

Performance Evaluation of Porous Pavement Concrete Incorporating Recycled Construction and Demolition Aggregates

José Ximenes^{1*}, José Aguiar², Jorge Pais³, Carlos de Jesus⁴, Carlos Palha⁵

¹ Universidade Nacional Timor Lorosa'e
^{2,3,4,5} University of Minho

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*Correspondence: José Ximenes

Email: jujeximeness@gmail.com

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Abstract: The objective of this study is to develop porous cement concrete for road pavements using construction waste aggregates to achieve the required surface characteristics. The research method in this study was laboratory experiments involving a series of concrete mixtures with varying waste content between 10% and 30%. Meanwhile, the cement content and water/cement ratio remained constant, based on previous studies in which the effects of these variables had been evaluated. The results of this study show that the performance of porous cement concrete has undergone two types of permeability evaluation tests, laser measurements for flatness and texture analysis, and the British Pendulum Test for friction evaluation. The aggregate gradation follows the PA12.5 specification, with a maximum aggregate size of 14 mm, serving as a reference concrete without recycled aggregates. Mechanical strength tests were included in the performance evaluation to measure the durability of the concrete. The findings of this study indicate that porous cement concrete containing demolition waste is a viable and sustainable solution for managing demolition waste materials.

Keywords: Porous Concrete; Recycled Aggregates; Construction And Demolition Waste; Permeable Pavements; Skid Resistance

Introduction

In general, studies evaluating road surface characteristics are very important to ensure adequate drainage performance, safety, and road surface grip (Zuo et al., 2025 ; Zhang et al., 2024). Similar studies have developed several measurement techniques to measure road surface texture on different scales. These measurements include macro surface texture, which is generally performed using methods such as the sand patch test, flow meter, or Circular Texture Meter (CTM), which are based on two-dimensional (2D) texture profiles (Abe et al., 2001; Flintsch et al., 2003). Parameters such as Mean Texture Depth (MTD), Mean Profile Depth (MPD), and Mean Quadratic Depth (MQD) are widely used to describe the macro texture of pavement surfaces and evaluate its influence on water drainage and tire-pavement interaction (Chen et al., 2019). In addition to macro texture, microtextured of pavement surfaces plays a critical role in determining skid resistance, especially in wet conditions. Micro texture is typically evaluated using indirect friction

measurement devices such as the British Pendulum Tester (BPT), Dynamic Friction Tester (DFT), and Locked-Wheel Skid Trailer, which are commonly used to estimate the friction performance between tires and road surfaces at low speeds (Meegoda and Gao, 2015; Zuniga-Garcia and Prozzi, 2016). Recent studies investigating the micro texture of road surfaces have been evaluated in further studies using high-resolution cameras in laboratory environments to obtain more detailed texture information (Chen et al., 2019). Furthermore, advanced high-resolution laser devices have emerged as practical tools for capturing three-dimensional (3D) surface texture data, offering sufficient accuracy to describe both the micro and macro textures of road surfaces (Meegoda and Gao, 2015). The acquisition of high-resolution surface texture information can greatly facilitate the analysis of the contribution of micro and macro textures to skid resistance (Zuniga-Garcia and Prozzi, 2016). In addition, 3D surface texture parameters have found widespread application in modern manufacturing industries to control and evaluate product surface quality (Leach, 2013). This distinguishes modern manufacturing from traditional manufacturing. For example, Leach (2013) emphasizes this difference, where traditional parameters only cover height information, while 3D surface texture parameters cover surface height, spatial information, hybrid, functional, and feature aspects. In this study, these parameters enable the characterization of surface texture functions and provide insights into texture characteristics from various perspectives that cannot be achieved by traditional texture parameters (Li et al., 2016). It is well known in similar literature from recent studies that researchers specializing in this field have attempted to evaluate road surface texture using 3D area parameters and establish correlations with friction resistance (Li et al., 2017; Peng et al., 2019; and Zou et al., 2021). Thus, this research study in this article uses 3D area parameters to assess changes in road surface texture due to traffic loads.

Concrete paving facilitates natural groundwater recharge and accelerates water evaporation from subsurface layers (Shaban et al., 2019 and Wang et al., 2020). The subsurface layer can be seen from the advantages of porous paving, which include sound absorption (Shaban et al., 2021), reduction of surface heating and the Urban Heat Island effect (Tam and Tam, 2007), and filtration of contaminants in water (Li et al., 2019).

