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Permeable concrete - water conservation

Concretos permeables - conservación del agua

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The use of pervious concrete in urban mobility infrastructure is analyzed. In addition, its properties are presented, as well as its possible uses and the type of infiltration it can have. The design of pavements presents a divergence condition, it attends to resistance, but not to water preservation. In this sense, research on alternatives that serve as a method of preservation and reuse is presented. The objective is that they not only allow vehicular traffic, but can also transport water internally, and make it reach the desired place. It is concluded that for sustainable and profitable urban mobility, the use of permeable concrete should be an alternative since it meets the requirements of infrastructure, management, and preservation of water resources. Actions are also required to improve and expand the possibilities of using permeable pavements, given some of their limitations.

Keywords: Concrete absorption, infiltration, permeable, pervious concrete, water

Se analiza el uso de los concretos permeables en la infraestructura para la movilidad urbana. Además, se presentan sus propiedades, cuáles podrían ser sus usos, y el tipo de infiltración que puede llegar a tener. El diseño de pavimentos presenta una condición de divergencia, atiende a la resistencia, pero no a la preservación del agua. En este sentido se presenta una investigación sobre alternativas que sirvan como método de preservación y además reutilización. El objetivo es que las mismas no solo permitan el tránsito vehicular, sino que pueda transportar el agua internamente, y hacer que llegue al lugar deseado. Se concluye que para una movilidad urbana sustentable y rentable, la utilización de concretos permeables debe ser una alternativa, ya que atienden a requerimientos de infraestructura, manejo y preservación del recurso agua. También se requieren acciones para mejorar y ampliar las posibilidades de utilización de los pavimentos permeables, dadas sus limitaciones.

Palabras clave: Absorción del concreto, permeable, infiltración, agua

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Introduction

This article aims to research permeable concrete. This can be evidenced in the research of various writers on this topic, which was taken as reference research to determine whether the water that seeps and stagnates in the voids of permeable concrete can somehow be reused, find a way to reuse this liquid would be a breakthrough, especially in the most abandoned and vulnerable areas. Thus we supply more than one need. Among them, we can highlight three, which are:

1. The implementation of functional roads.
2. The supply of drinking water.
3. Avoidance of flooding and, thus, disaster.

The research and writing of this complement very well with the previous background because it meets the conditions where previous concrete should be applied and used, which are areas with little vehicular traffic and areas where there is a lot of rainfall (Lin et al., 2019; Masum & Manzur, 2019; Şengün et al., 2019). In this article, we found a big problem of implementation in vulnerable areas because, in these areas, there needs to be more road maintenance. For this type of case, it is required that there is very great care.

Permeable concrete has the potential to provide multiple benefits in urban road networks, including improved functionality, increased access to clean water, and reduced flooding. However, it is important to carefully consider the limitations of permeable concrete, including its lower strength and higher cost compared to traditional concrete, and to prioritize maintenance and proper implementation in vulnerable areas. Overall, the use of permeable concrete in appropriate situations has the potential to bring significant benefits and should be further explored and researched (Aryan et al., 2019; Kia et al., 2018; Razzaghmanesh & Borst, 2019).

Problem statement

The problem that this article aims to address is how to effectively reuse the water that seeps and stagnates in the voids of permeable concrete, particularly in vulnerable areas where there may be challenges with road maintenance and a need for increased access to clean water. This problem is particularly relevant in areas with little vehicular traffic and high levels of rainfall, where permeable concrete has been identified as a potential solution. However, there are limitations to the use of permeable concrete, including its lower strength and higher cost compared to traditional concrete, that needs to be carefully considered to maximize its benefits and minimize any negative impacts. The goal of this research is to identify strategies for effectively reusing the water captured by permeable concrete in a way that meets the needs of these vulnerable communities and supports the long-term sustainability of their built environment.

Permeable concrete

In road construction, there are two main types of concrete: impermeable concrete, commonly used in highways, roads, streets etc (L.-M. Chen et al., 2019; Rohr-Suchalla & Wolfgramm, 2018). This is characterized by not absorbing water. This is a disadvantage compared to permeable concrete, which can absorb water despite not being used as much. This is because it is a type of concrete with high porosity. This porosity is obtained through a high content of related voids (J. Chen et al., 2019; Kim et al., 2016).

