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APPLICATION OF PERMEABLE COATING IN ORDER TO REDUCE OBSTRUCTIONS IN THE COVERING OF DRAINAGE ELEMENTS

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Abstract: The application of permeable coating is an effective strategy to reduce obstructions in the covering of drainage elements, such as manhole covers. Manhole covers, components of urban drainage systems, play a fundamental role in the proper management of rainwater, helping to reduce flooding events and facilitating the conduction of said water to receiving water bodies. During their useful life, these manhole covers may have their efficiency compromised due to obstruction due to the accumulation of solid waste eventually carried into the system. A permeable concrete plate was made, in accordance with ABNT NBR 16416:2015 with the addition of glass fibers, and cylindrical test specimens (10 cm x 20 cm) were made, with the same additions, and subsequently tested for compression in accordance with (ABNT NBR 5739:2018). A permeability test (ABNT NBR 16416:2015) was performed on the plate in order to measure its drainage capacity. The compressive strength results did not reach the value of 22.0 MPa predicted according to DNIT (2004) in any of the 3 scenarios tested. However, it is worth noting that scenarios 2 and 3 showed an increase in resistance when compared to the reference scenario. Scenario 1, even with the addition of fiberglass, did not show an increase in resistance in relation to the reference scenario. Regarding the drainage capacity of the plate, it was observed that it presented permeability levels of around 8.73% of the drainage capacity of a conventional manhole cover. It is concluded that the use of pervious concrete would require an increase in the area of the manhole cover so that the permeability is compatible with that provided by the conventional manhole cover.
Keywords: Drainage; Coating; Permeability.

INTRODUCTION

In contemporary societies, the challenges associated with urban drainage are becoming increasingly greater. In this context, there is a need to find solutions that mitigate the problems arising from the obstruction of drainage devices, which could consequently reduce the occurrence of flooding in large urban centers (TUCCI, 2003).

To treat this adverse situation has a direct impact on the quality of life and well-being of the population, which is why this article seeks to analyze new construction solutions for manhole covers, in order to use them on existing drainage elements and maintain, if possible, the same drainage efficiency as these, but without allowing the transport of unwanted particulate matter to the urban rainwater drainage system, because all unwanted materials will be retained in the lining itself (TUCCI, 2003).

Furthermore, the Brazilian legal system, through Law 11,445/2007, established the guidelines that must be followed at the national level regarding basic sanitation. This instrument subdivides basic sanitation into four main pillars: drinking water supply; sewage; urban cleaning and solid waste management; and drainage and management of urban rainwater. The theme of this article, therefore, is associated with basic sanitation through drainage and management of urban rainwater.

It is understood that this research contributes greatly to reducing the incidence of blockages in manholes, preventing the entry of coarse particles. In addition, it is believed that the proposed solution can contribute to enhancing the capacity of urban drainage systems and rainwater receiving bodies. Furthermore, this study seeks to optimize existing devices in terms of drainage efficiency on public roads (TUCCI, 2003).

The objective is to develop a permeable concrete, made with fiberglass, that will help prevent obstructions with little or no compromise on the efficiency of drainage on urban public roads, in situations of high-water volume. By carrying out laboratory tests on drainage and mechanical resistance, the aim is to develop the material in question in order to improve the technological performance of manhole covers on urban public roads.

Considering these aspects, the general objective of this study is to propose replacing the current manhole cover model with a coating that is permeable and prevents the passage of solids. The specific objectives are to verify which materials can make up a porous coating, as well as to carry out permeability and compressive strength tests on the chosen coatings and, therefore, to analyze the possible models to replace the current covers. In this sense, the aim is to prove the feasibility of using permeable concrete with fiberglass in the coating of the manholes currently used.

URBAN DRAINAGE IN BRAZIL

Drainage and rainwater management services in Brazilian urban areas are already supported by legislation. These legal mechanisms seek to facilitate access to this and other aspects that are part of the objectives of basic sanitation. In this sense, through engineering interventions ranging from the improvement of drainage infrastructure to the final destination of this water, article 2, item IV, of Law number: 11,445/2007 determines that there be:

> "IV - Availability, in urban areas, of drainage and rainwater management services, treatment, cleaning and preventive inspection of networks, suitable for public health, environmental protection and the safety of life and public and private property;" (BRAZIL, LAW 14,026/2020).