The rationale for this study is based on strong literature data from previous studies by the above researchers, where the study in this article stems from our motivation as researchers to examine the widespread exploitation of natural resources for personal gain, a phenomenon that has been going on for years but is not environmentally friendly and damages the balance of the ecosystem. Unbeknownst to many, this exploitation has contributed to environmental degradation and the gradual deterioration of ecosystems where human activities take place. For instance, the amount and types of waste have increased in line with population growth, urbanization, and industrialization.

Therefore, this study focuses on the development of permeable concrete for road paving applications by utilizing Construction and Demolition Waste (CDW). The goal is to achieve a long-term sustainability system in terms of environmental policy for the circular economy, while addressing the scarcity of new resources due to environmental policies as previous researchers had done before these most recent and relevant studies (Shuvo et al., 2026; Pessoa, 2024; Duraiswamy et al., 2024; and Chen et al., 2025). The scope of the study covers the evaluation of mechanical and functional characteristics, supported by a series of

laboratory tests on three concrete mixtures with recycled aggregates and reference concrete. For mechanical properties related to concrete pavement performance, compressive strength, flexural strength, dynamic modulus, and fatigue resistance were evaluated. For functional properties, air content, permeability, average texture depth, friction resistance, and 3D and 2D macro texture were evaluated (Subash et al., 2025; Khadka et al., 2025; Rusida et al., 2025; Chelurri et al., 2025; Ozel et al., 2025; Ferić et al., 2023; Ali et al., 2025; Fanijo et al., 2023; Kos et al., 2023; Hamada et al., 2023; Alhazmi et al., 2021; Alao, 2012).

This analysis is certainly very significant in contributing to the specific literature on the understanding of determination of cement concrete size, which allows for appropriate mechanical and functional performance when it comes to being applied in road surface construction.

Methodology

In the methodology session of this research, the research materials and methods are explained in detail in each sub-session of the discussion. In the sub-session material, the development of this research work, there are four materials used: Portland Cement 42.5 R, sand, normal aggregate, and construction and demolition waste (CDW) aggregate, which are presented in Table 1 Mechanical properties of Portland Cement CEM I 42.5 R, Table 2 Aggregate Particle Size Distribution, Table 3 Physical properties of normal aggregates, Table 4 Propriedades físicas do agregado reciclado, and Table 5 Composition of porous concrete, and further in Figure 1 Aggregate size distribution of REF, 10%, 20%, and 30% CDW cement porous concrete, Figure 2 Recycled aggregates used in this study, and Figure 3 Appearance of the slab and beams for laboratory tests. Meanwhile, in the method sub-session, this study presents three different types of CDW concrete, namely with CDW contents of 10%, 20%, and 30%, and the reference concrete was tested and compared using laser equipment. Thus, all concrete was produced with a water-cement ratio of 0.30 and compacted with vibration for 40 seconds. The material sub-section and method sub-section are presented in detail as follows:

Materials

For the development of this investigation, four materials were used: Portland Cement 42.5 R, sand, normal aggregates, and Construction and Demolition Waste (CDW) aggregates. Portland Cement (CEM I 42.5 R) (Instituto Português da Qualidade, IPQ, 2012). It has an ignition loss of 2.3%, a specific weight of 3120 kg/m³, and a Blaine fineness of 4072 cm²/g. The mechanical strengths of the cement at 2, 7, and 28 days are listed in Table 1.

Table 1. Mechanical properties of Portland Cement CEM I 42.5 R

Time (days)	Strength (MPa)	
	Flexural	Compressive
2	5.6	31.8
7	7.5	47.0
28	8.5	55.5

The aggregates utilized in the production of cement concrete comprised a blend of fine aggregate 0/4 mm, aggregate 4/10 mm, and aggregate 10/14 mm, which were combined with 10%, 20%, and 30% of CDW, respectively, to achieve the particle size distribution outlined in Table 2, by the Portuguese Construction Specifications for road pavement materials. Concurrently, concrete was fabricated using solely new aggregates following the average gradations of reference CDW concretes, denoted as REF, and it possesses the aggregate distribution as presented in Table 2.

