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Mix design and physical and mechanical properties of pervious concretes

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ABSTRACT: Fast-growing climate changes are known to have diverse impacts worldwide, even in large cities. Pervious concrete can be a successful safety solution for increasingly frequent heavy rains and floods. This study focuses on achieving an optimized pervious concrete within the scope of international standards by analyzing concretes made with different W/C ratios and vibration times. The results of the study show the strong influence of parameters such as porosity, permeability, and mechanical strengths. Concrete with 0.35 W/C ratio and 40 seconds vibration time was selected for its adequate physical and mechanical properties.

KEY WORDS: Pervious concrete; Water drainage; Permeability; Porosity; Compressive strength.

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RESUMEN: *Diseño de mezclas y propiedades físicas y mecánicas de hormigones permeables.* Los cambios climáticos cada vez más rápidos tienen impactos diversificados en todo el mundo, incluso en los grandes centros urbanos. El hormigón permeable puede ser una solución de seguridad exitosa para lluvias intensas e inundaciones cada vez más frecuentes. Este estudio se centró en lograr un hormigón permeable optimizado, dentro del alcance de los estándares internacionales, mediante el análisis de hormigones elaborados con diferentes relaciones A/C y tiempos de vibración. Los resultados muestran la fuerte influencia de parámetros como la porosidad, la permeabilidad y las resistencias mecánicas. Finalmente, se seleccionó un hormigón con relación A/C de 0.35 y tiempo de vibración de 40 segundos por sus adecuadas propiedades físicas y mecánicas.

PALABRAS CLAVE: Hormigón permeable; Drenaje de agua; Permeabilidad; Porosidad; Resistencia a compresión.

1. INTRODUCTION

Nowadays, society is focused on the risks associated with climate change, leading to serious, pervasive, and irreversible changes in economies and ecosystems worldwide (1). One of the most frequent effects of climate change is the severe rainfall that produces overflows in rivers and consequent floods in landfills, streets, and highways. The consequences of these phenomena are serious, both for populations and infrastructure, so solutions that minimize them have been implemented. One of these is the application of pervious surfaces to drain water which accumulates on pavement surfaces.

Pavement design in general, consists of determining the thickness of the pavement or of the several layers of which it is composed in order to resist the wheel loads of traffic and transmit them safely into the foundation soil. The present study was conducted considering pervious concrete in the wearing course.

Water in pavements is removed through a transverse slope and recently by providing pervious surfaces. In asphalt pavements, this technology is almost completely consolidated and successfully provides safe pavements during rainy conditions. However, for cement concrete pavements, more research is needed to consolidate efficient solutions.

Pervious concretes are materials of growing importance in building technologies and are currently used to build sustainable infrastructures and reduce the risks of urban floods. Pervious concrete can be found worldwide in the paving of roads, parking lots, sidewalks, viaducts, bike paths, or roadside drainage channels. It is also used in parks and residential areas, mainly due to its high permeability (2).

Pervious concrete is a sustainable building material which is made of widely available and easily handled materials (3). It contributes positively to environmental sustainability by removing the first flush pollutants from superficial water (e.g., engine oil or antifreeze liquids), reducing contamination hazards of underground water and nearby lakes.

Tennis et al. (4) show that pervious concrete presents high performance in removing pollutants from water. Portland cements achieved removal rates of 82% and 95% of suspended solids pollutants (5). Pervious pavements can increase circulation safety by preventing water build-up and reduce risks from hydroplaning, reduced surface ponding, glare, or even slipping (6).

According to Hendrickx (7), pervious concrete also reduces road noise. The pervious material structure allows easy escape for air trapped between tire and pavement, causing lower frequency road noise.

Pervious concrete provides several important environmental benefits, such as reducing the effect of urban heat islands, refilling of aquifers, and the effective reduction of rainwater runoff (8). By allowing infiltration of rainwater into soils with vegetation, pervious concrete reduces the need for water irrigation in urban landscapes (3). Therefore, pervious concrete can play an important role in achieving greener buildings and sustainable infrastructures (3).

Due to their great importance and growing use in different construction types, pervious concretes are referenced in the Storm Water Technologies Fact Sheet Bioretention by the United States Environmental Protection Agency for rainwater runoff management (9). However, the use of pervious concrete requires an appropriate mix design of concrete specimens. This affects the physical and mechanical properties such as permeability, porosity, and strength of the concrete.

The mechanical strength of pervious concrete is inversely proportional to porosity (10, 11). Typically, porosity ranges from 15% to 35%, which affects the permeability, mechanical strength, and durability (12). Solid advances in knowledge can be found in the literature on this topic (13), in which tests were carried out to determine porosity, whereas (14) and (15) analyzed mechanical parameters. (15) and (10) examined and characterized the material's acoustic parameters.

Pervious concrete porosity varies from 15% to 25% (16). The National Ready-Mix Concrete Association (NRMCA) indicates a minimum recommended value of 15% (17). Although porosity is widely accepted as an indicator of pavement permeability (18), it has been demonstrated that other parameters must be analyzed for an accurate prediction of permeability. Therefore, pervious concrete's porosity depends on both the W/C [Water/Cement] ratio and compaction during the making (19) studied the unit cost of ingredients for this type of mixture and concluded that the W/C had no significant effect on the unit cost of porous concrete, although it has a considerable effect on strength.

Achieving a suitable ratio between pores and mechanical strength will lead to optimized pervious concrete that is designed to meet specific performance requirements. Thus, the aim of this work is to develop a pervious concrete that is can be applied in concrete road pavements. The development of this concrete will be carried out by testing three W/C ratios and three vibration times. In the study, an appropriate aggregate was chosen in terms of size. According to (20), porosity is the main factor for estimating the efficiency of pervious concrete, with performance being more affected by aggregate type than size.

