Permeable concrete and their use to regulate the efficiency of watersheds in urban areas.

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Abstract: At present, cities in many parts of the world are affected by floods or storm runoff regulation problems due to the fact that there are more and more impervious surfaces that prevent a correct flow and absorption of water into the watershed. These problems not only affect people's quality of life, but also alter natural ecosystems.
Permeable concretes have very specific and necessary characteristics to solve surface waterproofing problems such as their permeability, porosity, resistance to compression and their density, which have been developed and improved over the years. In addition, through studies and depending on their application, it is proven that they provide great benefits such as the reduction of the heat island effect, their hydraulic performance, the reduction of traffic noise on the roads and a high slip resistance, which makes them nowadays one of the best and most efficient alternatives for use for urbanizations with a friendly environmental footprint.

***Index Terms*— impervious surfaces, permeability, permeable concrete, runoff, storm water, watershed.**

I. Introduction

IN the last years, paved surfaces in urban areas have increased due to a growth in the number of people who choose to live in cities. As urban areas expand, the amount of water that should be managed increases, generating the collapse of the existing systems. This problem is particularly visible on rainy days, when there is an excess of water flow given the fact that this water is not filtered by the ground anymore and it has to be carried to the river by sewer systems. This creates the need to replace these water-collection systems with conduits of higher dimensions generating important economic, environmental and social impacts.

The reduction in natural water filtration results in many problems related to the environment. In the first place, there is a deficit in the performance of underground natural watersheds. Moreover, the increase in waterproof areas entails an imbalance in the natural flow of water producing problems of erosion because of the speed gained by the fluid. As well as this, the water transported becomes highly contaminated due to contact with surfaces along its way, spilling all tis contamination rivers, lakes, and seas.

Addressing this issue has the direct result of improving the methods and systems that can help achieve the objectives in relation to the American National Academy of Engineering (NAE) Grand Challenge for Engineering: restore and improve urban infrastructure. One of the possible solutions to ensure the infrastructure problems derived from the vast paved area of cities, is the use of permeable concrete, which is considered within special type of concretes. This kind of concrete has cavities inside interconnected with each other which are produced by the lack of fine aggregate. These cavities allow water flow until the fluid gets to the ground and it is filtered by it. This material's low compression resistance does not allow its use on intensive surfaces but it can be used in low-traffic areas such as residential streets, sidewalks, and parking lots where the concrete is not subjected to great efforts. The use of this type of concrete in the mentioned areas allows an increase in permeable surfaces in urban areas relieving the sewer systems and helping to recover the underground natural watersheds.

The objective of this article is to review the most important characteristics of permeable concrete as an alternative to regulate the levels of watersheds in urban areas. To achieve this objective, this article is developed as follows. Firstly, the main and most important properties of this type of concrete will be developed. In the second place, the benefits that permeable concretes provide will be addressed then, some of the applications that could become a solution to the problem will be shown and finally the main tests and activities maintenance will be mentioned.

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J. Vittor is a civil engineering student at Universidad Tecnológica Nacional (UTN), Facultad Regional Paraná (FRP), Paraná, 3100, Argentina. juanmartinvittor@alu.frp.utn.edu.ar The present manuscript is part of the research activities in the Inglés II lesson at Universidad Tecnológica Nacional, Facultad Regional Paraná. Students are asked to research intoa topic so as to shed light on a topic of their interest within the National Academy of Engineering's Grand Challenges or the United Nations' Sustainable Development Goals frameworks. If sources have not been well paraphrased or credited, it might be due to students' developing intercultural communicative competence rather than a conscious intention to plagiarize a text. Should the reader have any questions regarding this work, please contact Graciela Yugdar Tófalo, Senior Lecturer, at gyugdar@frp.utn.edu.ar

II. PROPERTIES

A. Compressive strength

It is a fact that the properties of permeable concrete can vary given its composition according to the materials and mix design such as the water-cement ratio, binder content and compaction method, directly influencing its resistance to compression. In general, laboratory tests performed on these concretes show strength results ranging from 500 psi (3.5 MPa) to 4000 psi (28 MPa). The statistical mean resistance is close to 2500 psi (17 mPa), [2] allowing its use in numerous applications. Other researchers are not so optimistic about this result, showing that higher strengths can be obtained in the range of 800 psi (5.5 MPa) to 3000 psi (20.5 MPa). [3]

It should be clarified that there is no standardized method for conducting mechanical behavior studies on these concretes according to ASTM standards. Therefore, this property is not very relevant at present until consensus has been reached.

B. Density and Porosity.

The structures of permeable concretes present a large number of voids, and this gives it certain characteristics such as its low density and high porosity. The former is directly related to the number of voids that make up its structure and the type of coarse aggregate used. This property varies from 100 lb / ft³ (1600 kg / m³) to 125 lb / ft³ (2000 kg / m³) [3, 4].

Porosity is also related to the number of voids in its mass but with the difference that it varies in terms of the amount of fine aggregates in its composition, which can be completely eliminated. The type, size, grading of the aggregate, volume of the paste and their consistence are fundamental factors that determine the degree of porosity of the permeable concrete. [4].