It must be reiterated that the national guidelines on basic sanitation are subdivided into four main areas: drinking water supply, sewage, urban cleaning and solid waste management and, finally, drainage and management of rainwater (BRAZIL, LAW 14.026/2020).

The activities that initially involve collection, passing through building installations and culminating in the supply of water are those originating from the supply of drinking water. Sanitation, on the other hand, involves the operations of collection, transportation, treatment and final disposal of user effluents (BRAZIL, LAW 14.026/2020).

From this perspective, there is also a bias towards solid waste, as well as urban cleaning, which is distinguished from other aspects of basic sanitation because it involves, for example, manual or mechanical sweeping of public spaces, in addition to preserving them through the sanitation of community environments (BRAZIL, LAW 14.026/2020).

Regarding the subject of this article, the drainage and management of rainwater is associated with the aspects - as determined by (BRAZIL, LAW 14.026/2020, p.7) - "(...) of rainwater drainage, transportation, detention or retention to dampen flood flows, treatment and final disposal of drained rainwater, including cleaning and preventive inspection of networks". Advances in infrastructure in several countries have not kept up with the disorderly population growth that occurred in the middle of the last century, especially in the less developed countries. As a consequence of the lack of planning, cities were established on the banks of rivers and expanded around them without defined legislation. This situation, associated with the waterproofing of areas that were once permeable, continues to contribute to flooding events, and such occurrences take on large proportions, especially in densely populated areas. This is due to the inefficiency of existing urban drainage mechanisms and the impermeable environment, so that, after heavy rainfall, the water is unable to infiltrate and, ultimately, surface runoff occurs (TUCCI, 2003).

CURRENT DRAINAGE DEVICES

According to DNIT (2006), there are the following ways to drain rainwater from roadways: thalweg transposition drainage, surface drainage, pavement drainage, underground or deep drainage and urban crossing drainage.

It is in the context of urban crossing drainage that the manhole, the central element of this work – as well as the gutter, manhole, galleries and special structures are implemented. In this perspective, according to DNIT (2006), manholes can be classified as simple (Figures 1 and 2), with grates (Figures 3 and 4) or a combination of both (Figures 5 and 6).

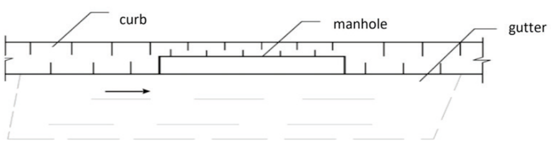

Figure 1: Model of Simple manhole cover

Source: DNIT, 2006.

Figure 2: Simple manhole cover

Source: Portal Itu, 2016.

Figure 4: Manhole with grill

Source: Ebanataw, 2021

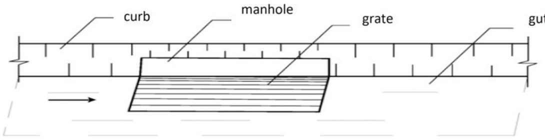

Figure 5: Model of combined manhole

Source: DNIT, 2006.

Figure 6: Combined manhole

Source: Concrealfa, 2017.

CHARACTERISTICS OF STORM DRAINS

According to DNIT (2004, p. 2) storm drains are conceptualized as follows:

> "Collection devices, located next to the edges of the shoulders or curbs of the urban road network that, through branches, transfer the runoff to the galleries or other collectors. Because they are located in urban areas, for safety reasons, they are covered by metal or concrete grids".

Furthermore, this device must be executed and installed on a concrete lining with a minimum characteristic strength (fck. min.) of 15 MPa. Its walls may be constructed of either concrete blocks or solid brick masonry. A concrete belt with the same minimum characteristic strength, mentioned above, must be implemented to serve as a base for the grate installation. If this cover (grate) is made of reinforced concrete, the fck. min. must be 22 MPa. (DNIT, 2004).

Regarding permeability, the ``*Portal do Projetista*`` (2016) reports that conventional manholes have grates with a permeability coefficient of 85.00 mm/s. Therefore, this quantity will be compared with the scenarios obtained in this experiment, for the purpose of verifying the drainage efficiency achieved in this work.

