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A Brief Review of the Environmental Benefits and Maintenance of Porous Concrete Paving Block

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Porous Concrete Paving Block (PCPB) is the most upper layer of permeable concrete block pavement in order to reduce stormwater runoff on the road pavement surface. The purpose of this work is to identify the impact of PCPB performance on the environment and maintenance required to ensure the pavement function optimally. This study assesses the main environmental advantages of PCPB in terms of reduced stormwater runoff, enhancing subsurface water quality and skid resistance, and minimizing traffic noise. Together with that, it contains PCPB performance, which is greatly impacted by mix design, installation method, service environment, and maintenance. Also, a brief discussion of the method for treating pavement pore blockage is included in this publication. Finally, new treatment technologies that can help increase PCPB performance in terms of water absorption are revealed for future research and innovation. This study aims to provide stakeholders and decision-makers with crucial information on managing stormwater and to promote the acceptance of PCPB as a demonstrable substitute for conventional pavement systems.

1. Introduction

The porous concrete paving block (PCPB) is a kind of permeable concrete with an open-pored network that enables rainfall to seep through the pavement and into the sub-base layer (SNI 03-0691, 1996). As a minimal strategic instrument, PCPB are being used to help monitor the environmental effects of infrastructure development and use. (Chopra et al., 2016). As an urban green option, PCPB is capable of being utilized to enhance or replace traditional infrastructure, mainly for low-load streets, parking lots, parks, and pedestrian routes (Selbig et al., 2019). Effective air voids between 15 and 30%, permeability between 20 and 500 m/d, and compressive strength between 5.5 and 20.5 MPa are just a few of the many features that a typical PCPB may possess (ACI 552R-10, 2010).

In heavily populated metropolitan areas, PCPB can have a large positive environmental impact. These may result in a decrease in the amount of runoff from rain (Gomes et al., 2021). Additionally, it is possible to simultaneously lessen the heat island effect and the issue of traffic noise. According to a recent review (Xie et al., 2019), permeable concrete mixes have a lot of potential for "low volumes" road pavements like local streets, pedestrian walkways, and driveways. If design procedures are followed, they may even be used in arteries and highways in the future.

Although PCPB has the potential to have positive environmental effects, issues like retention stress and clogging that jeopardize its long-term viability continue to be significant obstacles to its widespread use. One of the main factors is when the PCPB is clogged with dirt around it or when the pores are blocked due to the action of passing vehicles (Nan et al., 2021). This needs to be considered in all future PCPB design, fabrication or construction, preservation and maintenance projects. The goal of this study is to provide a critical evaluation of the state of information about PCPB in this condition, focusing on the environmental benefits and maintenance required for PCPB to function well.

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2. Methods

Recent review papers have been thoroughly investigated this technology's most current and predicted breakthroughs from the perspective of environmental benefits and maintenance techniques. Previous studies have concentrated on the creation and assessment of various PCPB kinds in the latest years. Also, when developing PCPB, elements like strength and ease of application are taken into consideration.

This study provides a summary of recent developments in assessing the environmental consequences of PCPB, given that it is an essential component of environmentally friendly infrastructure and a useful instrument for sustainable development. This article also discusses the maintenance required to keep a PCPB in good working order for a very long time.

To understand the relationship between PCPB durability, environmental advantages, and the composition of materials, literature materials were acquired using keyword searches on well-known databases like Scopus, Web of Science, Google Scholar, and others. The terms "paving block," "permeable pavement', slip resistance", "noise," "PCPB", and "clogging mechanism" were used. Examples of suitable sources are international journal articles, chosen professional conferences, and international books. Publications released after 2013 that met the following criteria were taken into consideration for this review: accuracy and validity, effect on PCPB research, a reflection of current PCPB research, and predictions of future trends in PCPB studies are all factors that should be considered when evaluating a review.

3. Environmental benefit

PCPB is associated with a number of ecological advantages, with decreased overflow and improved stormwater penetration, improved groundwater quality, increased surface slip resistance, and reduced traffic noise. These advantages can recover traffic safety, ecological awareness, and resilience. Government organizations in numerous nations are promoting green infrastructure initiatives in an effort to lower accident rates and environmental pollution. In this context, PCPB is viewed as a tool that has the potential to improve infiltration and slide resistance.