Because of their various advantages, concrete pavements are widely used worldwide (21). To design the concrete pavements, various design methods (22-25) are used in different countries. In most design guides (22, 24), resistance of concrete slabs and erosion of slab supports are two common cases of design failure. The purpose of the design is to determine the slab thickness required to resist the repeated application of axle loads during the life span of the pavement. In addition, flexural strength, modulus of elasticity and density are the important properties of concrete which are used to determine the required pavement thickness. Since the properties of the aggregates are used in preparing the concrete mixtures, it thus has an important impact on the properties of the concrete used in the design and its required thickness values. This may significantly alter based on the type of aggregate used.

The performance of the pervious concrete will be evaluated by assessing: i) fresh concrete workability by means of the slump, vee bee, density and air-void content tests; ii) hardened concrete with the following tests: immersion porosity, permeability, compressive strength and abrasion resistance.

At the end of the study, several recommendations are given for future research and design works. The authors believe that the results, discussions and recommendations of this study that are presented in the scope of the laboratory study will be highly beneficial for future studies and design applications, especially including the use of recycled aggregates.

2. MATERIALS AND MANUFACTURE OF PERVIOUS CONCRETE

2.1 Materials

Pervious concretes were produced from cement, water, and fine and coarse aggregates. Aggregates were produced by a specific process to obtain spherical or rounded-aggregate-shaped grains [empirical-based process], providing a uniform distribution of the different particle sizes in the concrete. Portland cement (CEM I 42.5 R) was used (26) with the properties shown in Tables 1 and 2.

Table 1. Portland cement CEM I 42.5 R properties (26).

Properties	Values
Accumulated diameter for 10% [µm]	1.33
Accumulated diameter for 50% [µm]	9.3
Accumulated diameter for 90% [µm]	24.2
Ignition loss [%]	2.33
Specific weight [kg/m^3]	3120
Blaine fineness [cm^2/g]	4072

It is assumed that the materials used, other than cement, are local materials and coarse and fine aggregates, natural sand and other materials available locally in all countries.

Table 2. Portland cement CEM I 42.5 R strength properties.

Age	Strength [MPa]	
	Flexural	Compressive
2	5.6	31.8
7	7.5	47.0
28	8.5	55.5

The use of water in concrete has two functions: to activate the binder and give the concrete workability. From the point of view of hydraulic activation of the binder material, the literature generally states that 23% of water in the binder is necessary to activate it, with the remaining amount destined for workability.

An important factor is the origin of the water used. NP EN 1008 (27) regulate the application of water in concrete and makes considerations about the source of the water, e.g., potable water.

Aggregates used in the concrete production were a mix of fine (0/4 mm aggregate), and coarse (4/10 mm and 10/14 mm aggregate) that allowed the particle size distribution presented in Table 3 to be obtained, following Portuguese construction specifications (28). Table 3 shows a synthesis of the particle size distribution of the aggregates. Table 4 shows the physical properties of the aggregate.

Table 3. Aggregate particle size distribution.

Sieve opening size [mm]	0.063	4	10	14	16
Cumulative passing [%]	0.0	13.5	49.1	37.4	100

Table 4. Physical properties of the aggregates.

Properties	Units	Standard	Aggregates		
			0/4	4/10	10/14
Density	kg/m^3	EN 1097-6	2670	2660	2620
Resistance to fragmentation [Los Angeles method]	%	EN 1097-2	-	20.64	23.17

Pervious concretes were prepared with different water/cement (W/C) ratios, 0.30, 0.35, and 0.40, and submitted to different vibration times (3000 vibrations/min at 50 Hz) during 20, 40, and 60 seconds. As shown in Table 5, nine concretes were made. For each concrete, three cubic specimens (150×150×150 mm) were made, making a total of 27 specimens. The aspect of the specimens can be seen in Figure 1.

Table 5. Pervious concrete mixes.

Water Cement	Vibration (s)	Quantities of materials [kg/m³]			
		CEM	Agg. 0/4	Agg. 4/10	Agg. 10/14
0.30	20	300	25	1391	324
	40				
	60				
0.35	20		22	1364	314
	40				
	60				
0.40	20		19	1337	305
	40				
	60				

In the production of the concrete specimens, care was taken to adjust the manufacturing process. After 24 hours, the specimens are removed from the mold and marked for curing in the chamber for up to 28 days at a temperature of 20ºC as per standard EN-12390-7 (29).

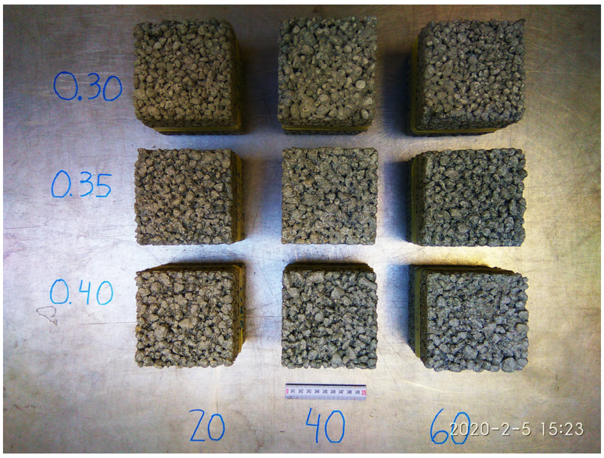

Figure 1. Aspect of the specimens made with different W/C ratios (horizontal label) and vibration times (vertical label).