In short, these characteristics have a direct impact on other properties of permeable concretes such as permeability and surface resistance against abrasion, however, the latter will not be developed in this article due to its low relevance in permeable concrete applications.

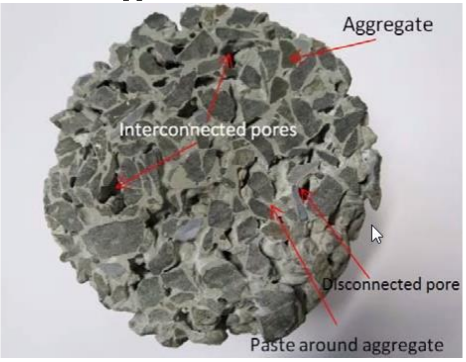

Figure 1 – Pervious concrete structure.[4].

C. Permeability

Due to the relatively large dimensions of their voids, a large part of the water absorbed by immersion subsequently escapes by filtration, shown by studies [3], where the water filtration rate varies between 3 gal / ft² / min (120 L / m² / min) and 8 gal / ft² / min (320 L / m² / min) depending on the size and number of holes. in its composition.

Permeability (Fig. 2) is one of the most important properties of this type of concrete since it allows regulating runoff on roads or paved areas, stores the water inside its structure until it is absorbed by the soil and preserves the watersheds. In addition, it is capable of bypassing and / or suppressing storm water management systems reducing the need to build water regulation systems. This helps to reduce the risk of flooding in urban areas and the preservation of the underground ecosystem.

Figure 2 – Water infiltration.[4].

III. ENVIRONMENTAL BENEFITS

A. Hydraulic performance.

Efficient hydraulic performance is one of the main assets of permeable concretes, which, thanks to the studies carried out, has been shown to directly depend on the degree of porosity contained in its matrix, the size of its alveoli determining its permeability, the method and the degree of compaction, as well as the use of polymeric additives, fluidizers or latex binders, which improve its durability and dimensionless stability.

This benefit generates an increase in the capacity to regulate stormwater runoff and provide resilience to the transportation system, [3] in addition, it reduces the action of pollutants that enter the soil and later into the watersheds.

Research shows that permeable concretes reduce the entry of salts, motor oils, fuels and sulfuric acid due to the density of pollutants that remain adhered within their internal structure for prolonged periods of time until their biological degradation, reducing the contamination of lakes, rivers and seas. [5]

B. Heat-island effect mitigation.

Heat islands are one of the effects generated by the high density of buildings in urban areas, which absorb solar radiation, maintaining very high temperatures on their surfaces. As a consequence of this, and given a high rate of air pollution, in densely populated cities hot air masses are generated directly affecting the life of adjacent ecosystems as well as that of human beings.

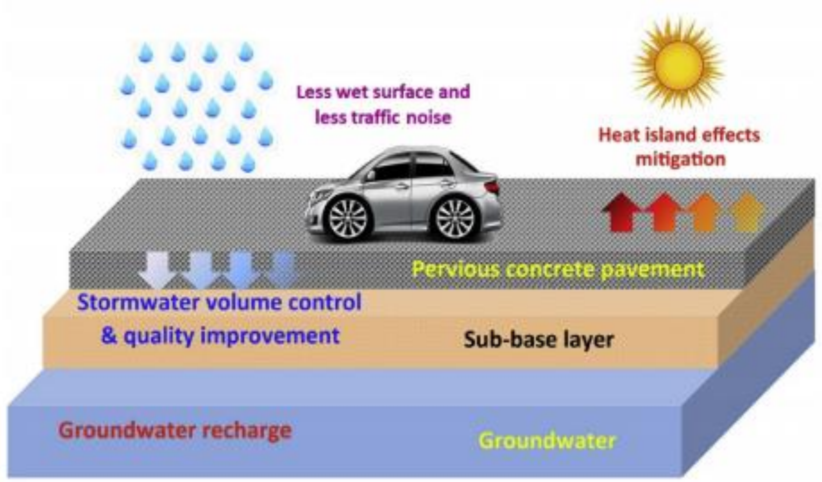

Figure 4 – Environmental Benefits [3]

At present, the design and implementation of permeable concrete applied to pavements and flat surfaces in direct contact with the earth, manages to reduce the heat island effect due to the fact that the absorbed heat from solar radiation is less compared to pavements. traditional. The light color of the concrete together with its structure of open pores allows the masses of hot air to remain in its structure for less time until they are absorbed by the earth or dissipated [3].

Since pervious concrete improves heat dissipation, it reduces the thermal impact that trees or vegetation surrounding paved areas can receive. On the other hand, in urban areas it generates a better feeling of comfort in hot climates since the ambient temperature in these places is lower than in areas where these concretes are not used.

C. Traffic noise reduction.

Noise pollution is one of the factors that permeable concretes help to control. In the vicinity of roads or urban areas with high traffic density, it is common to feel the sound generated by tires or motors. Since this sound cannot be absorbed naturally by the pavements, it bounces off generating sound waves that are too wide enough to propagate to a radio of 5 [km] [6].

