chadee, M.T.R. Jayasinghe, U. Rathnayake, Exploring the applicability of expanded polystyrene (EPS) based concrete panels as roof slab insulation in the tropics, Case Stud. Construc. Mater. 17 (2022) e01361, doi:10.1016/j.cscm.2022.e01361.
[2] M. Moazami Goodarzi, K. Naderi, F. Moghadas Nejad, Cracking resistance of hot-mix asphalt mixtures containing terminal blend rubberised asphalt nanocomposite at intermediate temperature, J. Mater. Civil Eng. 33 (10) (2021) Article 04021255, doi:10.1061/(ASCE)MT.1943-5533.0003875.
[3] J.S. Motter, L.F.R. Miranda, L.L.B. Bernucci, Performance of hot mix asphalt concrete produced with coarse recycled concrete aggregate, J. Mater. Civil Eng. 27 (11) (2015) Article 04015030, doi:10.1061/(ASCE)MT.1943-5533.0001284.
[4] G.O. Bamigboye, D. Ademola, M. Kareem, B. Orogbade, A. Odetoyan, A Adeniyi, in: Durability assessment of recycled aggregate in concrete production, The Structural Integrity of Recycled Aggregate Concrete Produced with Fillers and Pozzolans, Woodhead Publishing, 2022, pp. 445–467, doi:10.1016/B978-0-12-824105-9.00010-X.
[5] A. Milling, H. Martin, A. Mwasha, Design, construction, and in-service causes of premature pavement deterioration: a fuzzy Delphi application, J. Transport. Eng., Part B: Pavements 149 (1) (2023) Article 05022004, doi:10.1061/(ASCE)TE.1943-5436.0001135.
[6] Z.P. Bazant, J. Planas, Fracture and Size Effect in Concrete and other Quasi-Brittle Materials, 1st ed., Routlege, New York, 1998, doi:10.1201/9780203756799.
[7] L.P. Leon, J. Smith, A. Frank, Intermediate temperature fracture resistance of stone matrix asphalt containing untreated recycled concrete aggregate, Baltic J. Road Bridge Eng. 18 (1) (2023) 94–121, doi:10.7250/bjrbe.2023-18.590.