The aggregate distribution for the Reference (REF) and CDW is depicted in Figure 1, where it is evident that all four concretes exhibit the same aggregate gradation, with only minor variations observed in the 6.3 mm sieve. However, all variations fall within the limits stipulated by the Portuguese Specifications for porous concrete (Estradas de Portugal, S.A, 2014). The physical properties of recycled aggregates in terms of density and fragmentation resistance are indicated in Table 3 and Table 4. Concerning density, it is evident that new aggregates from a granite quarry typically exhibit a density of around 2.6-2.7 kg/m³, consistent with granites, while CDW has a density of approximately 2.2-2.3 kg/m³, relatively low for aggregates. This lower density results from the mixture of various materials present in the CDW. CDW aggregates comprise concrete and mortar from counterweight, recycled aggregate coating, and structural concrete mix, as depicted in Figure 2. Despite the lower density, CDW demonstrates good fragmentation resistance (36%) compared to recycled aggregates (20-23%).

Table 2. Aggregate Particle Size Distribution

Size (mm)	Lower Limit	Upper Limit	Percentage (%)			
			REF	10% CDW	20% CDW	30% CDW
14.00	100,00	100,00	100,00	100,00	100,00	100,00
12.50	100,00	100,00	99,00	100,00	100,00	100,00
10.00	90,00	100,00	91,00	95,27	90,54	90,81
6,30	47,00	64,00	47,50	62,33	56,54	50,76
4.00	27,00	39,00	27,00	31,30	27,24	27,21
2.00	22,00	32,00	22,00	21,27	22,00	21,94
1.00	15,00	28,00	15,00	17,96	16,50	15,49
0,50	13,00	25,00	13,00	13,52	13,95	13,00
0,063	7,00	11,00	7,00	9,10	9,00	7,98
0.00	0,00	0,00	0,00	0,00	0,00	0,00

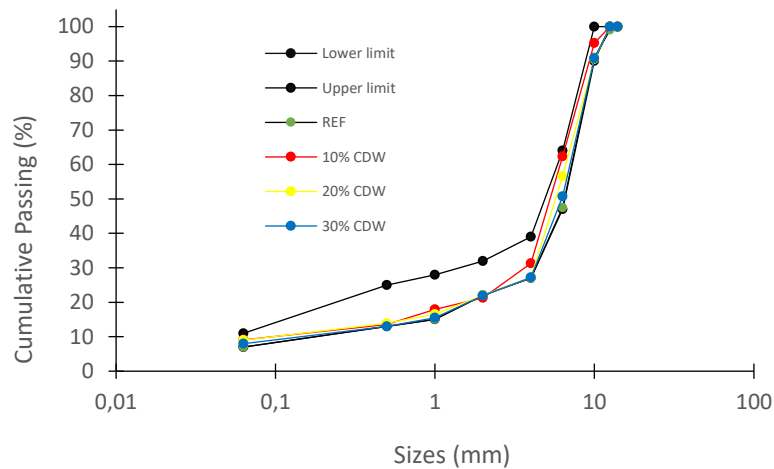


Figure 1. Aggregate size distribution of REF, 10%, 20%, and 30% CDW cement porous concrete

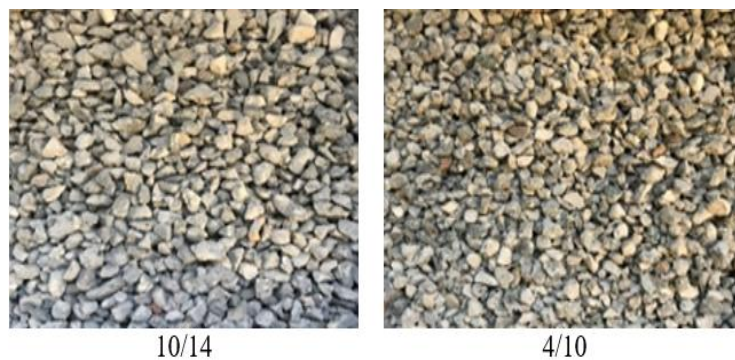


Figure 2. Recycled aggregates used in this study

Table 3. Physical properties of normal aggregates

Property	Unit	EN Standard (European Standard)	Aggregates		
			0/4	4/10	10/14
Normal density	kg/m ³	EN 1097-6:2016 [18]	2670	2660	2620
Normal aggregate fragmentation resistance (Los Angeles)	%	EN 1097-2:2011 [19]	-	20.64	23.17

Table 4. Propriedades físicas do agregado reciclado

Property	Unit	Padrão EN (Norma Europa)	Agregados	
			4/10	10/14
Recycled density	kg/m ³	EN 1097-6:2016 [18]	2273	2242
Recycled aggregate fragmentation resistance (Los Angeles)	%	EN 1097-2:2011 [19]	36.10	36.90

The porous concrete was prepared with a water-to-cement (W/C) ratio of 0.30 and subjected to vibration for 40 seconds. Four concretes were produced: one reference concrete

without CDW, and three concretes with CDW, containing 10%, 20%, and 30% of CDW, respectively. The composition of these concretes is outlined in Table 5.