TYPES OF CONCRETE

Concrete is the most widely used material in civil construction. This compound is derived from the mixture of at least one hydraulic binder, in this case cement, and also water, coarse aggregate and fine aggregate, in addition to other materials that may be added, such as additives. A pasty mixture is formed after being hydrated, which adheres to the aggregate fragments, forming a resistant mixture that is easy to mold, with high compressive strength. Thus, when hardened, it forms a rigid block that meets the necessary requirements. (MEHTA and MONTEIRO, 1994) There are several types of concrete, each one is designed to meet different needs and specific conditions. The main ones include: Reinforced concrete: it has steel bars inserted to increase flexural strength, making it ideal for structures subject to high loads, such as slabs and beams. Conventional concrete: it is the most common type, composed of cement, water, sand and gravel. Due to the low workability of this concrete, it is necessary to use agitating equipment for good compaction. This concrete requires a large amount of labor, due to its manual application (``*PORTAL DO CONCRETO*``, 2023).

- Fiber-reinforced concrete: contains steel or polymer fibers, which reduces cracking, increasing resistance to flexure, impact, surface wear and abrasion. (SUPREMO CONCRETO, 2023).
- Permeable concrete: designed to allow the passage of water, used in paving to reduce surface runoff.

ADDITION OF FIBERGLASS

The incorporation of glass fibers into permeable concrete is a technique that can improve its mechanical resistance without compromising its permeability.

When fibers are added to conventional concrete, the resulting material is called fiber-reinforced concrete (FRC). According to the classification of the International Bureau for the Standardization of Artificial Fibers (BISFA), the fibers can be of natural or artificial origin.

Glass fibers can be defined as filamentary materials with a length-to-diameter ratio of at least 100. Although there are no restrictions on the minimum diameter, the maximum must not exceed 0.25 mm. The mechanism of fiber formation, which contributes to their high tensile strength, is linked to the better attraction of their particles (SCHWARTZ, 1984). According to Hollaway (1993), the predominant characteristics of fibers used in the manufacture of composites are: high strength and modulus of elasticity, uniformity in the strength value of individual fibers, stability and maintenance of properties during handling, and low variation in diameters between filaments and surface roughness.

According to Figueiredo (2011), fibers that have a lower modulus of elasticity than hardened concrete are called low-modulus fibers. High-modulus fibers are those that have a higher modulus of elasticity than the aforementioned material. For applications in civil construction, fiberglass is considered more advantageous when compared to others, as it offers high tensile strength, high modulus of elasticity, and low production costs.

Fiberglass was used in this experiment in order to achieve mechanical resistance to withstand possible vehicle traffic in gutters and manholes.

For Figueiredo (2011), the efficiency of the fiber is related to its performance as a bridge for transferring stress in the concrete crack. A crack will provide a barrier to the propagation of traction, this is due to the tension lines that imply a concentration in the cracks.

With the use of fibers, it is expected to obtain less cracking of the concrete. (MINDESS, 1995).

One of the characteristics of the reinforcement obtained with fibers is the fact that they are distributed randomly in the material, strengthening the piece as a whole, and not in a specific alignment, as occurs with conventional reinforcements used in reinforced concrete (FIGUEIREDO, 2011).

METHODOLOGY

Among the various mechanical properties of concrete, the following stand out: resistance to simple axial compression and resistance to tensile strength due to diametrical compression. These properties are determined from specific tests according to the respective standard; these tests are for specification and quality control for application. (PINHEIRO, 2004).

EXPERIMENT

The experimental research aims to test the permeable lining, through the modeling of test specimens, verifying the resistance of the concrete to simple axial compression and its permeability coefficient to apply it in the manufacture of manhole covers. The procedures of ABNT NBR 16416 Annex A were adopted.

MATERIALS

The materials used in the research were Holcim brand CPV-ARI cement, coarse aggregates (gravel 0 and gravel 1), and fine aggregate (medium sand) from ``*Martins Lanna Mineração*``. In addition, CSM fiberglass – CS 405B 6.4 mm chopped fiber was used.

The reference mix for the pervious concrete used in the assembly of the piece was 1:3: 1.3:0.5 (mixture by mass). In addition, a water/cement ratio of 0.4 was used.

