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PERVIOUS PAVEMENTS FOR STORM WATER CONTROL

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Abstract

Pervious pavement is a special type of pavement with a high porosity used to reduce surface runoff and to recharge underground aquifer. It could also be used to trap solids and keep pollutants from contaminating the water stream. This review of literature examines existing studies methodologies, technologies, advantages and drawbacks on the use of pervious pavement for stormwater control and aquifer recharge. The result of the review revealed that cement content, water-cement ratio and compaction level affect the mechanical strength of pervious concrete in rigid pavement construction. Due to the complex nature pervious properties of this concrete. Pervious concrete requires stricter quality control of the concrete mixture proportioning as compared with the conventional concrete as there are no standard specification for testing. Surface sweeping method of pore-clogging removal was ineffective in the improvement of the hydraulic conductivity of pervious pavements, as it can only help in the removal of surface debris and not sediments removal from deep voids. The development of this pavement is a positive way forward for stormwater management and aquifer recharge. It is a viable technology in the reduction of stormwater runoff and the concentration of pollutants.
Keywords: Sustainable pavement, Pervious pavement, Rigid pavement, Flexible pavement, Runoff

1.0 Motivation

Globally, the development of concrete and asphaltic concrete infrastructure involves the use of airtight, watertight, airproof and waterproof material which impedes the percolation of water to the aquifer for groundwater recharge. To this end, it becomes difficult for rainwater to percolate and therefore are not useful for aquifer recharge. Often, they accumulate as run-off leading to erosion with the severe environment and economic problem. Rather than the water soaking the soil, it leads to flood, soil erosion and water depletion. In some critical condition, they lead to the loss of life and properties.

Therefore, one of the essential solutions to this problem is the development and design of pervious pavement for stormwater control which will also help in aquifer recharge [1-3]. Therefore, this review of literature assesses the techniques, methodologies and hydraulic requirement of pervious concrete for stormwater control for an erosion free road and environment in track with sustainability.

1.1 Introduction

The research of [4] avowed that pervious concrete was first introduced and used in Europe in the early 18th century. This was developed as a bearing wall and pavement surface. By the 19th century, its usage increased to serve the purpose of a load-bearing wall and panel. The same author affirmed that this unique concrete is also used in some part of Australia, and middle east. However, it became more popular after the second world war as a result of the shortage of cement for infrastructural development. During this era, it was used as a no-fine concrete used in the building of two-storey building in Scotland, Liverpool and Manchester. America embraced this concrete in the late 19th century and in India in the millennium years [5]. The primary purpose of this concrete is for building construction.

Recent developments in the use of this concrete involve the rain-drain concept. This is as a result of the fact that it allows a large amount of water into the underground which results into groundwater recharge and stormwater management ([6-8]. This recharge has encouraged the growth of the surface plant [9-10]. due to the availability and percolation of air and water [11]

2.0 Review of Literatures

Pervious concrete has numerous advantages but in the built and natural environment . The major concern involves the durability of distress and clogging. These barriers hinder its wide application. This deterioration may be due to premature failure and deterioration when exposed to both chemical and physical attacks [12]. The clogging may be due to the sediments from stormwater or the collapsed pores from the vehicle [13-14]. Moreover, it also has a lower compressive strength. When used as a pavement material, it is susceptible to ravelling and freezing and thawing damage [15]. Pervious concrete usually has

Despite the shortcoming of this concrete, it has some unique advantages. The use of this concrete has qualified some infrastructures for Leadership in Energy and Environmental Design (LEED) Green Building Rating System [16-18]. Another usage of this concrete is as shown in Table 1. Additionally, it has a lot of sustainability benefits [19]. The same author avowed that pervious concrete possesses drying shrinkage; lower mechanical strength compared with the conventional concrete. Additionally, it has a lower pressure on framework during construction, and it takes a longer curing time.