Table 5. Composition of porous concrete

Concrete designation	Use of CDW	Composition (kg/m ³)					
		CEM I 42,5	Water	Ag. 0/4	Ag. 4/10	Ag. 10/14	CDW 4/14
REF	0% de CDW	300	90.0	22.0	1391.0	314.0	0
CDW 10%	10% de CDW		90.0	22.4	1091.1	160.5	184.0
CDW 20%	20% de CDW		90.0	22.6	929.6	136.8	368.0
CDW 30%	30% de CDW		90.0	22.9	769.0	112.9	551.0

For each porous concrete, a slab with dimensions of 400×400×80 mm³ was manufactured for sand patch tests, British Pendulum friction tests, and texture tests. The appearance of the slab (hardened concrete) and beams viewed from the slabs for laboratory tests can be observed in Figure 3, along with the surface texture where the porosity of the concretes is visible.

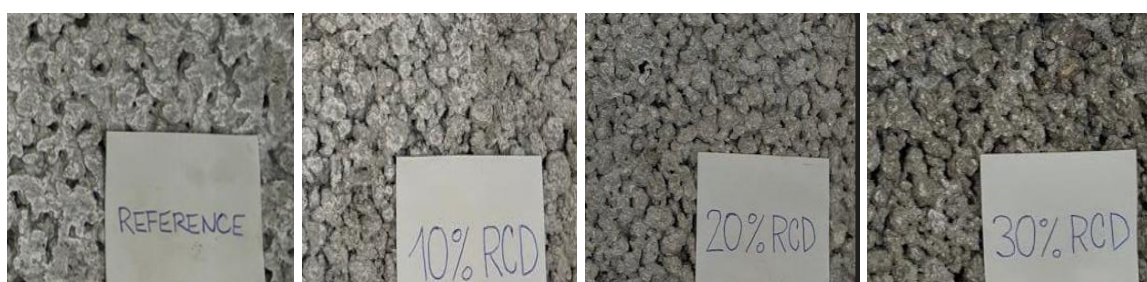


Figure 3. Appearance of the slab and beams for laboratory tests

In this study, three different CDW concretes (with 10%, 20%, and 30% CDW) and a reference concrete were examined and compared. All concretes were produced with a water-to-cement ratio of 0.30 and subjected to vibration for 40 seconds. The test program comprised assessments of both fresh and hardened concrete. The workability of the fresh concrete was evaluated using the Vibe test according to the EN 12350-3 standard (NP EN 12350-3, 2009). For hardened concrete, functional and mechanical tests were conducted to assess their properties and compare CDW concrete with the reference concrete. Before undergoing functional and mechanical tests, all specimens were subjected to saturation in a curing chamber by the EN 12390-2 standard (European Committee for Standardization (CEN), 2009)).

Functional properties were evaluated through the following tests:

- Permeability tests were conducted at LCS (Laboratório la Caminhos Santander) using the KLCS permeametry method to calculate the flow rate of CDW concretes, following the Spanish standard NLT-327/00 (IPQ, 2000). The test involved cubic specimens measuring 150×150×150 mm and slabs measuring 400×400×80 mm. A total of six cubes and four slabs were utilized at various test points for the assessment.