2.2 Manufacture of pervious concrete

Rigid pavements are made up of a cement concrete slab, which can rest directly on the foundation (in the case of roads subject to low traffic) or contain other layers between the foundation and the concrete slab, namely, layers of lean concrete.

For the pervious concrete design, the nine pervious concretes produced in the laboratory were tested for assessing:

2.2.1 Fresh concrete tests

Workability was tested by means of the slump and vee bee tests. The conventional slump test and the vee bee test were used to assess the concrete's rheological behavior. The slump test followed European standard EN 12350-2 (30). The Vee bee test followed European standard EN 12350-3 (31). A slump cone was placed into the cylinder container of the vee bee test equipment.

Next, fresh concrete density and air-void content were analyzed. Fresh concrete was tested by analyzing and correlating fresh density EN 12350-6 (32) with the air-void content EN 12350-7 (33).

2.2.2 Hardened concrete tests

After seven days the specimens are considered to be hardened concrete. Before the test, the dimensions of the specimen were measured in different positions and the average values of the areas and volume were calculated with calipers or rulers. The specimens were tested in accordance with the standard for testing hardened concrete EN-12390-7 (29).

2.2.2.1 Porosity by immersion

Considering that the porosity increase is matched with a decrease in strength on pervious concrete, the selection of the binder is of vital importance.

The porosity of pervious concrete mixtures has been calculated based on the following European standards, EN-12390-7 (29) and EN 1097-6 (34). Three specimens of each type of mixture with dimensions 100x100x100 mm were used to study the porosity in order to obtain an adequate mean of values. Each specimen was initially saturated. Then, lateral faces were sealed with an extendable sleeve. Finally, the bottom face was placed over an acrylic plate, and the resulting joints were sealed with silicone.

2.2.2.2 Permeability

The weight of each saturated specimen with the complete setup was recorded. Afterwards, the membrane was filled with water and weighed. The weight of the added water is the difference between the two weights. The value obtained is quantified as the percentage of pores.

The concrete permeability was characterized and assessed by determining the kf permeability [coefficient falling head], according to standard NLT327/00 (35). Following (36) and the report standard 522R-06 (37), the falling head permeability test was used for this purpose, as depicted in Figure 2a. Cylindrical specimens (100 mm in diameter and 200 mm in height) were used to test each concrete. Three specimens were used for each concrete.

Each specimen (with a cross-section of AC) was connected to a graduated cylinder (with a cross-section of AP), filled with de-aired water. Side leakage was prevented by sealing the specimen inside an extendable sleeve (Figure 2b).

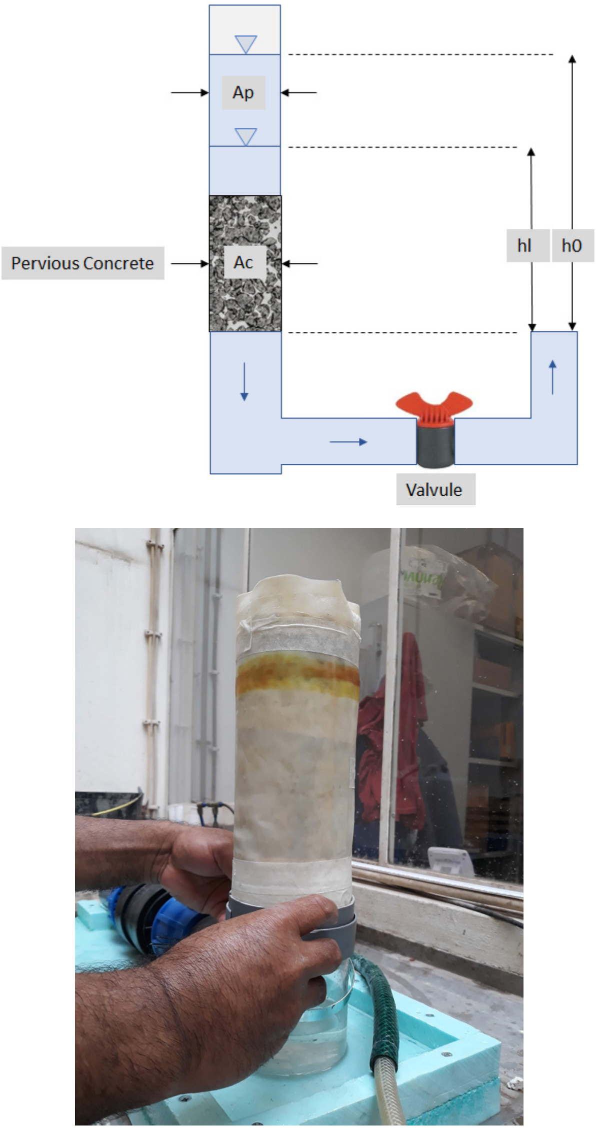

FIGURE 2. a) Schematics of the falling head permeability test apparatus and b) image of specimen preparation.