Permeable concrete is generally characterized by having in low quantities fine aggregates. On the contrary, it presents a large amount of cement to cover the particles of coarse aggregates. Performing this action, the concrete can remain firm, and with the voids mentioned above, which are those that allow the absorption of water, which can be recovered, filtered into the drain or stored in the subsoil, the implementation of this concrete is essential in a society as it would be a breakthrough and a great help for sustainable construction (in harmony with the environment). Although it is little used in places such as parking lots, parks, sidewalks and places with little vehicular flow, since one of the most significant drawbacks of this concrete is that it is much more fragile than waterproof concrete, it is recommended to be very clear about the water/cement ratio, because if it has a large percentage of voids, the same water absorption will cause the concrete to begin to crack, on the contrary, if the amount of voids is too small a percentage the concrete will not allow the water to seep enough to be reused.

Permeable concrete properties

It is not possible to speak specifically about fixed properties of this type of concrete since these properties depend on the percentage of voids that are in the mixture, which in turn depend on how it has been treated, the level of cement added, the water/cement ratio, the quality of the aggregates, however, we can say a few observations and recommendations to keep in mind when working with this concrete, One of them and one of the most important is to control the percentage of water that is applied to the mixture since this concrete requires very great precision, to make sure that the mixture is presenting a good water/cement ratio a straightforward experiment that can be performed is to take a little of the mixture and make a sphere if it practically maintains its shape it means that the mixture contains a good amount of water.

As for its effectiveness, although it has been used on many roads in the United States, there needs to be more research to say how efficient it is in using permeable concrete (Sehgal et al., 2018; Wu et al., 2017). Furthermore, concerning the reuse of absorbed water, it has yet to be discovered precisely how it can be reused since most of it remains stagnant in the pores until it evaporates or seeps into the drainage system or the subsoil.

Uses of permeable concrete

Since the emphasis of this type of concrete is thought in the construction based on the natural water cycle without the appearance of humidity, these concretes can be used in systems such as pavements with minimum traffic, parks, roads, courtyards, among its most common uses are these:

- Parkings
- Cycle paths
- Low water crossings
- Courtyards
- Artificial reefs
- Slope stabilization
- Revetment
- Greenhouse bases/floors
- Hydraulic structures
- Swimming pool covers
- Pavement edge drains
- Noise barriers

Minimal use

The current difficulty in achieving resistance, permeability and reuse of permeable pavements is one of the factors that have caused the use of this concrete to be very minimal. We present some factors that do not favorably help the use of this type of concrete.

Percentage of voids: The percentage of voids will not always be the same for all permeable concretes. This percentage will depend on certain factors such as the compaction of the concrete, the type of aggregates and their quality, and the water/cement ratio, i.e., the moisture content of the mix.

Linear compression: One of the problems in these types of concrete is that the compression is linear concerning the percentage of voids. This means that the higher the percentage of void, the compression that the concrete resists will be lower. This compression can be between 400 psi and 4000 psi, although it is more common to find in these concretes a compression between 600 psi to 1500 psi. Different or opposite case happens in the permeability since the percentage of voids is directly proportional.

Use of additives: Concerning this point, both positive and negative aspects can be presented. One of them is that this type of concrete allows the use of highly polluting additives, such as latex, silica, plastic, fibres or fly ash, without damaging the permeability or resistance of it. On the contrary, it improves the resistance of the concrete. The problem with using this type of additive is that they considerably raise the cost. Therefore, it is necessary to analyze very well in which situations they should be used to keep it manageable.

Aggregate geometry: Maximum size, origin and roughness or shape of the coarse aggregate.

Aggregate dependence: Permeable concrete presents a divergence concerning conventional concrete: the amount of paste used is limited, which is why its strength depends exclusively on the aggregates.

Unlike impermeable concretes, the resistance depends on how the contact between the aggregates is established. Its permeability does not depend on the shape of the aggregate. It will be the same if they are angular or rounded. On the other hand, if you want to gain more resistance, more uniform granulometry and maximum size are used. However, a bit of permeability is lost, but it is not too noticeable.

Water conservation

The main objective of using pervious concrete depends exclusively on water conservation and avoiding disasters or accidents due to excessive rainwater flow. Permeable concrete can let through about 36,000 mm of water/hour.

The proper strength-to-permeability ratio of pervious concrete is directly associated with a water/cement ratio between 0.27 and 0.30. These ratios are too low, so the concrete will have low workability. For this type of concrete, it is required that the paste is not too liquid because it can leak through the ducts where the water is absorbed, generating concrete with a high resistance level but low permeability.