- FH (Falling Head) Permeability Test: For this test, two concrete cylinders were prepared, each with dimensions of 100 mm in diameter and 200 mm in height. To prevent any leakage from the transverse sides, the specimens were sealed within extendable sleeves and placed in closed plastic tubes, ensuring no water leakage while flowing axially through the sample, following the guidelines of ACI 522R-2010 (American Concrete Institute Committee, ACI 522R-10, 2010).
- Immersion porosity for void content measurement was conducted according to NP 581/69 (NP – 581, 1969). This measurement was carried out by the EN 12350-1 standard (NP EN 12350-1, 2009). to verify compliance with the recommendation of maintaining a void content between 15% and 35% of the total concrete volume.
- Sand Patch Test: The measurement of macrotexture using the sand patch method (ASTM E965-96) (ASTM International - ASTM E965-96, 1996) involves spreading a known volume of sand or glass microspheres ($25000\text{mm}^3 \pm 150\text{mm}^3$) over the pavement surface with circular movements of a suitable device, such as a wooden spreader with rubber coating. The size of the patch is measured in four directions, and the average is taken to calculate the height of the macrotexture, or sand height. The specimens used are plates measuring 400x400x80 mm.
- British Pendulum Friction Test: The tests were conducted on all slabs measuring 400x400x80 mm. The principle of the pendulum test involves a standard rubber slider mounted at the end of a pendulum arm. The pendulum arm is released from a horizontal position, and the energy loss as the slider assembly passes over the specimen surface is measured by the reduction in the length of the upward movement using a calibrated scale. This method provides a measure of the slip or skid resistance properties of a surface in both field and laboratory settings. The samples used were produced in the laboratory, did not undergo any wear from traffic circulation, and were tested under identical conditions.
- Surface Characterization Tests for Evaluating Concrete Surface Macrotexture: The macrotexture of the surfaces was evaluated by calculating the Average Profile Depth (APD) using laser equipment, as per Anglo-Saxon terminology. Surface characterization was conducted utilizing the laser equipment depicted in Figure 4.



Figure 4. Appearance of the laser equipment for profile depth

Mechanical properties were assessed through the evaluation of:

- Compressive Strength: Hydraulic equipment was employed to ascertain the compressive strength of the concrete. During this test, a loading rate of 13.5 kN/s was

applied, adjusted according to the size of the specimens (150 x 150 x 150 mm). Four types of specimens were utilized for each concrete, by the EN 206:2013+A1:2017 standard (IPQ, 2017).

- Flexural Strength Tests: Specimens measuring 400 × 100 × 100 mm³ were utilized, following the guidelines outlined in EN standards EN 12390-1 and EN 12390-5 (CEN, 2003). Three specimens of each concrete were subjected to these tests.

Result and Discussion

Fresh Concrete

To assess the fresh concrete, the Vibe test (IPQ, 2009) was employed, utilizing the following criteria: extremely dry (32-18 s), very stiff (18-10 s), stiff (10-5 s), stiff plastic (5-3 s), and plastic (3-0 s). The results obtained indicated a medium stiff class, characterized by a Vebe test duration of 5 to 10 seconds, as illustrated in Figure 5A.

The concretes exhibit good workability, as indicated in Figure 5B. Those produced with Construction and Demolition Waste (CDW) display Vibe test results closely resembling the reference concrete. The concrete with 20% CDW showed the closest resemblance to the reference test. However, increasing the CDW content resulted in reduced Vibe test results, indicating normal to good workability. Although the CDW workability test increased slightly, it approaches the limit of stiff concrete.

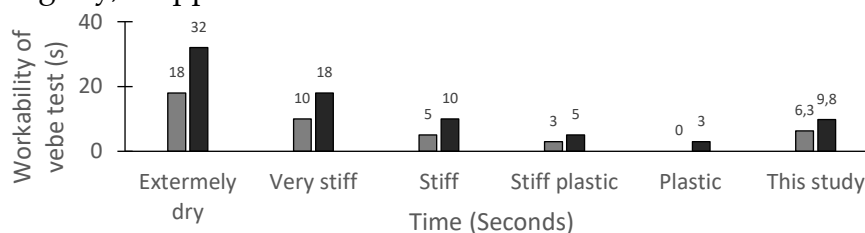


Figure 5. Comparison of Vebe test and workability standard

Permeability and Porosity

The water permeability values measured with the LCS permeameter should be between 10 and 35 seconds. If both percentages of aggregates used meet the specifications defined in 14.03.2.4 for the specific mixture, the lower one is adopted.

In addition to the procedures referred to in item 15.03.2.2-3, the following should be considered: a mixture of normal concrete (REF) and three concretes with different percentages of recycled coarse aggregates is applied, with the amount of cement and vibration being the same.

The permeability and porosity of the concretes were evaluated by the following: Permeability test using LCS, obtaining a permeability coefficient k ranging from 19.6 to 34 mm/s for slabs and from 4.6 to 12.9 mm/s for cubes. Falling Head (FH) permeability test with a permeability coefficient k ranging from 2.5 to 12 mm/s. Porosity test by immersion where the results range from 18.6% to 21.9%.

The results of these three tests for all concretes are indicated in Figures 6 and 7, where the results obtained are within the limits of the standard, and the results from published

articles, as shown in Figure 6A, comparing the LCS permeability test is 19.6 - 34.0 mm/s. The results obtained in the test program of this work were compared with the literature indicated in Figures 6A, 6B, and Figure 7.