The water flows through the specimens, where kf is the permeability coefficient (mm/s). The test tube is filled with water to a given height h0 (mm), and after the valve of the test tube is opened, the water flows until it reaches h1. The test time is recorded between h0 and h1. The permeability coefficient was calculated using the Darcy equation (Equation [1]):

$$k_f = \frac{A_p \times L}{A_c \times t} In\left(\frac{h_0}{h_1}\right) \qquad [1]$$

where:
K_f– permeability coefficient (mm/s)
A_p– transparent pipe of cross-sectional area (m^2)
A_c– cross sections area (in m^2)
L – water traveled a distance (in m)
t – time (in seconds)
h_0 – level of water dropped zero (in m)
h_1– level of water dropped from height (in m)

Flow and permeability were determined using the LCS (laboratory la Caminos Santander) permeameter test, following the Spanish standard NLT-327/00 (35) as shown in Figure 3, using 150×150×150 mm cubic specimens. Three specimens per concrete were tested. Time was recorded for the flow of a given volume of water through a hole 3 cm in diameter. The flow resulting from the loss of water load was quantified by the permeability coefficient KLCS.

FIGURE 3. a) Schematics (32) and b) image of the permeameter used to quantify flow.

The permeability coefficient (K_{LCS}) was calculated based on the flow time T (in seconds), according to Equation [2]:

$$K_{LCS} = 7.624 - 1.348\,Ln\,T \qquad [2]$$

where:
K_{LCS} – permeability coefficient (mm/s)
T – time (s)
Equation [2] allows the characterization of pervious concrete permeability and validates the calculated coefficients in compliance with the technical requirements for pervious pavements defined in European standard EN 13108-7 (38).

2.2.3 The mechanical tests

The different concretes were tested for mechanical characterization, using specimens aged for 28 days. Strength was assessed by compression following EN 12390-3 (39). In the case of this test, a speed of 13.5 kN/s was applied according to the dimension of the specimen and perpendicularly to the faces of the specimen.

Abrasion resistance was evaluated using the abrasion test following the standard NLT-362/92 (40), in which the mass lost after 300 rotations at a speed of 33 rpm in the Los Angeles drum is measured. The smaller the test result, the higher the abrasion resistance.

In Spain, the method of formulating bituminous mixtures uses the Cantabro test, which was developed with the aim of evaluating the wear loss of the wear layer. This test consists of determining the mass loss due to wear of cylinder-type draining concrete specimens (Ø100 mm and 150 mm in height), subjected to 300 cycles in the Los Angeles wear machine, without balls.

The test consists of molding six specimens, of which three are placed in a humid chamber (CH) at 25ºC for 672 hours and the rest are initially immersed in water at 25ºC, where they remain for 28 days and are then removed from the water and kept in a free environment at 25ºC for 24 hours. After this time, the specimens were then measured at Ø 100 mm and 63 mm thick and weighed (40).

At the end of the test, the specimen is cleaned with a compressor and then the specimen is weighed and the Los Angeles coefficient (LA) (40) is calculated, based on Equation [3]:

$$\text{P}(\%) = \frac{P_1 - P_2}{P_1} x100 \qquad [3]$$

Where:
P = resistance of wear (%),
P1 = initial mass of the specimen (g),
P2 = retained mass (g).

3. ANALYSIS AND DISCUSSION OF THE EXPERIMENTAL RESULTS

The workability of the pervious concrete was assessed by the slump and vee bee tests (see Figures 4a and 4b, respectively), and the results are indicated in Table 5. The slump test results show a constant value of 0, consistent with typical workability behavior for pervious concretes.

FIGURE 4. a) Slump test and b) Vee bee test.

The results of the Vee bee test vary from 6.17 to 9.67 s, indicating that as the W/C ratio of the mixtures increases, the value of the vee bee test decreases, meaning that the concretes have higher workability, as expected.

3.1 Fresh concrete density and air content

Figure 5 presents the results of the fresh concrete density and air content. Density varies between 1886 kg/m^3 and 2088 kg/m^3, while air-void content varies between 4% and 7%. These values are consistent with the literature for pervious concrete (17).

Table 6. Workability parameters for the pervious concrete.

Concrete	Slump Test [mm] EN 12350-2:2016	Vee bee Test [s] EN 12350-3:2011
C0.30-20	0	
C0.30-40	0	9.67
C0.30-60	0	
C0.35-20	0	
C0.35-40	0	8.00
C0.35-60	0	
C0.40-20	0	
C0.40-40	0	6.17
C0.40-60	0	

The values presented in Figure 5 also show that air-void content is similar for the C0.30 and C0.35 concretes. C0.40 presents higher air-void content due to the higher water content. It seems that a correlation exists between air-void content and density.

3.2 Porosity

The porosity results, presented in Figure 6, are in the range between 20.1% and 24.6%. The lowest values were achieved by C0.40-40 and the highest by C0.30-40 concrete.

Porosity presents a linear trend according to the values observed in Figure 6. The trend is related to a relationship between the times of vibration and the water/binder ratios of each mixture. However, the porosity is significantly reduced as the W/C ratio increases, as seen in the trend in Figure 6. This is due to the better workability of the concretes with a higher W/C ratio. There is also a tendency to decrease the porosity with the increase of the vibration time. This is due to some segregation of the concrete with higher vibration times.

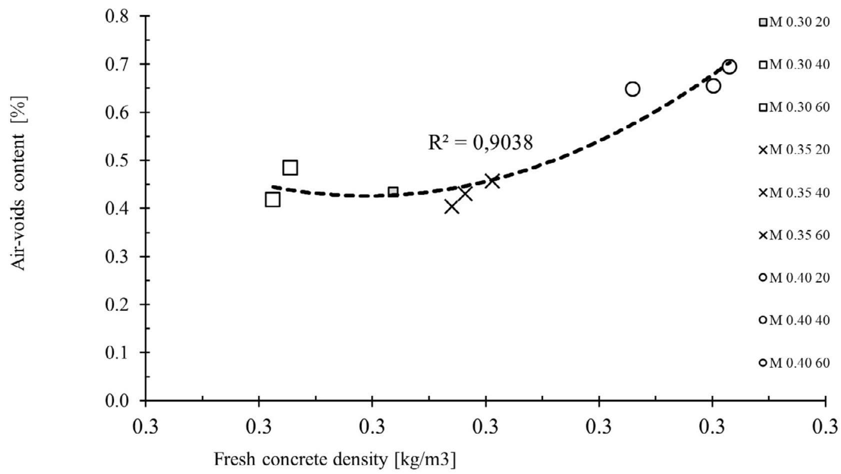

Figure 5. Correlation between air content and fresh concrete density.