Features				
Material	**Feature 1**	**Feature 2**	**Feature 3**	**Feature of reference**
Cement (Kg)	1	1	1	1
Gravel 1 (Kg)	3	3	3	3
Gravel 0 (Kg)	1,3	1,3	1,3	1,3
Medium Sand (Kg)	0,5	0,5	0,5	0,5
Factor a/c	0,4	0,4	0,4	0,4
Fibers (g/dm3)	1	5	10	0

Table 1: Features used

Source: Own authors (2023)

Finally, the difference obtained in each mix was defined as a function of the amount of fiberglass per cubic decimeter of material inserted into the concrete.

METHOD

The procedure for preparing the concrete was in accordance with ABNT NBR 12821: Preparation of concrete in the laboratory – Procedure.

The preparation of the test specimens was carried out in accordance with ABNT NBR 5738; concrete procedure for molding and curing test specimens. Regarding the axial compression tests, the procedures set forth in ABNT NBR 5739; Concrete Compression test of cylindrical test specimens were followed.

Figure 7: Concrete compaction

Elaborated by the author (2023)

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Figure 8: Concrete production

Elaborated by the author (2023)

Figure 9: Axial compression strength test

Elaborated by the author (2023)

Figure 10: Rupture of the test specimen

Elaborated by the author (2023)

Figure 11: Shear rupture

Source: NBR 5739:2018

Figure 12: Sheared specimen

Elaborated by the author (2023)

The permeability test was carried out in accordance with ABNT NBR 16416 Annex A – Determination of the permeability coefficient of permeable pavement.

DESCRIPTION

The tests were carried out in the laboratory of ``*Centro Universitário Newton Paiva*`` in order to meet the normative requirements existing in the aforementioned standards.

The permeability coefficient test was performed in accordance with ABNT NBR 16416 annex A, which aims to measure the permeability of permeable pavement and can be used in the field or in the laboratory. According to item A.2 of the aforementioned standard, the execution consists of using a circular shape, with a determined area of (150 ± 10) mm and a minimum height of 50 mm. The cylinder has two reference lines with a distance of 10 mm to 15 mm in relation to the lower face of the ring. The material must be rigid enough not to deform. A sealing material is applied to the ring at the interface between it and the surface of the draining pavement to be analyzed. After previously moistening the test specimen to be tested, the water mass is poured into the shape and the infiltration time of the total volume poured is timed. The permeability coefficient is calculated, as a function of time (s), using the following formula:

$$k = \frac{C.M}{D^2.T}$$

Where:

K = infiltration rate (mm/h)

C = 4,585,666,000 - constant value

M = mass of water (kg)

D = diameter of the circular structure adopted (mm)

T = time it takes for the mass of water to be infiltrated

A total of 18 kg of water was poured onto the permeable concrete plate in order to determine the water infiltration rate. In this scenario, three tests were carried out on each ring.

Figure 13: Permeability coefficient test

Elaborated by the author (2023)

RESULTS AND DISCUSSION

Compression rupture (MPa)				
ESSAY	REFERENCE	FEATURE 1	FEATURE 2	FEATURE 3
1° rupture	12,34	6,95	13,41	18,17
2° rupture	13,21	11,77	14,73	12,16

Table 1: Axial compression strength test

Elaborated by the author (2023)

PERMEABILITY COEFFICIENT TEST				
ESSAY	DIAMETER (mm)	WATER MASS (Kg)	TIME (s)	INFILTRATION RATE (mm/s)
1	150,00	18,00	147,87	6,891
2	150,00	18,00	150,32	6,779
3	150,00	18,00	152,79	6,670
4	150,00	18,00	137,37	7,418
5	150,00	18,00	137,97	7,386
6	150,00	18,00	138,58	7,353

Table 2: Permeability test

Elaborated by the author (2023)

The result of the permeability coefficient test is given in millimeters per second (mm/s), so it is possible to calculate the volume of water passing through in a given period for any area size.