Table 1: Advantages of Pervious concrete

S/N	Advantages	Author
1	Development of lightweight wall concrete for buildings	[20-21].
2	Pervious concrete as a thermal insulator in building	[23];
3	Pervious concrete used as a wearing course for tennis court zoos etc.	[24-25]
4	Pervious concrete in the construction of Low-speed, and low trafficked road as lightweight concrete.	[26])
5	Construction of a parking space using a pervious concrete	[27]
6	Pervious concrete for the reduction of stormwater volume and the reduction of pollutants concentration.	[28-29]
7	Pervious concrete used in the construction of greenhouse floors for freestanding water.	[30-31]

8	Pervious concrete used for noise reduction in pavement construction due to the interaction of tyres.	[32]
9	Used for the reduction of the effect of urban heat island	[32]
10	Pervious concrete for the improvement of skid resistance and reduction in road splash.	[32-35]
11	Uses of pervious concrete in the recharge of the groundwater table.	[28,36]
12	Pervious concrete in the preservation of native ecosystems	[28, 35-36]
13	Pervious concrete in the infiltration of stormwater through the pavement interlayer	[37-39]

The use of this concrete is a promising technology in stimulating the natural process of infiltration in the built environment [40].

2.1 Hydraulic Requirement of Pervious Concrete

The use of low impact compaction tool has been employed to reduce the environmental impact of building and infrastructure using this unique concrete [41-43]. In the research of Neithalath et al., 2010 and Tennis et al., 2004 the porosity of the concrete is between the range 15%-30% while the standard permeability value ranges from 8 to 20 mm / s. This value has been used in the design of this concrete as drainage layers for pavements structures [44-45]. Other researches on the porosity of pervious concrete are as shown in Table 2.

Table 2: Previous research outcome on the porosity of pervious concrete

S/N	Description	Authors
1	Cement paste volume to inter particles void ratio	[46]
2	Compaction decreases the infiltration rate of pervious concrete pavements.	[47]
3	There exists a strong positive influence on the porosity and hydraulic properties but a negative influence on the strengths of pervious concrete.	[48]

4	The use of polymer latex and sand produced an acceptable permeability and mechanical strength.	[50]
5	Established that vertical porosity distribution plays a vital role in the hydraulic properties of pervious concrete	[51-52]
6	The void ratio should not be used as the only parameters to determine the hydraulic performance of pervious concrete.	[40]
7	Effective air voids are one of the most critical factors that determine the hydraulic and mechanical properties of pervious concrete	[53-55]
8	Removal of dissolved Cu and Zn	[56]
9	Removal of heavy metals, long term effect	[57]
10	Assessment of the pollutant concentrations	[58]

2.2 Devices and Methodology Adopted

Embedded ring infiltrometer is a recent tool for evaluating the infiltration rates of newly installed PCPs; future research should focus on this. The design manufacture and techniques involved in the development of pervious concrete has improved tremendously over the last few decades [59-61]. The recent methodologies as reported by ACI Committee 522 (ACI 522R10) and the ASCE past paved task committee [62]. Additionally, the research of Schaefer et al., 2006; and Kevern et al., 2008 and 2010) investigated in America revealed that water-cement ration of the range of 0.27 and 0.43 is appropriate for the previous concrete mixture. The same author affirmed an aggregate size between 4.76 and 25.4mm. The authors further demonstrated the development of the mix design methods for pervious concrete, especially in cold climates. [63] also stated that pervious concrete requires a stricter quality control of concrete mix design compared with the conventional concrete. This is important in a bid to ensure that the paste is completely coated and adheres to the aggregates. This ensures enough resistance and permeability.

Additionally, the level of aggregate humidity must be closely controlled. Permeability test is usually carried out using ASTM 1688, 1701, 1747, 1754). A falling head permeability test for the head is the most common form of laboratory test as avowed by [64-66]. According to Chopra et al., [67], hydraulic conductivity and the creation of a new field test tool called an embedded ring infiltrometer is used to determine the penetration levels on newly constructed pervious concrete.

2.3 Mechanical Properties

Some of the most common properties for determining the mechanical properties of pervious concrete is the compressive strength test. It is worthy to note due to the complex nature of pervious properties of this concrete; ASTM has not released a standard test method for its mechanical properties. This is due to the complex properties of this concrete because of its porous nature. The standards used in assessing its mechanical properties is the conventional ASTM C39 standard.