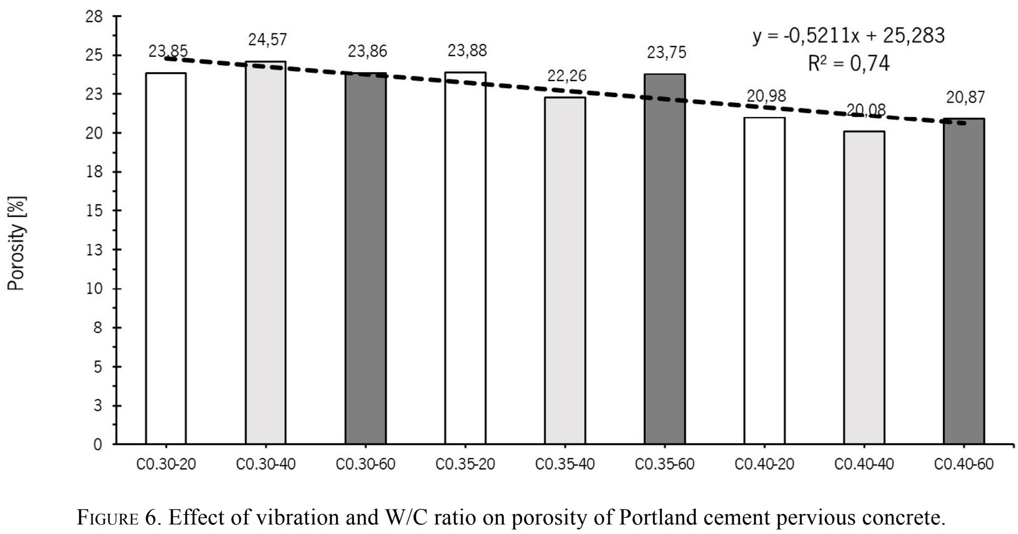

Figure 6. Effect of vibration and W/C ratio on porosity of Portland cement pervious concrete.

3.3 Permeability

Concrete permeability was evaluated by the falling head permeability test and the LCS test as described in the methodology. The results will be expressed as a function of the water absorption because they are related to the air voids in the concrete.

The permeability obtained with the falling head permeability test is indicated in Figure 7 compared to the permeability results, while Figure 8 presents the LCS permeability. The comparison between both permeabilities is indicated in Figure 9.

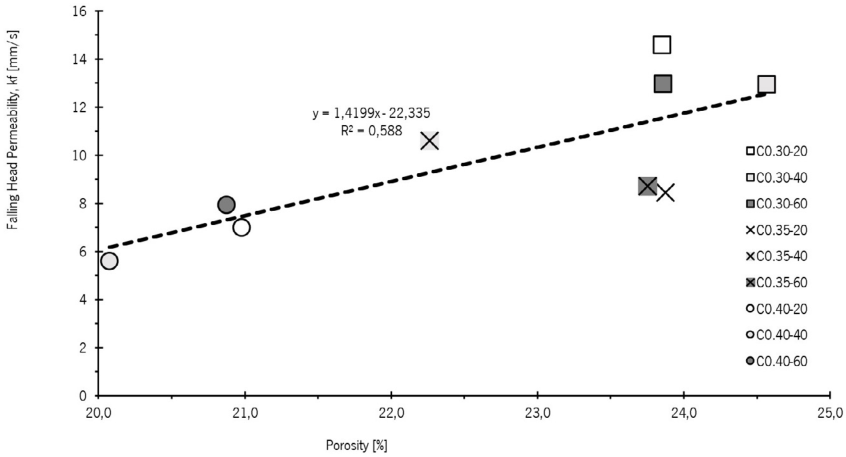

FIGURE 7. Permeability in falling head test.

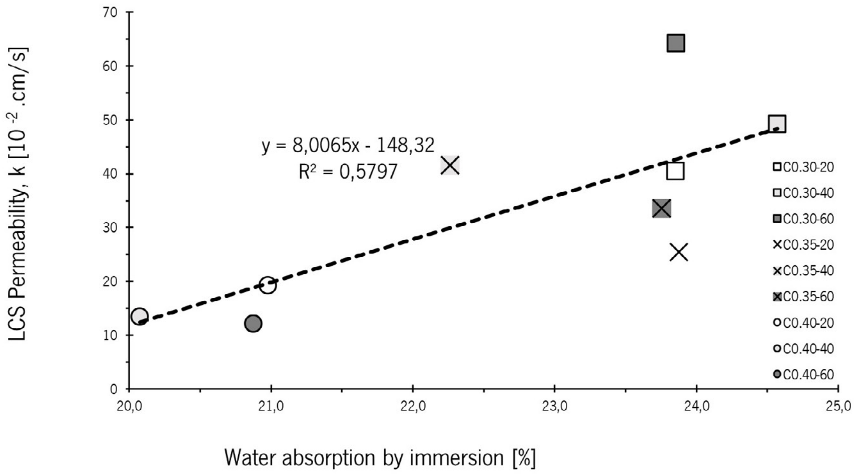

FIGURE 8. Permeability in LCS test.