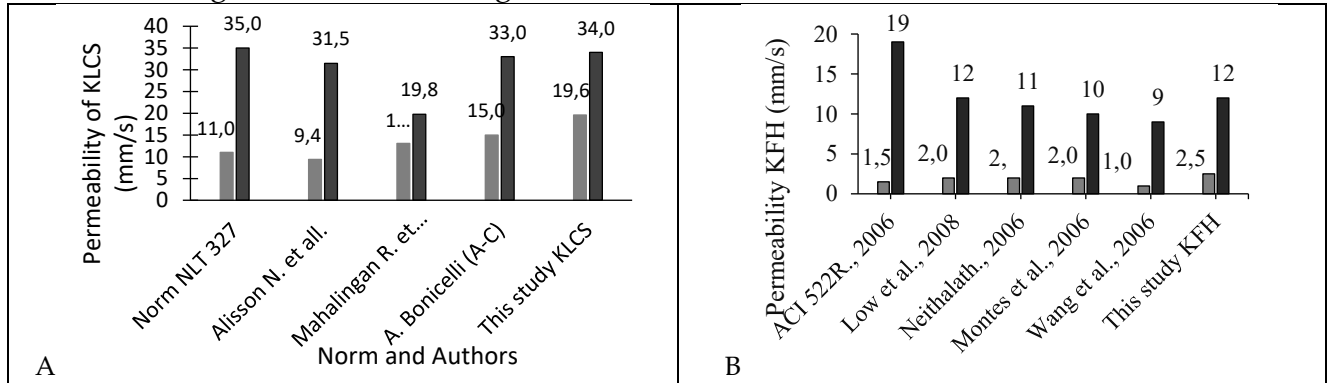


Figure 6. A) Comparison of LCS permeability test [22, 32, 33, and 34] and B) FH permeability [23, 27, 35, 36, and 12] with standards and published articles

The results of the KFH permeability tests for draining concrete cylinders are shown in Figure 6B; the tests are compared with other published tests. The results of the porosity tests with draining concrete cubes (100x100x100 mm) are compared with other published tests in Figure 7.

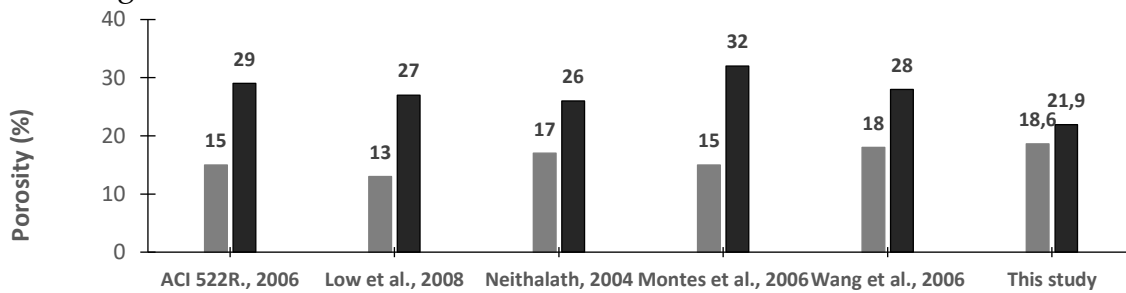


Figure 7. Comparison of immersion porosity with standard and articles [22, 27, 35, 36, and 12]

Sand Patch Tests, Average Texture Depths, British Pendulum Friction

The Portuguese specifications for porous asphalt pavements [37] specify that the average texture depth (PMT) should be greater than 1.2 mm. This value is defined for porous asphalt concrete but can be used as a reference for cementitious concrete pavements. From the analysis of the PMT results in Figure 8B, it is concluded that the PA 12.5 type mixtures (REF concrete and 10%, 20%, and 30% CDW) are not within the normal range because they are above 1.2 mm from the normal test.