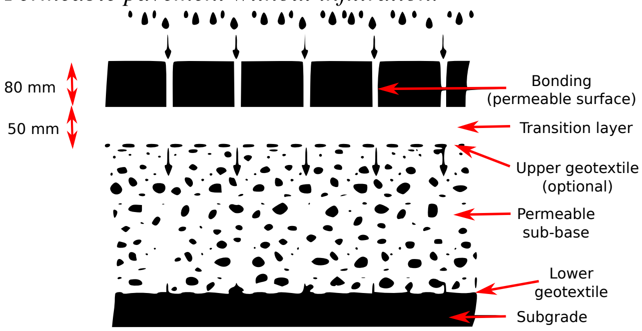
Water conservation can be achieved by different systems, depending on the use and the area where it is located. This depends directly on the following application systems.

No infiltration

Also known as permeable pavements with exfiltration, they are designed to allow water to pass through the surface of the pavement but not to infiltrate into the ground below (Fig. 1). This can be useful in situations where it is not desirable or practical to allow water to infiltrate the ground,

Figure 1

Permeable pavement without infiltration.



such as in areas with high water tables or where the soil is contaminated. Permeable pavements with exfiltration can help conserve water by reducing the amount of stormwater runoff generated during rain events. When it rains on impervious surfaces like traditional pavements, the water cannot soak into the ground and instead runs off into storm drains or other surface water bodies. This can cause flooding and erosion and result in rivers and streams pollution.

Permeable pavements with exfiltration allow water to pass through the pavement's surface and be collected in a subsurface storage system, where it can be treated or reused. This can help reduce the volume of stormwater runoff and prevent flooding and erosion while conserving water resources. However, it's important to note that permeable pavements with exfiltration differ from traditional ones designed to allow water to infiltrate the ground below. While both types of permeable pavements can help manage stormwater and conserve water resources, they work in different ways and are best suited for different applications.

Systems with infiltration

System A - Complete Infiltration: All water penetrates through the surface layer, through the lower courses of the pavement, and into the subgrade. This system does not discharge any water into traditional drainage systems, but some water may be retained within the pavement before it permeates into the subgrade.

System B - Partial Infiltration: The underlying soil provides some level of permeability and infiltration is acceptable. Outlet pipes are installed within the subbase layer to allow excess water that cannot penetrate the existing soil to drain into watercourses, salts, sewers, and so on.

System C - Full Attenuation: This system is typically used where water recycling is required, where water may be contaminated or where the subgrade is impermeable. An impermeable membrane is installed above the subgrade and outlet pipes are installed within the subbase layer. The water can be captured and harvested for use in non-potable applications such as irrigation, toilet flushing, etc.

Absorption capacity of permeable concrete and advantages in vulnerable areas

The first known uses of permeable concrete occurred in Europe in the 19th century. However, its applications grew particularly after the Second World War as a response to the need to rebuild buildings and roads with limited means. The shortage of materials, as well as their high cost and transportation, led to the use of a concrete without fines that reduced the cement (paste) content in the mixes and allowed for the recycling of rubble. Research in Costa Rica on the design of permeable concrete mixes using river and hill aggregates and then subjecting them to uniaxial compression and permeability tests obtained results showing that both properties have an inverse relationship, as generally the variables that positively affect resistance do so negatively with permeability.

Given the above, it is known that this type of concrete should be used in areas with low vehicle traffic and that the few vehicles that flow through these types of roads are of low weight, which is closely related to the objective of this article's research, if it is possible to determine that the water absorbed by permeable concrete can be reused in some way, it could be applied in vulnerable areas and in arid lands where it takes many months to rain, as they would meet the main condition required by permeable concrete by being less traveled. Another advantage of recovering the absorbed water would be the great benefit it would have for the environment.

However, the implementation of permeable concrete in vulnerable areas could also pose a series of problems, because, just as this concrete is very effective in absorbing liquid and retaining it for a long time, it also requires very meticulous care with constant cleaning, otherwise the voids it has will be clogged with dirt, leaving a concrete with the same problems as the waterproof concrete, but with a much lower resistance.

Some research has established the advantages of the use of this technology, in particular, in areas with low vehicle flow it is better to use permeable concrete than traditional concrete, as the latter can bring certain problems to the area. Some of these are:

- When there is too much rain, the water level can rise and cause floods
- The water cannot be properly filtered into the soil, which can cause two problems: first, serious cracking in the concrete due to water getting stuck in the few

voids in the concrete, and second, sinkholes in the roads

- Rainwater cannot be well filtered through the drainage system, so it cannot be treated and the water supply would be much lower. This research also mentions that permeable concrete has been used for more than 100 years.