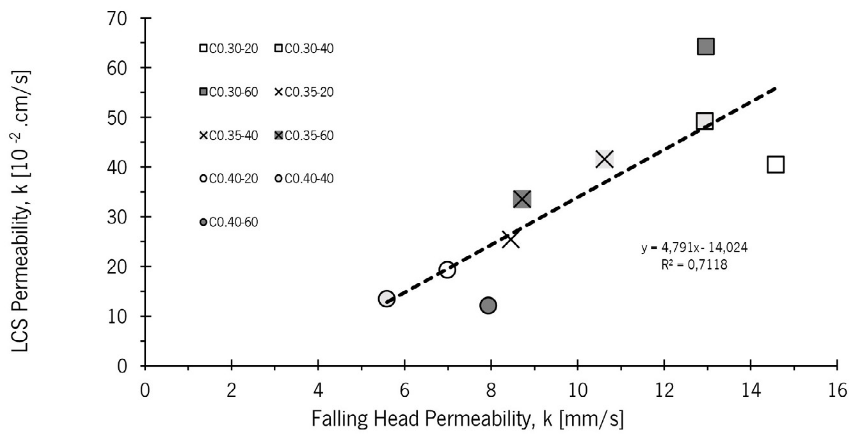

FIGURE 9. Correlation between falling head and LCS permeability.

Figure 7 shows that an increase in porosity is matched by an increase in falling head values, thus revealing the influence of vibration times over the porous structures of the mixes.

During the study, it became clear that increases in the W/C ratio of the mixes are related to lower porosity and permeability, as observed in both the falling head and LCS permeability tests results (Figure 7 and 8).

Figure 9 shows a linear correlation between the falling head and LCS permeability tests values. Such results confirm that higher W/C ratios are related to lower permeability values in both tests, as previously explained. This is due to the greater workability.

Technical requirements in EP – Estradas de Portugal (28) for pavement surface courses, following the in situ permeability parameters of standard NLT-327 (35), require acceptable drainage values for pervious concretes in a range between 10 and 30 seconds. These correspond to a LCS coefficient of permeability between 20.89 and 91.85 (10^{-2} cm/s).

The results of the study show that C0.30 and C0.35 concretes comply with such requirements. C0.30 permeability values fall into the minimum limit value, whereas C0.35 shows acceptable mid-range values. Therefore, C0.35 results comply with acceptable technical requirements for pervious concrete wear layers for pavements. The concretes tested were also rated for vertical permeability according to European Standard EN 13108-7 (38), as shown in Table 7.

The results of the study show that all tested concretes comply with EN 13108-7 (38) standard regarding application of pervious concretes. C0.30 is rated as superior class (kv4.0), whereas C0.40 is rated as low class (kv1.0 – kv1.5) but with considerable vertical permeability values.

Table 7. Minimum vertical permeability requirements for pervious concretes.

Min. vertical permeability [10^{-3} m/s]	Category - k_v	Concrete
4.0	$k_{v4.0}$	C0.30
3.5	$k_{v3.5}$	
3.0	$k_{v3.0}$	
2.5	$k_{v2.5}$	C0.35
2.0	$k_{v2.0}$	C0.35
1.5	$k_{v1.5}$	C0.40
1.0	$k_{v1.0}$	C0.40
0.5	$k_{v0.5}$	
0.1	$k_{v0.1}$	
n.a.	k_{vNA}	

3.4 Compressive strength

Figure 10 presents the compressive strength results for each concrete tested. With a range of values between 16 and 22 MPa, results show that the concretes comply with the technical requirements regarding compressive strength resistance parameter for pervious pavements (39).

These results show that C0.40 concretes achieved higher compressive strength values. Due to greater workability, C0.40 concrete with 60-second vibration has the highest compressive strength value (22.20 MPa). Regarding the porosity results, values are in a range between 20.0% and 24.5%.

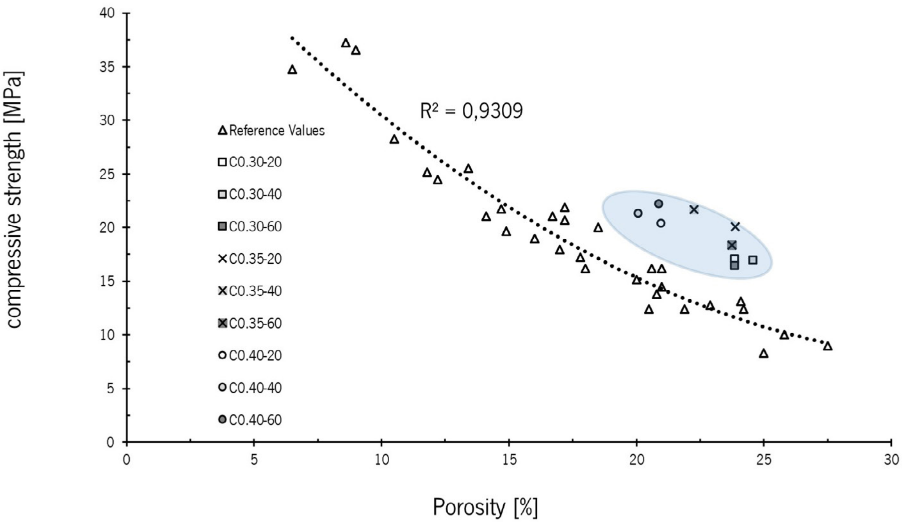

Figure 10. Correlation between compressive strength, porosity and reference values (39).