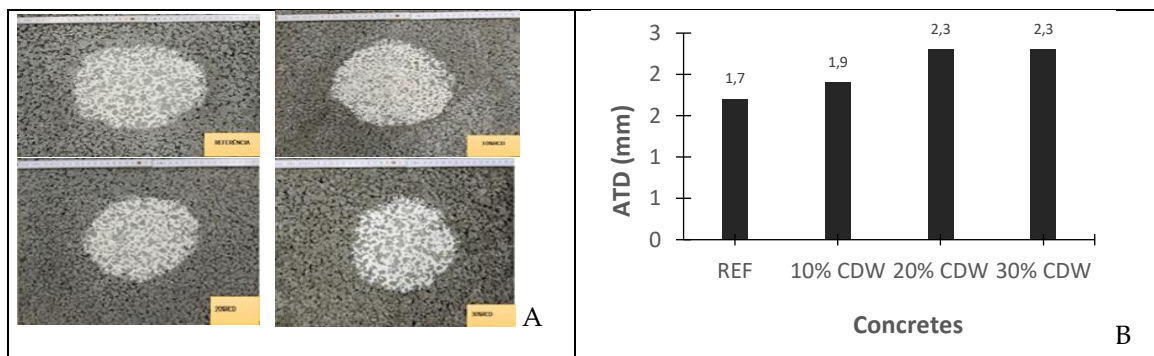


Figure 8. A) Sand patch tests and B) average texture depth (PMT) tests

Slip resistance/skid resistance is a property of the traveled surface that limits the relative movement between the tire contact of a vehicle and the surface.

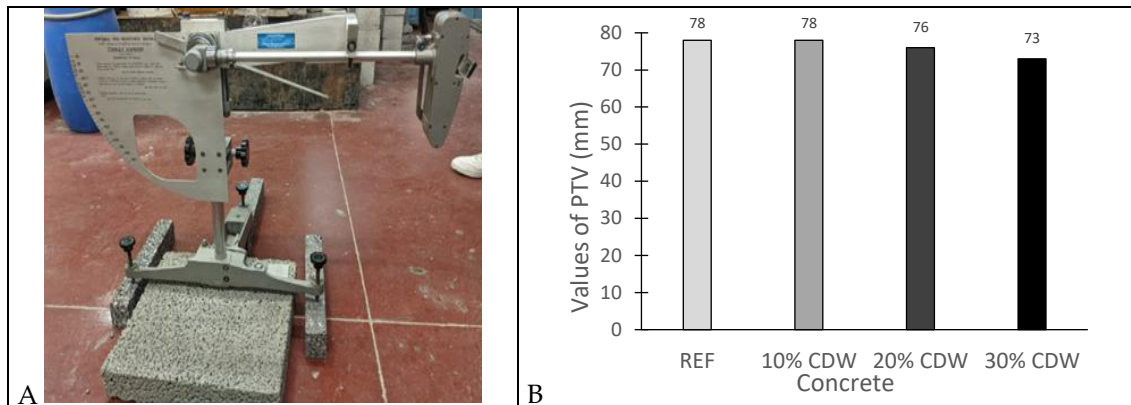


Figure 9. A) British Pendulum tests and test slab, B) test results

Upon analyzing the tests in Figure 9B, it was found that the results show that the texture of the concrete is good for friction and prevents aquaplaning in rainy seasons.

Compressive and Flexural Strength Tests

Table 6 presents the results of compressive and flexural strength for each concrete. With a range of values between 8.9 to 21.7 MPa, the results show that the tested concretes meet the technical requirements.

Table 6. Results of compressive and flexural strength tests

Concrete Mixtures	Use of CDW	Strength (MPa)	
		Compression	Flexural
REF	0% de CDW	21,7	4,3
10% CDW	10% de CDW	8,9	2,1
20% CDW	20% de CDW	18,6	3,7
30% CDW	30% de CDW	16,7	3,6

This concrete with 10% CDW is not sufficient for normal and heavy construction pavement, but it can be used for constructing pavement for pedestrian, bicycle, and motorcycle traffic. In this study, a moderate conclusion is that 20% CDW is close to the reference result.

Conclusion

This study's conclusion is divided into two parts: substantive conclusions (interdisciplinary *rationale* and recommendations for future research in a brief synthesis) developed by da Costa (2024) and technical conclusions (study results) which is based on this investigation's tests conducted in the civil engineering laboratory.