Already with the above mentioned we can see that the main objective of the research is closely related to the above background because if it is possible to reuse the water absorbed by the permeable concrete, it is appropriate to use it in areas of high rainfall and poor road flow would be perfect for application in villages or sidewalks, the implementation of such concrete would be a great benefit for these populations, They would be roads that due to the type of traffic would last long enough and it would also help for the water supply in this type of areas, especially in areas where the supply is almost null, and there is no access to drinking water, this problem would also be solved because of the voids that the concrete has to filter the water and is stored in these, this water can be somehow reused to supply these areas and to provide a solution to the water shortage in these areas.

There has been quite a lot of research on permeable concrete and how it could be implemented in everyday life, so we could say that there is enough background to be able to carry out the research and answer the question asked.

Some conditions and recommendations to be met by the area where the study can yield better results include the following factors:

- Roads or streets where there is little vehicular traffic. This is to avoid cracking or sinking of the concrete at the time of testing.
- Vulnerable areas with a lack of water. This type of area should be taken into account at the time of the conclusion and results of the experiments since if it is possible to conclude that this water can be reused in some way, it can be used for water supply.
- Areas of high rainfall. The implementation of permeable concrete in this type of area is indispensable because it avoids major flooding and thus the loss of their homes for the families living there, however, being able to reuse the stagnant water in the voids of the concrete would be a great acquisition of this resource that after being treated will be used in the supply of the city or area where this pavement is implemented.

We consider it important to write this article because if we can determine how to reuse the water absorbed by the permeable concrete we can help families, who have almost no access to this vital resource such as water, in their rainy seasons this water can be used to the maximum and thus in times of drought suffer for this resource, also so that in areas where the rainy seasons cause great tragedies, floods can be avoided as much as possible and the stored water can serve as sustenance for this area, that the water can be treated to make it drinkable and achieve a good supply of this vital resource for human life.

How can we ensure that the water absorbed by permeable concrete can be reused?

The mere fact of imagining that there is a possibility of reusing such an important natural resource as water, which to date has claimed the lives of hundreds of people, generates shock, considering that the lack of access to water kills 780,000 people in the world every year, according to a UN report, which highlights the challenge it will pose in the coming years.

Permeable concrete pavements are structures composed of a permeable concrete top layer, a base similar to any other pavement, which in this case can store and manage water, and optionally a drainage system that can be more or less complex depending on the needs, and the natural supporting soil, which can infiltrate water depending on its properties. This type of pavement offers several advantages, such as managing water resources more efficiently, reducing flooding and runoff, improving water quality, and reducing pollutants from entering the groundwater.

What we are looking for is to be able to reuse or give them use to the rainwater of the cities by carrying out different mechanisms that help to collect, conduct and also purify this natural resource in the following way:

Storm sewer system: As is well known, it consists of a network of conduits, catchment structures, and complementary structures. Its objective is the management, control, and conduction of rainwater that falls on the roofs of buildings, streets and avenues, sidewalks, and gardens, among others. So through these, we seek that under each construction of these streets, and roads of permeable concrete there is a storm drainage system so that water absorbed by these can reach a place and can be conducted, and thus avoid problems such as those presented by freezing in cold areas and evaporation in hot areas, likewise risks of loosening and sliding of the earth will be avoided since the absorbed water will have a conductor and its irrigation levels would be greatly reduced.

In the storm sewer system design water filters: The filters are devices made of porous materials and activated carbon; the activated carbon thanks to its chemical properties allows purifying the water, which would come directly from the pavement. When passing through the filters their job is to retain harmful particles such as rust, iron, mud, and bacteria, among others that can bring the water that at the same time can be harmful to health; these filters help to purify water, and thus to achieve access to drinking water. Although its initial cost may be a little high, its service and as it is projected to the future could bear good fruits, and in such case, it is recovered and would earn much more than what was invested, so therefore it is very feasible to implement and carry out.

Design roads, sewers and filters: These are intended to help convey water to places where there are shortages, as the Colombian Ministry of Housing, City and Territory declared 46 municipalities in a state of public calamity after being affected by water shortages and the drought season in that country. The most worrisome water supply situation is in the department of Bolivar, in northern Colombia, after 37 of its 46 localities were affected. With less than 15 regions with damages, it is followed by Boyacá, Santander, Córdoba, Cundinamarca, La Guajira, Antioquia, Valle del Cauca, Sucre, and Cesar. The state organ indicated that the number of places affected rose from 108 to 114, after the incorporation of the municipalities of Chiquinquirá, Soacha, Cáqueza, Ansermanuevo, La Cumbre, and San Pedro. In this way, each of these 46 municipalities will be reached using the same permeable concrete roads, and their problems will be reduced due to lack of water, which can also be taken and used in places where crops require irrigation systems.