3.1 Hydraulic performance

The hydraulic performance of PCPBs is discussed in this section, additionally to the measurement of permeability and the relationship between permeability and porosity. Hydraulic Performance refers to PCPB's capacity to lessen the amount of runoff from rain and to offer resilience to society and the transportation system. The testing procedure has an impact on PCPB's hydraulic qualities (Kamali et al., 2017). The ability of a substance to allow entry water to travel over a porous matrix when subjected to a void is known as permeability. The ASTM family of test standards control permeability tests, which are typically carried out on samples of permeable concrete in testing facilities or outdoors (National Standard, 2010). The falling head permeability test is the most typical kind of lab evaluation (Andres-Valeri et al., 2018). For the permeability test, the specimen is covered on all angles, and the length chronological it takes for water required to its surface to descent in height is noted. In order to compute hydraulic conductivity, initial and final head pressures, as well as time, are used.

Chopra et al (2016) created an embedded ring infiltrometer, a brand-new field test tool, to measure the penetration rate of recently installed PCPBs. Nazari et al. (2019) was found to be excellent agreement between the ASTM and SF-9 standards and the NCAT and SF-4 permeability measurements. They evaluated different method tests, including the falling head, infiltration test, and constant head method.

3.2 Traffic noise reduction

PCPB has demonstrated advantages for lessening traffic noise (Xie et al., 2019). Traditional concrete had noise levels between 100 and 110 decibels adjusted (dBA) in 2009 and 2010, while permeable concrete had noise levels between 96 and 98 dBA. Permeable cement concrete (PCC) "shows superior sound absorption capacities than porous asphalt," according to a laboratory study by (Chu and Fwa, 2019). Purdue University researchers created a quiet, long-lasting permeable pavement material in the early 2000s (Neithalath, 2006). Moreover, Schaefer et al. (2009) reported the MnROAD Low Volume Road's permeable concrete layer noise reduction impact, and found a very quiet surface.

The geometry and a number of other factors, such as the concrete pavement's tortuosity, aggregate size, air spaces or porosity, and airflow resistance per unit length, all affect how well permeable concrete pavements absorb sound. (Arenas and Crocker, 2010). Crocker et al. (2005) the influence of thickness on PCPB sound decrease. The wide of the porous surface has an inverse relationship with the absorbed peak frequency in general. Yet the thickness of the porous surface is inversely correlated with the thickness of the top frequency. According to laboratory research, noise absorption is best at 80 mm thickness. According to field test results, the PCPB application can minimize noise by 48 dB (Tian et al., 2013).

3.3 Skid resistance

Despite the fact that there isn't much evidence in the published literature to back this claim, PCPBs have reportedly been discovered to have better slid resistance than their waterproof equivalents (Jusli., 2014). According to Nguyen et al. (2014), cemented PCPB has a significantly greater skid resistance rating than its water-resistant cousin, which is advantageous for safety in traffic. However, tests utilizing a British pendulum tester (ASTM E303) on a parking lot with permeable pavement revealed PCPB to have the same skid resistance as conventional asphalt (Hidayah et al., 2014). According to Yeih et al. (2015), When aerosol arc burner waste was substituted for aggregate, PCPB exhibited improved strength, higher slip resistance, and a higher coefficient of permeability.
According to Kevern (2011), permeable concrete specimens exhibit a more controlled gait cycle and less slide when compared to impermeable pavement. This was attributed to the PCPB under winter conditions having " coefficient of friction, added contact pressure, and reduced likelihood for waterlogging and surface freezing." Using kinetic biomechanical study, Raja et al. (2013) verified the advantages of this PCPB in lowering the risk of slipping.
The roughness of the road surface has been shown to be an important factor to consider when evaluating slip resistance in previous studies (Ye et al. , 2019). The ability of a pavement to resist slipping can be significantly increased by texturing (Li et al., 2016). Additionally, micro-texture is largely associated to low speed and dry friction, whereas macro-texture has a major impact on slip resistance of the pavement surface, particularly in high-speed and/or rainy road conditions (Chen et al., 2013). Pratico and Astolfi (2017) claim that microtexturing is in charge of frequencies below 0.5 mm and maximum amplitudes between 0.3 mm and 0.5 mm.
The macro texture, on the other hand, has a peak-to-peak amplitude between 0.1 mm and 20 mm and a wavelength between 0.5 mm and 50 mm. Microtexturing produces surface roughness that interfaces with rubber on a cellular characteristics and fosters stickiness. By integrating the fractal dimensions of the micro and macro textures, it is possible to predict PCPB's slip resistance.

