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A Methodology For The Design Of Hydraulic Concrete Mixtures, For The Porous Pavement Project, Using Construction Materials From Northern Colombia

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Abstract: The adverse environmental effects caused by climate change and the rapid growth of cities due to the increase in population, contributing to an increase in impervious surfaces, combined with poor management of water resources, have generated problems of overflows of urban streams and floods, as well as contamination of natural streams, by deposit of waste present in the streets or houses. Given this situation, where the environment requires viable and effective solutions to mitigate or reduce this problem, various solutions strategies are proposed, as is the case of permeable concrete, material this can be very useful for the construction of roads, parking areas and cover residential areas or other scenarios where traffic volumes are low. This solution contributes to urban drainage, as it allows water infiltration into the soil. Permeable concrete does not have a standardization in the methodology used for the dosing of materials, there are several methodologies that have been developed and tested in different parts of the world. For this reason, the present investigation aims to propose a methodology to obtain a dosage for permeable concrete, starting from the physical and mechanical properties of the materials involved in the mixture, following the guidelines of the research called Laboratory study of mixture proportioning for previous concrete pavement. The objective is to obtain a mix design that meets the requirements of freshness workability and hardened resistance and permeability. For this purpose, the materials have been characterized and theoretical mixing designs have been made, to then be evaluated in practice, producing concrete mixtures and performing workability tests, permeability, compressive strength and break module. On the basis of these tests, it was possible to obtain a permeable concrete that meets the requirements for low-volume transit routes (f'c > 21 MPa, Mr > 3.8 MPa).

Keywords: concrete permeable, mixing design, permeability, resistance, dosing.

1. INTRODUCTION

Hydrological processes in urban areas are being transformed by phenomena such as climate change and the progressive increase in population, coupled with unplanned urbanization [1], [2]. The manifestations of these two phenomena are quite broad and complex, on the one hand, climate change is immersed in a world of constant and dynamic transformation where the main factors that affect it, are the modification of land cover and use, the accelerated growth of urbanization, increased industrialization and increased transport [3], manifested in the increase in frequency and intensity of precipitation as well as temperatures [4]. On the other hand, the second factor that affects the hydrological cycle is the increase of the population and the little existing planning, with the lack of awareness when urbanizing many sites indiscriminately, resulting in urban centres directly influencing climate change [5]. An example of this can be seen in areas that are covered with waterproof materials such as concrete, which reflect ultraviolet rays and prevent the natural passage of water to the lower layers of the ground, resulting in increased volumes of surface runoff along streets, streams or rivers.

Given the problems raised, it is important to seek solutions that help mitigate the impacts of the hydrological cycle, as is the case with Sustainable Urban Drainage Systems and permeable pavements that provide an alternative to reduce impacts to the natural water cycle, helping to restore its cycle and contributing to making cities more resilient [1]. In urban areas, the management of pavements is essential, as they cover around 30 to 45 % of the exposed surfaces [6] and are expected to continue growing. For this reason, its correct design and implementation can be an incentive to mitigate these two challenges: urbanization and climate change [7].

The massive use of traditional (waterproof) pavements in large urbanized areas brings problems in the evacuation of runoff water from the rains, because the natural recharge capacity of the water is noticeably reduced, increasing the flow of surface runoff and thereby the risk of flooding [8] [9]. In addition to this, when rainwater runs off, it drags with it to sources of water, solid materials and some pollutants that are present in the streets [10]. The current solutions within the cities, have consisted in collecting, driving and evacuating rainwater quickly, through canal systems and sewers, but bringing with it a series of environmental problems, as a loss of the natural wealth of rivers or of their capacity to respond to floods and that sewerage systems are unable to absorb all runoff from new impermeable areas, which causes flooding and water quality issues, the contribution of pollutants to water resources [11], [12], [13], [14].

For all the above, is that the implementation of permeable pavements in industrialized countries has brought with it some benefits such as the recharge of aquifers and the reduction of the effects of rain on the pavement, as is the case of increasing the safety of drivers, avoiding phenomena such as hydroplaning or waterlogging on the tracks [15]. This type of pavement has practical applications in low-traffic road structures, such as parking areas, paths, pedestrian or cyclist paths and other structures with low traffic levels [16]. In that order of ideas, for the management of rainwater, permeable pavements are part of the set of measures that can be carried out to meet the criteria of environmental sustainability in relation to construction works in transport, infrastructure and everything related to the exploitation, conservation and management of rainwater. Permeable pavements mitigate peak flows caused by heavy rainfall and surface runoff [17]. Permeable concrete functions as a rainwater retention lagoon and allows rainwater to infiltrate the land over a larger area, facilitating local recharge of groundwater supplies. All these benefits lead to more effective land use. Permeable concrete also naturally filters rainwater and reduces pollution loads that may enter streams, lagoons and rivers [18].