Substantive Conclusions

This study produces long-term objectives and recommendations for the foundation of integrating civil engineering, earth sciences, and climate change, as well as measurement efficiency within the framework of ecology and the circular economy (interdisciplinary suggestions) from da Costa (2024), an Indonesian-Timorese Senior Expert, Research Professor Fellow, and Collaborative Project Lead in Europe, Prof. Dr. rer. nat. Apolonia Diana Sherly da Costa. She is an expert in Interdisciplinary Earth Science Resilience in Institute of Landscape Ecology, University of Münster, Germany, In her Springer's book titled: "Building Resilience for Flood Disaster", published by Springer Nature in the Springer Natural Hazards Series, a synthesis of environmental engineering, geography, climate change adaptation, socio-ecology, economic, and human activities combination for further research encapsulates a unique trajectory of cross-disciplinary science that puts them together into a single scientific account of her discovery. The theoretical framework of this comprehensive interdisciplinary study conducted by da Costa (2024) conformed by previous researchers, Zhang et al., (2024) regarding "A Structural Optimization of Urban Drainage Systems: An Optimization Approach for Mitigating Urban Floods" which then align with and inspire the objectives and recommendations of this research as there are further scientific aspects that merit further exploration, which this study has not yet addressed. Thus, the foundation of this laboratory research-article draws on specialized scientific recommendations from da Costa's integration on her own expertise of interdisciplinary earth science resilience by which her expertise spans also in geography, environmental/flood disaster-rescue engineering, and climate change adaptation, combined with civil/human activities, ecology, circular economy, and sustainability science pioneered by her. Therefore, in the context of future research, specifically regarding climate change adaptation—it is also necessary to prioritize resilience against blockages and long-term hydrological efficiency which this study hasn't researched yet. This flood resilience and hydrological efficiency stem from permeable concrete integrated with CDW. The objectives and recommendations are to ensure this system remains effective and efficient. A specific example is aimed at reducing urban flooding by facilitating groundwater infiltration during unpredictable extreme weather events in the rainy season and during significant storms. Furthermore, the scientific recommendations and contributions of this research, when examined from the perspectives of geosciences and hydrogeology, suggest that, for instance, the use of a 10% CDW mixture should be reduced for low-load applications—such as pedestrian paths or bike lanes—with the aim of maintaining structural integrity and maximizing soil-water interaction in urban metropolitan areas. Furthermore, applying advancements in key scientific principles within the holistic field of environmental engineering, ecology, and the circular economy is pivotal, where investigations into mix designs can be optimized to examine in detail the use of any chemical admixtures and/or cementitious additives required. The benefit of applying the principles of holistic environmental engineering from these two scientific pillars is to balance and minimize the mechanical strength and stiffness modulus inherent in recycled aggregates. Thus, it can be concluded that the application of these two scientific pillars within the discourse on the

integration of civil engineering, geoscience, and climate change serves as a framework for the development and maintenance of a more resilient built environment in a sustainable manner. In conclusion, the use of sustainable materials from low-carbon initiatives in modern civil engineering can be wisely implemented in future cutting-edge research related to this topic.

Based on the synthesis of this research study's suggestion inspired by da Costa (2024), the findings are presented in the form of a list of data and a comprehensive discussion result of the *Technical Conclusions*.

Technical Conclusions

- The results of the Vebe test, conducted with a water-to-cement ratio (W/C) of 0.30 and vibration for 40 seconds, indicate a workability value ranging from 6.25 to 9.75 seconds. Additionally, the void content falls within the range of 3.20 to 7.96%, and the density of fresh concrete ranges from 1973.3 to 2139.0 kg/m³. The void volumes or porosity values range from 18.59 to 21.94%, suggesting that they comply with the standard requirements. These results collectively demonstrate satisfactory workability, void content, and density characteristics of the concrete, meeting the specified standards for the intended application.
- The porous surface of this mixture containing 10%, 20%, and 30% Construction and Demolition Waste (CDW) in addition to the reference mix offers the advantage of not requiring grooves in surface construction.
- Based on the results presented and discussed in this article, permeable concrete was identified as optimized due to its mechanical performance, respecting permeability specifications.
- With compressive strength values ranging from 8.9 MPa to 21.7 MPa, it was demonstrated that all concretes tested met the requirements for permeable concrete compressive strength. While the compressive strength of 8.9 MPa for the concrete containing 10% Construction and Demolition Waste (CDW) may not be suitable for supporting normal vehicular traffic, it can still be utilized for floors intended for the transportation of motorcycles, bicycles, and pedestrians in urban and metropolitan areas.
- Analyzing the results of sand patch tests, British pendulum tests, and texture analysis, it was confirmed that the incorporation of recycled aggregates generally leads to a reduction in strength, likely due to the increased stiffness modulus of recycled mixtures. Void contents were observed across the entire range of temperatures and frequencies. The purpose of testing this porous concrete is to prevent aquaplaning during the rainy season. The field study of macrotexture enabled us to conclude.

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