4. Maintenance

4.1 Clogging mechanism

The clogging system in porous paving is a problem that can reduce the functionality of the PCPB technology. Sand, clay, eroding silt from the surroundings or transported by cars, and organic material from nearby plants are among the substances that clog pipes (Kia et al., 2017). PCPB will clog over time because the solid particles are stuck and accumulate. Rainwater carries these particles into the pavement layer. This particle is coupled with the pressure of passing traffic. The particles fill the space on the PCPB. Over time these particles will close the cavity in the PCPB that causes water to stagnate on the surface (Zhanget al., 2018).
The PCPB clogging has attracted the interest of many researchers, especially in the clogging mechanism and maintenance methods. In a recent assessment, the clogging issue in porous concrete was resolved (Razzaghmanesh and Beecham, 2018). In his review, the highest infiltration rate occurs in areas with high rainfall, so they are recommended that maintenance be carried out two until four times a year. The clogging of PCPB by sand and mud, which can lessen the infiltration of PCPB, has been the subject of extensive investigation (Kapoor et al., 2021). When compared to translucent concrete built with a significant aggregate proportion, the former is more prone to clogging. Finding a balance between the rate of unbound base course (UBC) infiltration and exfiltration is crucial when analyzing the impact of porous concrete, especially when the porous concrete is constructed of coarse aggregates (Barišić et al., 2020).

4.2 Maintenance

Maintenance of porous paving is essential. Usually, the main problem with porous paving is the clogging in the cavity, so that the function of porous paving is lost. Dust, sludge, or sand delivered by motorized vehicles or by people themselves causes these clogs (Boogaard et al., 2014). Paves with small cavities are more likely to suffer damage than large diameters (Barišić et al., 2020). Several studies have shown that the depth of blockage only occurs on the surface. Therefore, it is necessary to treat the surface layer that can restore PCPB performance to its original state. Apart from that area with high rainfall, the infiltration rate has decreased significantly, even since the two years since installation. Therefore, routine maintenance is required two to four times a year (Razzaghmanesh and Borst, 2018). Lin et al. (2016) suggest that maintenance be carried out within two years after installation using a vacuum cleaner (Lin et al., 2016).
Lifting the top 2 cm, mechanical road sweeping, air sweeping, suctioning, high-pressure water jetting, and grinding porous asphalt are a few of the PCPB treatment techniques that have been developed (Winston et al., 2016). With some techniques, a lift of up to 2.5 cm can practically bring a 21-year-old asphalt surface back to its original condition. Yet, individuals favor suction-based upkeep over mechanical sweeping. According to

research, the best way to maintain permeable pavements is to use a high-pressure vacuum followed by a high suction vacuum (Selbig et al., 2019). The answer key for the selected paper on permeable pavement maintenance can be found in Table 1. From Table 1, it can be seen that the maintenance of permeable pavement should be carried out routinely two to four times a year. Maintenance can be carried out using a high vacuum cleaner, which is the most effective method compared to mechanical sweeping and high-pressure water flow. The other method is by lifting the top 2 cm can restore the pavement as new condition.

Table 1: A summary of significant studies on permeable pavement maintenance

Ref	Region	Findings/critical review
Sehgal et al., 2018	Canada	The long-term hydraulic performance of permeable interlocking concrete pavers requires routine maintenance.
James et al., 2018	Ontario	Regular cleanouts are required for quickly cleaned-out PICPs (RCPP).
Atoyebi et al., 2020	Nigeria	Ponding was the best curing technique since it produced the highest compressive strength.
Winston et al., 2016	USA and Sweden	A 21-year-old porous asphalt pavement's SIR was nearly restored to like-new state after milling to a depth of 2.5 cm.
Danz et al., 2020	USA	While maintaining permeable pavement, high-pressure washing and high-suction vacuuming are used.

5. Conclusions and Future Trends

An overview of PCPB's environmental benefits, design, manufacture, maintenance, and durability is provided in this study, which is followed by a review of recent studies on advanced simulation and characterization. In recent years, the PCPB field has gotten increased attention. PCPB is a type of environmentally friendly construction that can be utilized in addition to or in substitute of conventional infrastructure and significantly aid in the establishment of low-impact and sustainable communities. The application of PCPB has a lot of potential to bring about a number of positive environmental effects, according to this review. First, by using water infiltration techniques, precipitation runoff may be effectively controlled and groundwater quality can be raised. Second, the use of PCPB lowers the risk of falls caused by slippage, improves skid resistance, and lowers traffic noise without sacrificing its mechanical or durability features. In general, the mix of proportion, design, building techniques, environment service, and maintenance activities of a PCPB determine its hydraulic performance and durability. The main factors affecting the mechanical quality and performance of PCPB are aggregate size, mix proportion, manufacturing process and treatment. New technologies will be developed to increase the environmental advantages and strength of PCPBs without significantly reducing their infiltration capabilities.

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