Permeable concrete has been available for construction for 100 years, but without a specific use within the construction sector; but for about 40 years, in countries such as the USA, Australia and in Europe, research has been carried out to improve the strength and durability characteristics of this type of pavement, with the aim of using them in streets, parking lots and covering residential areas to avoid runoff [19]. In Colombia, some authors recommend this type of permeable pavement systems as a sustainable urban drainage technique, as an alternative solution to the drainage problem [20].

For all the above, the concrete technology and the improvement of the environmental conditions, are coupled in the porous concrete, which allows the infiltration of water through its surface and provide a temporary storage, for its subsequent arrangement. The design of porous concrete for road infrastructure works provides the following benefits: it reduces the risk of circulation in the presence of rain, decreases thermal and humidity gradients, and in a complementary way, the material provides two additional functions, related to drainage and self-ventilation, by increasing the structure of the macro pores; consequence of water infiltration on the surface of the pavement [21].

The permeable concrete is composed mostly of coarse aggregate, cement and water, which favors the creation of a porous type structure, which allows the passage of water through the material, characteristic this one that makes it of low resistance, porous and of very low structural quality, but which allows you to filter rainwater and avoid surface runoff [20]. In porous concrete, the rate of voids varies between 15 % and 35 %, usually used for mixtures, quantities of cement between 270-415 kg/m^3, aggregates between 1190-1480 kg/m^3 and as regards water/cement ratios (a/c), these commonly range from 0,28 to 0,40 [22]. As for the compressive strength, the values obtained in the literature vary between 2.8-28 MPa, the permeability coefficient ranges between 0.2-5.4 m/s and the pore sizes between 2-8 mm, depending on the type of aggregate used and the compaction method adopted [23].

For the design of porous pavements, there is not a single general methodology that applies to all countries, regions, climatic conditions, transit conditions, among other variables to consider, but rather, that have emerged in different parts of the world, methodologies that meet the conditions sought in each project and studies have been conducted to try to generalize these standard dosing methods for the production of permeable concrete. Among the methods that have already been tested and implemented, those developed by the following entities stand out: National Ready

Mixed Concrete Association- NRMCA, American Concrete Institute - ACI 522, Nguyen et al. , Yahia e Kabagire, Jimma and Rangaraju, Costa and Gentil [24]. The large number of methods mentioned above and the lack of a global methodology for the design of permeable concrete indicate that permeable concrete is a complex material, since its performance depends on factors such as: the amount of cement, the ratio a/c, the type and form of aggregates, the use of chemical additives and the application, compaction and curing processes [25].

The purpose of this investigation is to propose a methodology for the design of permeable concrete, taking into account the characteristics of cement as well as the aggregates to be used, taking as a starting point a desired percentage of voids. For this purpose, aggregates were used from the area near the city of Sincelejo in northern Colombia, having stone aggregates from the exploitation of sedimentary and crushed limestones and sand exploited on the riverbank, both with granulometry bands that met the material specifications of Colombia. The methodology followed as a guide for the realization of the mixing design (dosages of materials) was that of the research entitled "Laboratory study of mixture proportioning for previous concrete pavement", managing to take from them, the bases and important considerations as a starting point for the design and manufacture of the permeable concrete. To verify the strength properties, compression tests and break modules were performed at different ages, to control the evolution of the resistance (3, 7 and 28 days). In order to make a proper dosage, several designs must be made and the quantities of the materials must be changed, until a combination of them satisfies the requirements sought in the concrete mixture.

2. MATERIALS AND METHODS

The present research was developed in three phases, through which it was possible to carry out a mixture design that could be used for the porous pavements project, in accordance with the quality of the available materials. Below is a description of each of the phases involved.

2.1. Phase One: characterization of materials. At this stage, laboratory tests were carried out on the granular materials available for the design of the mixture. The first test carried out and one of the most important, was the particle size of the materials for the preparation of the mixture, which allowed to evaluate the size distribution of the aggregates, both coarse and fine and review the feasibility of them to realize the design or the need to improve their particle size distribution, in order to be able to meet the specifications for the use of them in concrete mixtures for porous pavements.

The bulk aggregate was supplied by the company Agregados de Sucre, located in the municipality of Tolú Viejo, Sucre (in northern Colombia) and for the conduct of the tests, the Colombian Technical Standards (NTC 77) were used. Two types of aggregates were available, categorized by their nominal maximum size, one ¾" inch (19.0mm) and the other 3/8" (9.5mm). After determining the particle size of the coarse aggregates, specific weights and unit masses were tested in accordance with NTC - 92.