CONCLUSION

After obtaining the results of the compressive strength test of the pervious concrete prepared in this experiment, compressive strength values that met the value recommended by DNIT (22.0 MPa) were not achieved. It was found that in the Mixture 2 and Mixture 3 scenarios, the increase in strength expected by the addition of glass fibers, in relation to the Reference Mixture scenario, was observed in at least one of the CPs. In the Mixture 1 scenario, the compressive strengths obtained were lower than the Reference Mixture scenario, even with the addition of glass fibers. Analyzing, specifically, the Mixture 1 scenario, it is possible that the compressive strength results obtained lower than the reference scenario were the result of non-compliance in the compaction of the test specimens of this mix. Analyzing the permeability test, although positive infiltration results were found, which demonstrates the drainage capacity of the concrete, the highest total flow rate obtained in the experiment, 7.42 mm/s, does not match the total flow rate obtained by the manhole covers currently used, with 85.00 mm/s, as previously mentioned.

It must also be noted that the permeable coating tends to have its infiltration rate reduced over time, due to the possible accumulation of particles in the voids of the permeable concrete.

Considering the aforementioned aspects, it can be concluded that, for the proposed solution to be viable to be used with current materials and technologies, a larger area than the current standard would be necessary to achieve the same efficiency. However, it is possible to use the aforementioned solution in other applications that do not receive large loads, such as sidewalks and areas where there is no heavy vehicle traffic.

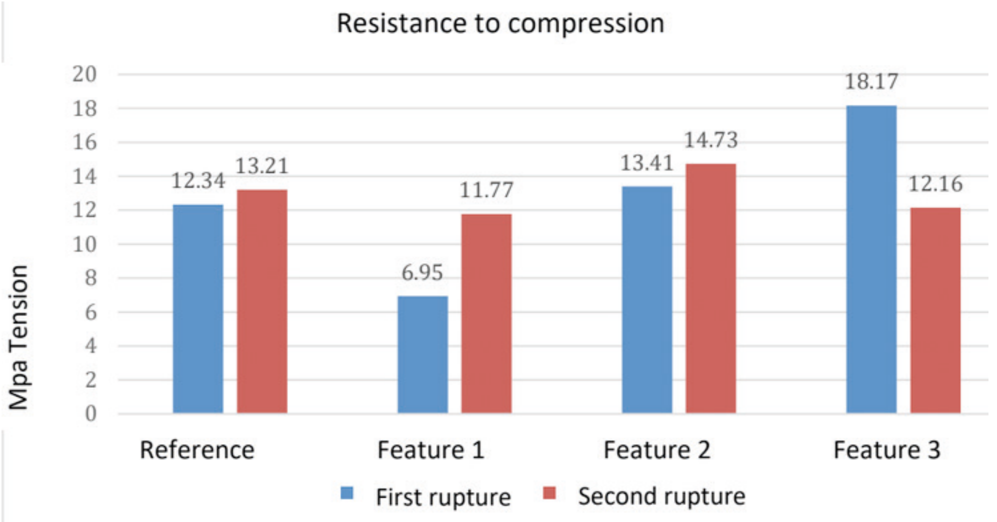

Table 2: Axial compression strength test

Elaborated by the author (2023)

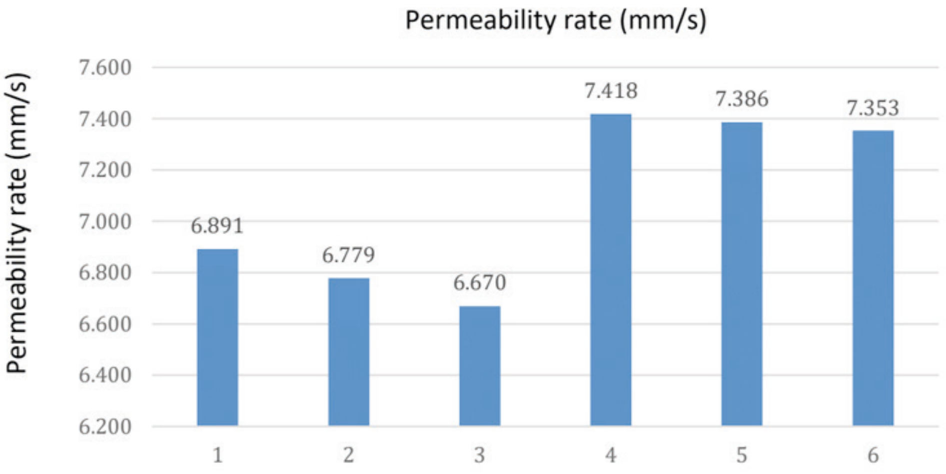

Table 3: Permeability test

Elaborated by the author (2023)

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