The values obtained, both for compressive strength and for porosity content of aged specimens, correlate well with reference values (39). Higher compressive strength was obtained for the concretes with lower porosity, as expected.

3.5 Abrasion test

Figure 11 presents the abrasion test results and their correlation with compressive strength. The results for lower W/C ratios correspond to higher abrasion concrete.

The concrete with the highest W/C ratio (C0.40) presented the lowest abrasion and the highest compressive strength; it can be seen that an increased W/C ratio produces better concretes with high compressive strength and low loss of mass by abrasion. A linear fit can be proposed for this relationship, despite the reduced correlation coefficient of 0.65 obtained for these nine measurements. These results can be also justified by the lower porosity of the concretes with the highest W/C ratio (Figure 11).

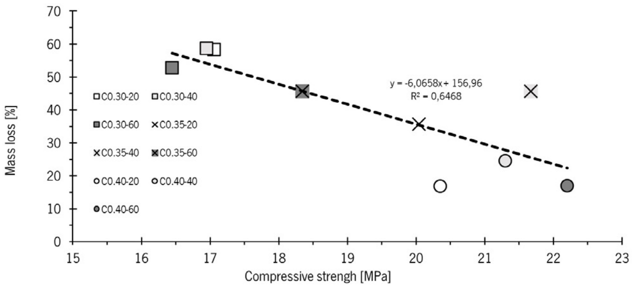

Figure 11. Correlation between compressive strength and mass loss by abrasion.

3.6 Porosity modeling using Image J software

The porosity analysis was performed using the same cubic specimens used in the porosity tests. Specimens were filled with a very fluid cement to ensure that all existent pores were filled in. After that, specimens were divided into four slices of 25 mm each. The porosity of each specimen is calculated as the average value of all slices (34).

By applying an image processing procedure, black and white images are produced for each slice. Porosity is quantified as a percentage by dividing the white by the total area. Using this process, a digital image showing vertical porosity for each specimen face is achieved. Porosity analysis was carried out in the specimens used in the hydraulic conductivity tests, in which vertical permeability was evaluated.

The first stage is to make images of each slice face, using a known scale (see Figure 12a). The scale will be used by the software to relate pore dimensions and to quantify the percentage. In the second stage, each image is formatted to 8-bit black and white

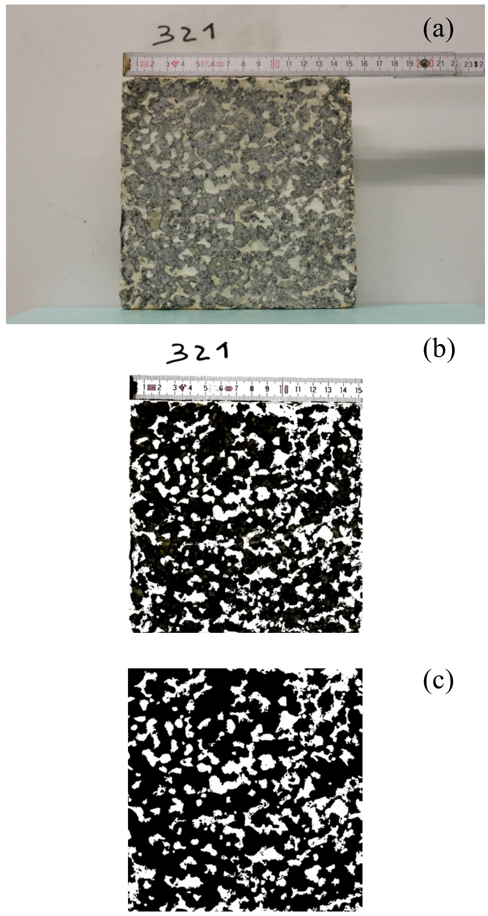

Figure 12. Examples of different stages of the porosity analysis procedure performed on a C0.30-20 specimen: [a] untreated image; [b] 8-bit back and white image; [c] image detail.

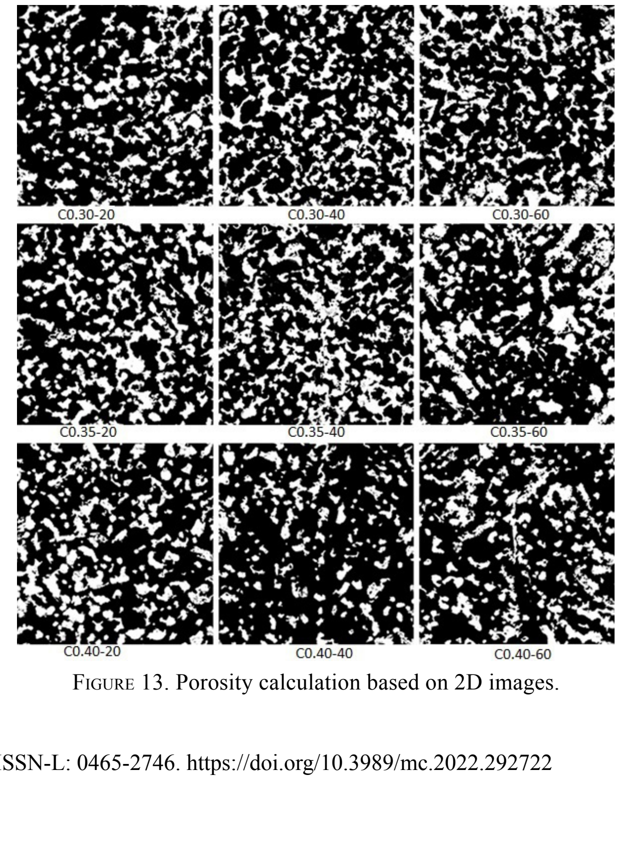

Figure 13. Porosity calculation based on 2D images.