The fine aggregate was acquired from the company Concretos de Lorica, located in the municipality of Lorica, Córdoba. For the characterization of this material, the granulometric analysis was initially carried out using the specification of NTC-77. Subsequently, the sand specific gravity test was carried out, based on the standards INV E 222-13 / INV E 136-13, of the National Road Institute.

The cement used for the development of the research was selected from the Ultracem brand, categorized by the manufacturer as type ART of Structural Use, which complies with the NTC standards required for this type of use in Colombia.

In addition, of the three main materials mentioned above for the design of mixtures, **additives** were used to improve or counteract some of their properties. In the first instance, an additive was used to delay the setting time of the mixture, through the product Eucom WR-85 of Toxement. In addition, an additive called Plastol HR-DF- from Toxement was used to reduce the mixing water in the mixture.

The water used for the design of mixtures, as well as for the manufacture of porous concrete, corresponded to the drinking water coming from the aqueduct of the municipality of Sincelejo.

In this way, it was possible to determine the feasibility of using the materials and additives for the mixing design and to move to the next phase.

2.2. Phase Two: design of the mixture. This corresponds to the centerpiece of the present investigation. At this point, as there is no standardized method for the design of a mixture of permeable concrete, a methodology was designed and implemented, which allowed to support the application of a dosing method for this type of concrete, based on the water-to-cement and the percentage of voids.

To carry out this phase of the study, the document Laboratory study of mixture proportioning for previous concrete paves was taken as a reference, and 18 designs of permeable concrete mixtures were carried out for the present investigation, with different water-cement ratios, which varied between 0.29 and 0.41, with their respective ratio of voids. The aim was that the dosing system should be based on the relationship between the initial quantity of available voids, corresponding to the voids of the thick aggregates and the final volumetric ratio, which is produced by the inclusion of cement paste with sand to the general mixture.

For the preparation of the mixture, the premise was that for a unit volume of aggregates, the density of the mixture can be calculated by adding the mass of the components and dividing it by the unit volume, obtaining what is called theoretical density and which is represented according to Eq. 1:

$$\text{Theoretical density} = \frac{(\mathrm{A} + \mathrm{C} + \mathrm{W})/\,1}{1} \quad \text{Ec. 1}$$

Where:

A = mass of aggregate
C = mass of cement
W = mass of water

Then, once the materials are mixed and the concrete is compacted, the cement paste will fill the gaps between the aggregates and will also be introduced into the particles of the aggregate, separating these and increasing the volume thereof, so the final volume will be higher, due to the sponging of the mixture. Figure 1 illustrates the above effect.

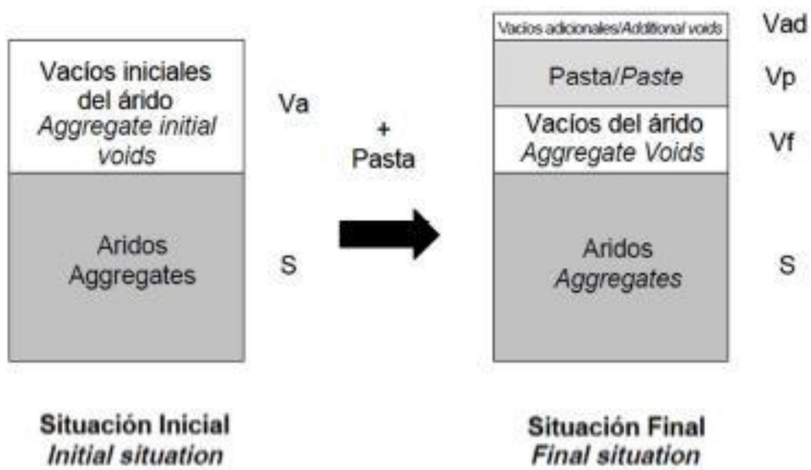

Figure 1. Volume changes in a concrete mixture.
Source: Castro, de Solminihac, Videla y Fernandez, 2009

For the purpose of the present research, the authors have considered the following variables related to the characteristics of the materials, to take them into consideration in the mixing design:

- Apparent Specific Gravity
- Aggregate Size
- Loose Unit Mass
- Compact Unit Mass
- Absorption
- Natural Moisture

On the other hand, for the case of the properties of the mixture obtained, the following parameters were analyzed and evaluated:

- Resistance specified in the design
- Average resistance required
- Settlement of the mixture
- Percentage of voids

- Water-cement ratio

The guiding document "Laboratory study of mixture proportioning for previous concrete paves" states that in order to produce a porous concrete, the percentage of voids of the concrete mixture should be between 15 and 20 %, the water-cement ratio between 0.29 and 0.41 and the sand-cement ratio should be combined in ratios 1:1. For the case of the settlement, typical values for rigid pavements are taken and subsequently, they must be adjusted to obtain an adequate manageability on site.