Water reservoir: Water is one of the most precious and at the same time scarce goods. That is why it is of prime necessity to have a water tank that stores this resource in perfect hygienic-sanitary conditions. Water tanks are liquid storage containers that arise as an evolution to all those problems of water supply. Their beginnings started in different fields such as agriculture, livestock, and, of course, personal supply.

Preventing flooding in many parts of the world: Floods are a current problem that has caused thousands of catastrophic events on the roads, and streets, rains have caused thousands of catastrophic accidents thus becoming an imminent danger when it rains and in other cases overflowing rivers that destroy everything in its path. and to this we must add the number of deaths that have been generated, by so many traffic accidents, the permeable concrete could be the most effective solution to this, through the mechanism mentioned above. This is a type of asphalt that absorbs water and, most strikingly, does so in large quantities. With a drainage capacity never seen before, this compound is capable of absorbing no less than 4,000 liters of water in less than a minute.

Hence, their main function is to allow access to water whenever you want, regardless of any supply interruptions that may occur. Water tanks can be installed underground, at ground level, or in some higher areas depending on their use, although the operation is always the same:

1. Water is piped through the utility mains to all properties.
2. Once there, the water is placed in storage tanks such as cisterns and elevated tanks.
3. Finally, the main branch is connected to an endless valve and a float in order to control the water inflow.

In this way, we can conserve the water obtained through the absorption process so that when there is a drought in the country we have that extra resource that can help us to meet some of the needs that we may lack at that time.

Limitations of permeable concrete

Permeable concrete has several limitations that should be considered when determining its suitability for a particular application. Some of these limitations include:

1. Low strength: Permeable concrete typically has lower strength compared to traditional concrete, which can limit its use in applications that require high structural strength, such as bridge decks or heavily trafficked roads. Its use in areas with heavy traffic is very limited, due to its structure and shape, which makes its wear much greater.
2. Freeze-thaw durability: Permeable concrete can be prone to damage from freeze-thaw cycles, especially if it is not properly designed and constructed. This can limit its use in areas with harsh winter climates.
3. They require greater attention and care in the design depending on the type of soil used, such as expansive soils and those susceptible to freezing; although when the water reuse process is carried out, soils susceptible to freezing would disappear.
4. Maintenance: Permeable concrete requires regular maintenance to ensure that it remains effective in capturing and filtering water. This can include regularly cleaning and removing debris from the pores of the concrete, as well as maintaining the surrounding drainage systems.
5. Longer curing time.

6. Sensitivity to water content and control in fresh concrete.

7. Cost: Permeable concrete can be more expensive to produce and install compared to traditional concrete, due to the need for specialized equipment and materials.

8. Limited applications: Permeable concrete is most effective in low-traffic areas and is not suitable for use in high-traffic environments or in areas with heavy loads. It may also not be suitable for use in areas with high water tables or in areas with unstable soils.

9. Considering that these concretes are not very well known, it is foreseen that specialized construction practices will be necessary in order to carry out the procedures and make good use of these concretes.

10. Special attention may be required in cases of elevated groundwater levels.

Conclusion

New technologies make the world evolve day by day, civil engineering cannot be left behind. The needs to create and innovate are increasingly greater, today there are roads, not only with the ability to communicate some places with others but also help to obtain a resource as important as water, it seeks to achieve social, environmental and economic benefits, which can be increased by the use of permeable materials in most urban roads.

Permeable pavements have shown their capacity to avoid undesirable features and events derived from impermeability. Therefore, their use is highly recommended in road networks based on the criteria of water preservation and mobility of people.

Further research should be carried out to learn how to effectively deal with the negative side effects of permeable concretes, in addition to investigating the feasibility of expanding their range of applications through additional research work.

In conclusion, permeable concrete has emerged as a promising solution to address some of the challenges faced by traditional concrete in urban road networks. Its ability to capture and filter water, as well as its potential to reduce flooding and improve water quality, makes it a valuable tool for achieving social, environmental, and economic benefits. While there are limitations to the use of permeable concrete, including its lower strength and higher cost compared to traditional concrete, ongoing research is working to address these issues and expand the range of its applications. Overall, the use of permeable concrete in urban road networks holds great potential for improving the sustainability and resilience of our built environment.

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