At present, the design of permeable pavements takes the size and type of aggregates, their porosity, cement contents and fundamentally the thickness of the compression layer, as the main parameters obtaining a great acoustic absorption efficiency.

The noise levels of traditional concrete range between 100 [dBA] and 110 [dBA], while permeable concrete (without special aggregates or additives) range between 96 [dBA] and 98 [dBA]. In 2003, researchers from the University of Perdue [3] developed silent permeable paving materials, managing to form pavement layers of less thickness than traditional ones with a high acoustic absorption capacity since the peak frequency of sound absorbed is inversely proportional to the thickness of the porous surface. The results obtained from the field studies carried out on these pavements show that a thickness of 80 [mm] has an acoustic absorption capacity of 48 [dBA] with an adequate resistance to compression, this thickness is considered the optimum to obtain a great performance on roads or parking lots. [3]

D. Skid resistance improvement.

According to their surface appearance, permeable concretes have a great resistance to sliding. This benefit depends on the degree of porocity, its density, surface uniformity, water-cement ratio, aggregate size and degree of permeability, since they increase its friction coefficient. [7]

Slip resistance is very important for the design of roads, sidewalks or highways as they improve their safety thanks to the properties mentioned above. The ability to store water in its structure and its permeability avoid the formation of water mirrors or its superficial freezing that usually causes accidents, hydroplaning or operational interruptions.

Researchers demonstrate that the use of furnace slag in shaping the mix of these concretes improves their permeability, compressive strength and skid resistance, making application surfaces more efficient [3]. Other researchers [7] affirm that the use of RCA (recycled coarse aggregates) does not generate significant differences in terms of slip resistance. The use of this type of aggregate benefits the environment since recycled concrete from demolitions is used.

IV. APPLICATIONS

Permeable concrete has many possible applications from walls in buildings that are used to improve thermal insulation to acoustic sound barriers that, due to its porosity and open pore structure, allow it to absorb acoustic waves. [6] However, this type of concrete is more used on sidewalks, pavements and parking lots in light-traffic areas due to the lower resistance to compression compared to normal concrete, another widely used application is as rigid drainage layers that make use of its permeability property to filter water from pollutants coming from the surface.

Other applications that can benefit from the use of the PC are: greenhouse floors, tennis courts, zoo areas, slope stabilization, seawalls, and so on. [4,6] Although there are many applications in which the use of PC is possible, it is necessary to pay close attention in the areas where the concrete must be reinforced through steel bars since there is a high risk of corrosion due to the structure of interconnected voids where water can infiltrate.

Pervious concrete requires specialized procedures and it is very important that these are executed correctly to achieve design characteristics. The placement of the mixture in the given time, its consolidation, the elaboration of expansion joints and a correct curing [2] are fundamental stages for the realization of a correct permeable concrete that guarantees a correct filtration of the water in addition to ensuring its durability over time.

Generally, a permeable concrete is made up of 4 layers, [4] firstly there is the soil and this must have sufficient load capacity to support the loads foreseen in the design. After the soil, it is necessary to place a non-woven geotextile that has the function of containing the upper filter layer as well as guaranteeing a correct filtration of the water in the soil. Above this is placed a drainage layer made up of stones of different sizes, the layer has the function of being a reservoir of water in case of intense rainfall as well as containing the contaminants from the surface. Finally, the upper layer is the permeable concrete of which its main characteristics have already been developed.

Figure 5 – Typical Permeable concrete section [4]

V. Inspection and Maintenance

The testing and inspection of concrete is essential to corroborate its correct execution, so after seven days samples of the controls must be taken and the acceptance tests verified. Generally, a typical test rate is three cores per 100 yd3 (75 m3) and compressive strength tests are not recommended due to dependence on compaction, obtaining different values depending on the area analyzed.

As a measure of acceptance, samples should not have an average weight less than 5 lb/ft3 (80 kg / m3) of the design unit weight. In addition, the thickness or height of the specimen should not be less than 1⁄2 inch (13 mm) of the design thickness [2].

Pervious concrete does not need much maintenance; however, precautions must be taken not to clog the interconnected pore structure. Sand particles, soil, leaves, and rocks can infiltrate voids and impede water flow, reducing the usefulness of the pavement [2, 3].

VI. Conclusion

According to what is analyzed in this article, it is shown that the use of permeable concrete contributes enormously to improving the regulation capacity of watersheds in urban areas where it will definitely reduce flooding and maximize water filtration. Given that it has excellent properties, mainly its permeability and its ability to regulate runoff in paved areas, it should be taken into consideration for future urban developments or as a solution to problems that condition the life of ecosystems and affect the quality of human life.

Over the years it has been seen that the performance of these concretes improves, this is due to the advancement of technology and new forming techniques. Currently, many first world countries have taken the initiative to adopt these concretes as the main option for their projects since they have a great versatility of application, they generate safer and cheaper surfaces but above all because they are friendly with the environment, demonstrating that they are the new flooring trend for the future.

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