To obtain the proportions or quantities of each of the materials involved in the mixture of porous concrete, the values of the properties of the materials mentioned above were taken, obtaining the quantities of cement, sand, water and gravel, in that order, respectively. During the mixing design, it is important to have the humidity control of the aggregates and make the corresponding corrections, in order to work with the water-cement relationship previously determined.

For the cement content, Eq. 2 is used:

$$\text{Cement weight} = \frac{\text{paste volume}}{\left(\frac{1}{\text{cement density}} + \frac{\frac{A}{C}}{\text{water density}}\right)} \qquad (\text{Ec. } 2)$$

From the expression shown, the cement weight is obtained and based on the density, the volume of cement is obtained for each cubic meter of porous concrete.

For the sand content, the recommendation of the guiding document "Laboratory study of mixture proportioning for previous concrete paves" was followed, in which it is stated that the amount of cement and sand, must be in proportion 1:1. Based on the latter ratio and on the amount of cement calculated with Eq. 2, you can finally determine the amount of sand to use, in accordance with Eq. 3. This ratio 1:1 is by weight, so the density of the sand is used to calculate the volume of sand.

$$\text{Sand weight} = \text{Cement weight} \qquad (\text{Ec. } 3)$$

Likewise, to calculate the amount of water (in liters) required for the preparation of the porous concrete mixture, the amount of cement in the mixture is used (in weight), which is multiplied by the ratio A/C chosen, according to Eq. 4.

$$\text{Liters of water} = A/C \times \text{Weight of cement} \qquad (\text{Ec. } 4)$$

For the case of thick aggregates, the equation of the unit volume is used and solved for the volume of aggregates, resulting in Eq. 5

$$\text{Aggregate volume} = 1 - (\text{V. cement} + \text{V. water} + \text{V. voids}) \quad (\text{Ec. } 5)$$

And by making use of the density of the gravel, you can get the weight of the granular materials per cubic meter of mixture, as shown in Eq. 6

$$\text{Gravel dry weight} = \text{Aggregate volume} \times \text{Gravel density} \quad (\text{Ec. } 6)$$

The moisture content of the materials must be taken into account in order to determine the exact proportions and quantities of the materials. For this purpose, the equation is used to calculate the weight of the wet aggregates, as presented in Eq. 7

$$\text{Gravel wet weight} = \text{Gravel dry weight} \times \left(1 + \frac{\%\ \text{moisture}}{100}\right) \quad (\text{Ec. } 7)$$

On the other hand, a correction should be made taking into account the absorption of the aggregates, which subtracts water from the mixture and may cause the ratio A/C to be lower than the one proposed, for which equations 8 and 9 are used.

$$\text{Moisture correction} = \text{Aggregate dry weight} \times \left(\frac{\%\text{moisture}}{100} + \frac{\%\text{absorption}}{100}\right) \quad (\text{Ec. } 8)$$

$$\text{Effective water} = \text{Correction for humidity} - \text{Quantity of design water} \quad (\text{Ec. } 9)$$

Then, the dosage of the required additives should be calculated, based on the properties sought and the recommendations given by the manufacturer of the product.

At the end of this phase, you have all the quantities of materials to obtain a volumetric unit of the porous concrete mixture and you go to Phase 3.

2.3. Third Phase: manufacture of the porous concrete mixture and verification of its properties. The essential purpose of this stage is to be able to evaluate the effectiveness of the design of the mixture. For this purpose, in the first instance, a dosage was carried out for a volume of approximately 0.20 m³ of concrete, with the aim of carrying out laboratory tests on the mixture in the fresh state and on the hardened concrete, at different ages. Cylinders of 4" x 8" were manufactured for compression strength tests, while 6" x 6" x 21" beams were manufactured for flexural strength tests. In each case, 6 samples were taken, which were tested at 3, 7 and 28 days, respectively. The sampling process for concrete specimens was based on standard INV 402 - 13.

After all the tests have been carried out, the working formula of the mixture was evaluated on the basis of the results obtained, and appropriate adjustments were made, as appropriate, until the desired results could be obtained, with which it was possible to define an optimal working formula for mixing design purposes.

3. RESULTS AND DISCUSSION

The results of tests on granular materials (coarse and fine aggregates) and cement are summarized below. In the first instance, Figure 2 is shown, which represents the granulometry for the coarse aggregate with TMN of ¾". As can be seen from the above figure, the material does not meet the specification used.