Table 3: Physical and mechanical properties of pervious concrete

S/N	Description	Standard
1	Water: Cement ratio	0.27 to 0.40
2	Aggregate: Cement ratio	4 to 6:1
3	Admixture	5 -7 %
4	Fine: Coarse aggregate ratio	0 to 1:1
	Mechanical properties	
1	Density	1600 to 2000 Kg/m3
2	Compressive Strength	3.5 to 28 MPa
3	Flexural Strength	1 to 3.8 MPa
4	Tensile Strength	1 to 3 MPa
5	Permeability	8-20 mm/s
6	Porosity	15 to 35%
7	Slump	Zero

Source: ASTM Standard

2.4 Sustainable materials and technologies in Pervious Concrete

Several sustainable materials and techniques have been used for the development of pervious concrete. Table 4 showed these materials and technologies.

S/N	Description	Authors
1	The use of fly ash and iron oxide in pervious concrete for the removal of phosphorus.	[68]
2	Rural road construction using pervious concrete	[69]
3	Development of pervious concrete using titanium dioxide as a photocatalyst for the construction of a green urban road.	[70]
4	Durability and corrosion control of pervious concrete.	[71]
5	Effect of soil moisture and chemical properties of pervious concrete.	[72]
7	Multidirectional benefits of pervious concrete in terms of sustainability and environmental impact.	[73]
8	Sustainability benefits of pervious concrete	[74]

9	Assessment of the Long-term drainage performance	[75]
10	Assessment of the total suspended solids	[76-77]

2.5 Maintenance Activities of Pervious Pavements

The improvement of the hydraulic conductivity of pervious concrete is one of the focus f the routine maintenance action. This will help in the repair and rehabilitation of the functional, structural and drainage defects [78-79]. One of the significant drawbacks of pervious concrete is the pore-clogging issue [80-82]. According to the research of [83], it is a functional defect. The author assessed the clogging dynamics of pervious concrete using reflectometers. A special type of reflector called the Time Domain Reflector (TDR) was used by [84], which proved to be effective in improving the hydraulic properties of pervious concrete.

Furthermore, [85] adopted the use of a vacuum truck sweeper which is an effective deep penetrating clogging removal equipment. However, this was just effective in the removal of sediments. The use of pressure washing was also used in removing the clogs. It is worthy to note that pressure washing proved to be more effective and showed higher rejuvenation efficiency than the use of a vacuum sweeper. [86] affirmed that the use of both pressure sweeping and vacuum cleaning could improve the infiltration of water by 90%. These methods are effective but cannot overcome the defect of improper construction [87]. Both pressure washing and pressure blowing improved the infiltration rates of the pervious concrete.
The combined use of these two maintenance activities has resulted in an almost 200fold rise atfield s ites. [88]. Surface sweeping has been unsuccessful in enhancing hydraulic conductivity, as it can onl y eliminate debris from the surface but not from the

deep voids [88].

3.0 Conclusion

This review of the literature assessed the use of pervious concrete in pavement construction. This was done by assessing the advantages, drawbacks, technologies, methodology and maintenance of this concrete in the construction of concrete for stormwater control. To this end, the hydraulic and porosity requirements were espoused. The result of the review revealed that:

i. The use of both pressure sweeping and vacuum cleaning can improve the infiltration of water by 90%
ii. Surface sweeping method of pore-clogging removal was ineffective in the improvement of the hydraulic conductivity of pavements. This is because it can only help in the removal of surface debris and not sediments removal from deep voids.
iii. Due to the complex properties of this concrete, ASTM has not released a standard test method for its mechanical properties.
iv. Pervious concrete requires stricter quality control of the concrete mixture proportioning as compared with the conventional concrete.
v. The aggregate moisture level must be carefully monitored,
vi. lower mechanical strength compared with the conventional concrete.
vii. The primary concern involves durability distress and clogging. These barriers hinder its wide application
viii. When used as a pavement material, it is susceptible to ravelling and to freezing and thawing damage

3.1 Recommendation

Future research should focus on the assessment of the effectiveness of embedded ring infiltrometer in the evaluation of the rate of infiltration of pervious concrete.

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