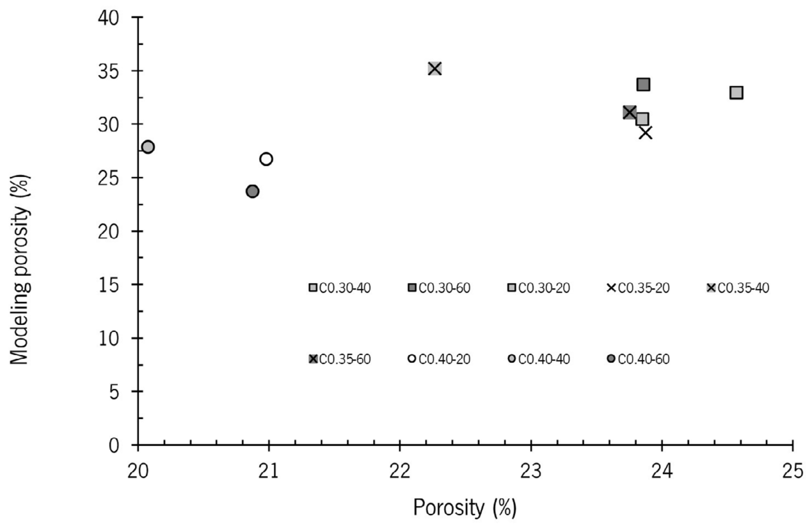

FIGURE 14. Correlation between modeling porosity and porosity.

images, allowing the software to distinguish pores from the solid areas (Figure12b and Figure 12c).

Figure 13 presents digital images showing the porosity for a single slice of each concrete, in which the porosity variation due to W/C ratio and vibration time can be observed. Figure 14 presents the correlation between porosity and modeling porosity.

Test results for modeling porosity show values in the range between 23.7% and 35.2%, whereas for the immersion porosity test results, values are between 20.0% and 24.5%. Thus, a trend can be established between porosity and water absorption; however, the values of both are different. The difference is mainly due to the calculation of the total porosity.

The method for modeling porosity calculation includes the entire porosity of the area of the specimen under test, including the closed porosity that does not have access to permeability. This factor contributes somehow to a small dispersion of porosity values in both methods. Another reason that is related to the difference in presented values is with the location of the slice in the sample, which probably affects the evaluation of porosity.

In the global analysis of the porosity study carried out for both methods we concluded that the lower the W/C ratio, the greater the total porosity.

4. CONCLUSIONS

In this study, several different permeable concretes were designed and tested to obtain an optimized concrete for road pavements with simple materials. This is aimed at improving safety regarding wet weather disasters e.g., aquaplaning, friction and sticking by quickly removing rainwater from the

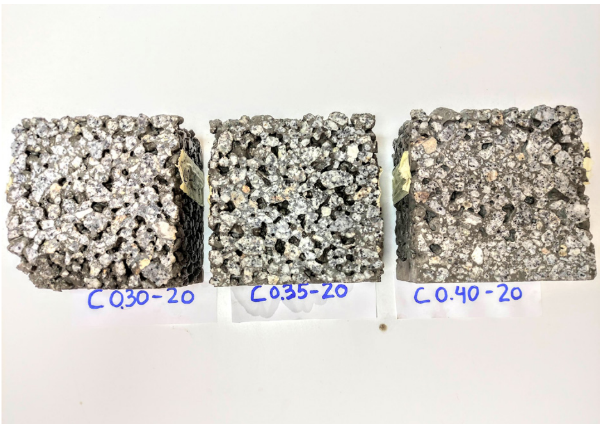

FIGURE 15. Visual observation of the porosity in the cut of the specimen section for each type of W/C mixture.

surface. From the study carried out in this work, some conclusions can be drawn:

• The slump test results did not allow any correlation to be established between the concretes studied. A constant value of 0 was obtained for all concretes, matching a typical value for pervious concrete. However, from the Vee bee test results, C0.40 concretes present the best workability.

• The mechanical characterization tests showed that 0.40 W/C ratio concretes achieved higher compressive strength. Due to its higher workability, C0.40-60 presented the highest compressive strength (22.20 MPa).

• The results show a trend of continuous permeability increase following the decrease in the W/C ratio. Such behavior is due to the concrete's rheology properties.

• LCS permeability shows that the C0.30 and C0.35 mixes comply with the technical permeability specifications for pervious concretes.

• Results also show that these concretes comply with standard EN 13108-7 for application of pervious concretes. C0.30 is rated as the superior class (kv4.0), whereas C0.35 is rated as the mid-range class (kv2.0–kv2.5), but with considerable vertical permeability.

• The study showed modeling porosity values ranging between 23.7% and 35.2%, whereas for the porosity, these are between 20.0% and 24.5%.

• A similar trend was observed for strength. An increase in permeability is matched with a compressive decrease in strength resistance.

• With values ranging from 16 MPa to 22 MPa, it was proven that all tested concretes comply with the pervious concrete requirements for compressive strength resistance. Results from the Cantabria abrasion test also revealed that lower W/C ratios are matched with low abrasion resistance.

• From the results presented and discussed here, C0.35-40 concrete complied with the technical requirements for pervious concretes and was identified as the most optimized due to its superior mechanical performance, respecting permeability specifications.

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