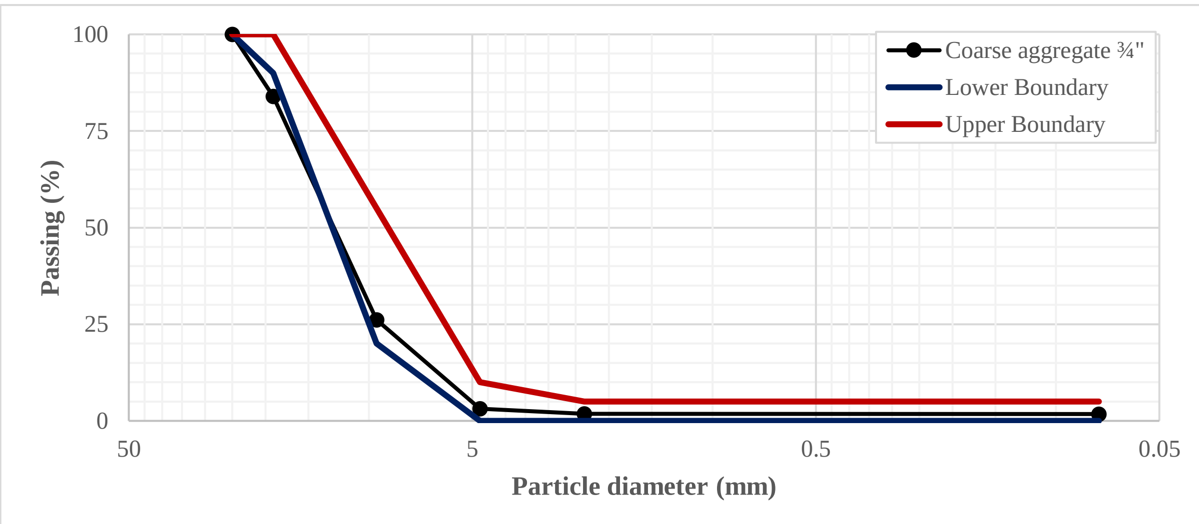

Figure 2. Granulometry of coarse aggregate of nominal maximum size ¾"
Source: self made

On the other hand, Figure 3 shows the granulometry for the other coarse aggregate available for the mixing design (added with 3/8" TMN). As can be seen, this also does not meet, being the particle size curve shifted towards the lower limit of the specification.

In view of the above, a granulometric stabilization was carried out, using for this purpose the same aggregates available, in a proportion of 50% of the gravel of ¾" with 50% of the gravel of 3/8", thus a coarse material fit within the specified particle size band for coarse aggregates could be obtained (see Figure 4).

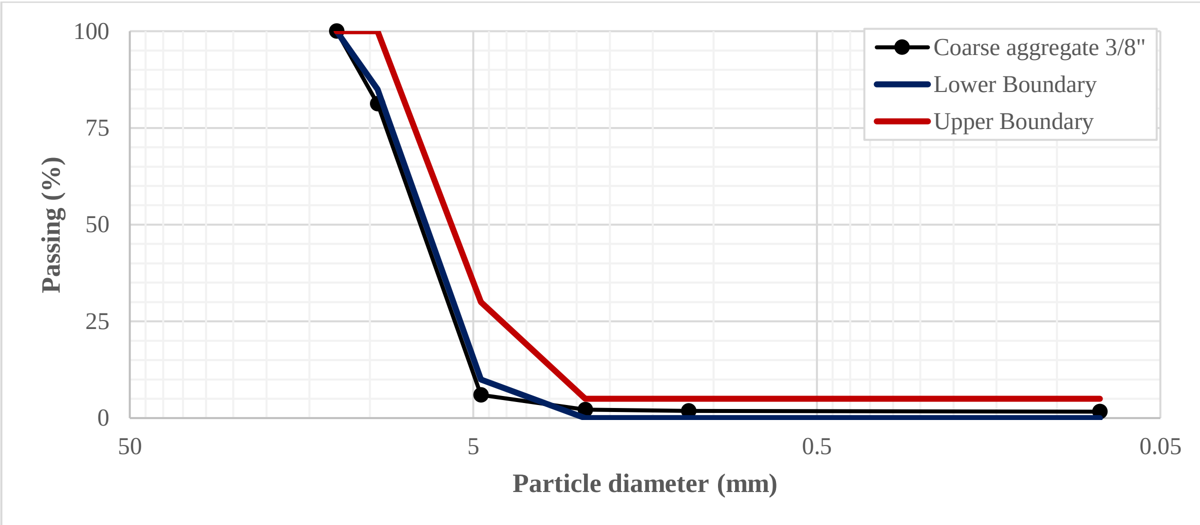

Figure 3. Granulometry of the coarse aggregate of nominal maximum size 3/8"
Source: self made

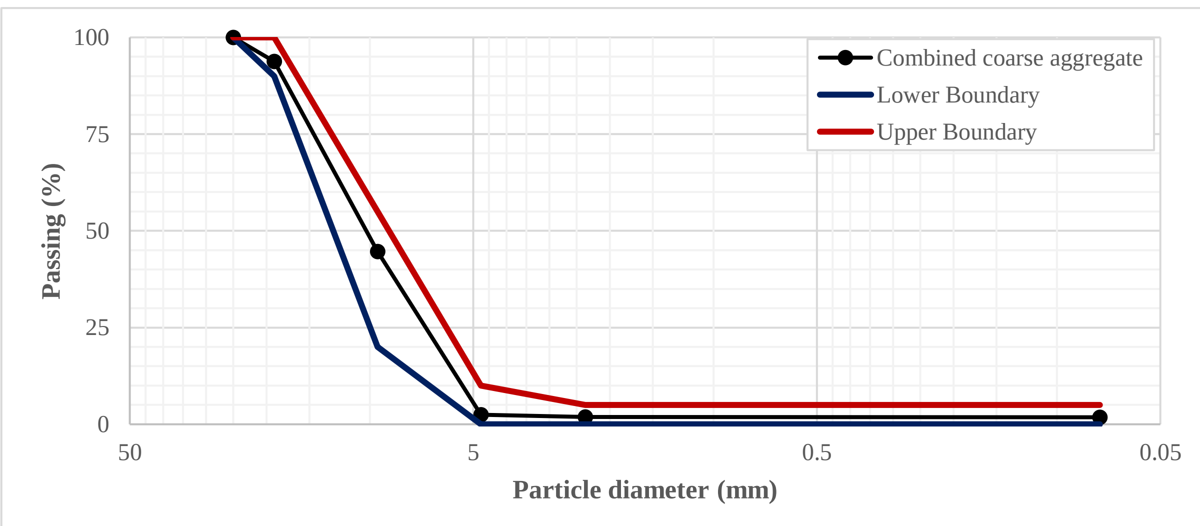

Figure 4. Granulometry of the combined coarse aggregate
Source: self made

In the case of sand, the granulometric properties were satisfied by the material provided from the company Concretos de Lorica, located in the town of Lorica - Córdoba. Figure 5 shows a graphical representation of the boundary curves proposed in the specification and the particle size curve of the fine aggregate.

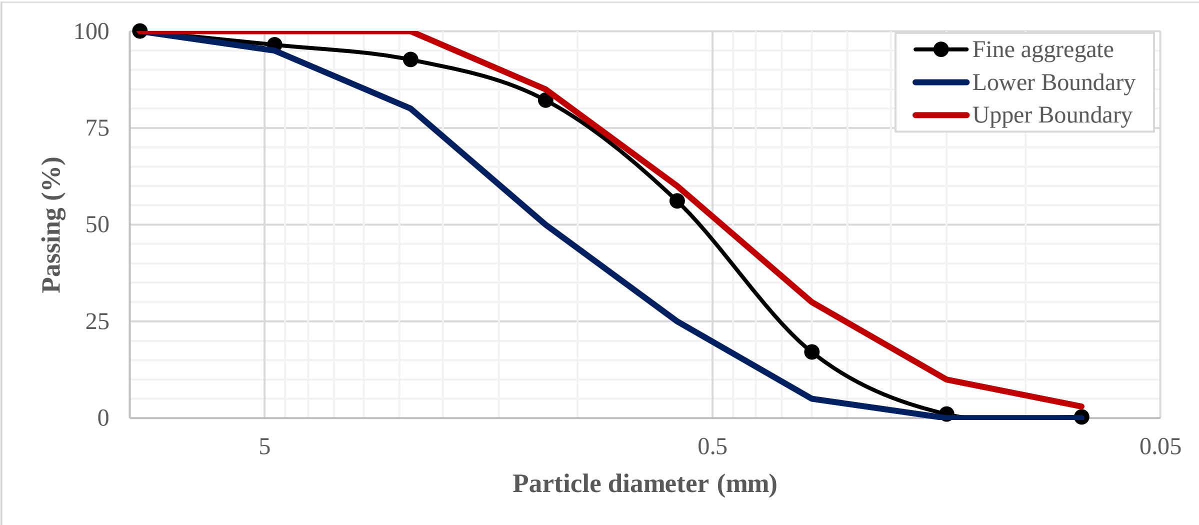

Figure 5. Fine aggregate granulometry
Source: self made

Other data of particular interest for the design of concrete mixtures correspond to those obtained from material-specific gravity tests. Table 1 and 2 show the values resulting from the specific gravity tests, both for the combined coarse material (gravel) and for the fine material (sand), being able to obtain the specific gravity data Bulk, Gravity Specific Bulk SSS, apparent specific gravity, loose unit masses, compact unit masses and absorption of materials. In addition, Table 3 presents the main technical specifications of the cement to be used in the mixture.

Table 1. Specific gravity test for mixed material

Specific Gravity and Absorption of Coarse Aggregate (INV E-223-13)	
Specific gravity (OD) (kg/m³)	**2500**
Specific gravity (SSD) (kg/m³)	**2590**
Apparent specific gravity (kg/m³)	**2750**
Absorption (%)	**3.5**

Source: self made

Table 2. Specific gravity test for sand.

Specific Gravity and Absorption of Fine Aggregate (INV E-222-13)	
Specific gravity (OD) (kg/m³)	**2590**
Specific gravity (SSD) (kg/m³)	**2600**
Apparent specific gravity (kg/m³)	**2610**
Absorption (%)	**0.4**

Source: self made

Table 3. Specifications of cement

ENSAYOS FÍSICOS	MÉTODO DE ENSAYO	NTC 121	ASMT C 1157	ULTRACEM
Contenido de Aire en volumen, %	NTC 224	Max. 12,0	Max. 12,0	Max. 12,0
Finura (permeabilidad al aire), cm 2 /g	NTC 33			
Finura en Tamiz N° 325 (45um), %	NTC 294			
Expansión en autoclave, %	NTC 107	Máx. 0,80	Máx. 0,80	Máx. 0,80
Expansión barras de Mortero (14 días), %	NTC 4927	Máx. 0,020	Máx. 0,020	Máx. 0,020
RESISTENCIA A LA COMPRESIÓN				
1 Día, MPa (PSI)	NTC 220	Mín. 11,0 (1595)	Mín. 12,0 (1740)	Mín. 12,0 (1740)
3 Días, MPa (PSI)	NTC 220	Mín. 22,0 (3190)	Mín. 24,0 (3480)	Mín. 24,0 (3480)
7 Días, MPa (PSI)	NTC 220			
28 Días, MPa (PSI)	NTC 220			
TIEMPO DE FRAGUADO VICAT				
Tiempo de fraguado inicial, min	NTC 118	Mín. 45 – Max. 420	Mín. 45 – Max. 420	Mín. 45 – Max.420

Source: Product catalog Ultracem cements

Regarding additives for the preparation of the mixture, EUCOM WR-85 from Toxcement was used to delay the setting times and PLASTOL HR-DF from Toxcement to reduce the kneading water in the mixture obtained.

It should be noted that the use of additives in the mixture improves its manageability, which allows the inclusion of other materials such as mineral pigments powder, through which mixtures can be generated with colors that give a more pleasing aesthetic to the eye. For the particular case under study, red and green were used.

Once all the tests were carried out on the granular materials and the properties of the same, as well as the cement and the additives, the design of the mixture for porous concrete was carried out, in such a way that the compressive strength could be guaranteed, the bending strength as well as the required permeability.

In Table 4 the initial values of the properties of each of the materials that make up the concrete mixture are presented and in Table 5, the minimum specifications that must have the mixture of fresh and hardened concrete, in order to meet the design requirements for porous concrete.

Table 4. Initial material properties (input data)

PROPERTIES	COARSE AGGREGATE	FINE AGGREGATE	CEMENT	WATER
Apparent specific gravity (kg/m³)	2750	2610	3120	1000
Sizes of Aggregate (mm)	25	9.5	--	--
Loose Unit Mass (kg/m³)	1346	1563	1150	--
Compact Unit Mass (kg/m³)	1462	1672	--	--

Absorption (%)	3.5	0.4	--	--
Natural moisture (%)	3.1	5.1	--	--

Source: self made

Table 5. Concrete design parameters

PARAMETER	VALUE
Compressive strength (f'c) (MPa)	21
Compressive strength (f'c) (psi)	3000
Coarse Aggregate (mm)	19
Consistency	Dry
Maximum Slump (mm)	127
Structure Type	Pavement
Air void (%)	0.20
Water-Cement Ratio	0.41
Sand/Cement ratio	1.10

Source: self made

It should be taken into account for the design of the mixture, since there is no standardized methodology for the design of porous concrete, the process of obtaining the proportions of materials that meet certain specifications and requirements, becomes an iterative process in which the quantities of materials must be adjusted until a combination satisfies the proposed requirements.

For the present case, the first mixing design was made following the guidelines of the guide text "Laboratory study of mixture proportioning for previous concrete paviment" and the expressions described in the methodology of this document. Based on these considerations, the quantities of materials presented in Table 6 were obtained.

Table 6. Proportions of the materials to be mixed

MATERIALS	DENSITY (kg/m^3)	DRY WEIGHT (kg/m^3)	DRY VOLUME (m^3)	WET WEIGHT (kg/m^3)	WET VOLUME (m^3)
Cement	3120	385	0.12	385	0.12
Sand	2613	385	0.15	405	0.15
Aggregate	2745	1425	0.52	1470	0.54
Water	1000	157.85	0.16	145.00	0.15
Eucom WR-85	1170	1.35	0.00	1.35	0.00
Plastol HR-DF	1054	1.54	0.00	1.54	0.00
Air Void	0	0	0.20	0	0.20

Total	2356	1.15	2408	1.16

Source: self made

The concrete prepared according to the dosage presented in Table 6 was satisfactory, according to the results obtained in all the tests of manageability and resistance. In Table 7, it can be observed that the values of resistance to unconnected compression and bending were higher than expected, by 80 % and 73 %, respectively.

Table 7. Compressive and tensile strength (initial design)

COMPRESSIVE STRENGTH (4" X 8" CYLINDRICAL CONCRETE SPECIMENS)				**TENSILE STRENGTH (6" X 6" X 21" CONCRETE BEAMS)**			
Days	**Load (KN)**	**Strength (MPa)**	**Mean strength (MPa)**	**Days**	**Load (KN)**	**Strength (MPa)**	**Mean strength (MPa)**
3	185.20	23.58	22.46	3	185.20	23.58	22.46
3	167.50	21.33		3	167.50	21.33	
7	223.50	28.46	26.75	7	223.50	28.46	26.75
7	196.60	25.03		7	196.60	25.03	
28	318.30	40.53	37.83	28	318.30	40.53	37.83
28	275.90	35.13		28	275.90	35.13	

Source: self made

For the above reason, another mixing design was carried out adjusting the proportions of the materials in order to obtain an optimal mixing design, both in terms of manageability, resistance, permeability, as well as in economics. Table 8 presents the quantities of materials in the optimized mix design, which obtained values closer to those expected. It is worth mentioning, that the addition of pigments in the mixture did not generate an increase in the water-cement ratio since the dye values with respect to the amount of cement were very low (0.10%), so the addition of said material did not have a major impact on other properties of the concrete; but instead, the aesthetic part could be improved.

Table 8. Quantities of materials of the final design

MATERIALS	DENSITY (kg/m³)	DRY WEIGHT (kg/m³)	DRY VOLUME (m³)	WET WEIGHT (kg/m³)	WET VOLUME (m³)
Cement	3120	306	0.10	306	0.10
Sand	2613	122	0.05	128	0.05
Aggregate	2745	1388	0.51	1431	0.52
Water	1000	116.20	0.12	116.20	0.12
Eucom WR-85	1170	1.07	0.00	1.07	0.00
Plastol HR-DF	1054	1.22	0.00	1.22	0.00
Air Void	0	0	0.28	0	0.28
Total		1934	1.06	1983	1.07

Source: self made

As can be seen in Table 9, the resistances obtained based on the final quantities of materials used in the permeable concrete mix design are satisfactory, yielding an average of 24,15 MPa at compression and 3.83 MPa at bending. These values are suitable for the design of a structure of low vehicular traffic, allowing the passage of automobiles, without affecting the mechanical properties of the concrete.

It should be noted that the value of resistance to bending is equivalent to 15% of the value of resistance to compression, which is consistent with what was established by other authors, as is the case of Diego Sánchez de Guzmán, who establishes that the resistance to bending of concrete fluctuates between 10% and 20% of its resistance to compression.

Table 9. Resistance to compression and bending (final design)

COMPRESSIVE STRENGTH (4" X 8" CYLINDRICAL CONCRETE SPECIMENS)				TENSILE STRENGTH (6" X 6" X 21" CONCRETE BEAMS)			
Days	**Load (KN)**	**Strength (MPa)**	**Mean strength (MPa)**	**Days**	**Load (KN)**	**Strength (MPa)**	**Mean strength (MPa)**
3	115.50	14.93	15.25	3	18.40	2.45	2.37
3	120.40	15.56		3	17.30	2.28	
7	151.80	19.62	19.29	7	22.82	3.04	2.97
7	146.70	18.96		7	21.75	2.90	
28	187.00	24.17	24.15	28	28.24	3.77	3.83
28	186.40	24.11		28	29.20	3.89	

Source: self made

4. CONCLUSIONS

A procedure for the dosing of high permeability hydraulic concrete mixtures, useful for the porous pavement project, could be shown in the present investigation. To this end, we used the characterization of the materials to be used, such as stone aggregates and hydraulic cement. According to the results obtained, it was found that with natural aggregates from the populations of Toluviejo and Lorica, located in northern Colombia, concrete mixtures can be obtained that meet all the desired requirements to be used in porous pavement projects, with which you can count on an alternative solution of road infrastructure friendly with the environment and that also, can allow a very safe transitability to users who move through the road corridors in which such a technique can be implemented.

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