A Review Paper on Pervious Concrete

Darshankumar Patel[1], Basweshwar Jirwankar[2]

[1]Assistant Professor, Department of Civil Engineering, SVKM's Institute of Technology, Dhule
[2]Assistant Professor, Department of Civil Engineering, SVKM's Institute of Technology, Dhule

---***---

Abstract - *Permeable concrete is a form of concrete that is made up of cement, coarse aggregates, water, and, if necessary, admixtures along with other cementitious materials. Because no fine particles are employed in the concrete matrix, the amount of voids is higher, allowing liquid to flow through its body. As a result, permeable concrete is referred to as porous concrete and permeable concrete. A great deal of research is being conducted in the subject of pervious concrete. Because of its porosity and voids, permeable concrete has a lower compressive strength than ordinary concrete. As a result, despite its many advantages, the use of permeable concrete remains limited. Pervious concrete can be used for a wider range of applications if its compressive and flexural strengths are enhanced. For the time being, pervious concrete is generally used on low-traffic highways. If the qualities are enhanced, it can be used for moderate and heavy traffic inflexible pavements as well. Furthermore, pervious concrete prevents storm water surface runoff, facilitates ground water recharging, and maximizes the use of available land.*

Key Words: Pervious, Concrete, Mix Design, Pozzolanic, Permeable

1. Introduction

The last few years have seen a huge increase in the popularity of sustainable construction methods. For the sake of our society's general health and wellbeing, it is crucial to lessen the pressure on the environment. While this green movement has resulted in a variety of new designs and technologies, one of its most significant effects has been on stormwater management (SWM). Permeable concrete is able to capture rainwater runoff and remove trace pollutants, making it one of the best management practises for SWM quality (NRMCA 2004). Despite the fact that permeable concrete has been around for a while, interest in it has significantly increased recently as a result of the adoption of the federal clean water legislation. One of its first applications was in southern Georgia, where permeable concrete was chosen with consideration for the preservation of the local ecosystem (Ferguson, 2005). Since then, permeable concrete designs have been used in Florida, New Mexico, Utah, California, Oklahoma, Illinois, and Wisconsin (Mathis 1990).

P The use of Portland cement permeable concrete (PCPC) is becoming more popular. In many jurisdictions across the United States, environmental benefits like reducing water and soil pollution, managing stormwater runoff, and restoring groundwater supplies have taken centre stage (Kajio et al 1998). According to ACI Committee 522 (2006), permeable concrete is a type of "no-fines" or open-graded concrete that enables rainwater to seep through to the sub-base below.

On heavily trafficked roads, permeable concrete develops a moderate amount of surface ravelling and has a rough texture with a honeycombed surface. A paste is made using a carefully measured amount of water and cementitious materials. In order to prevent the paste from flowing off during mixing and placement, the paste then forms a thick coating around the aggregate particles. By applying enough paste to coat the particles, a network of connected voids that allows water and air to pass through is maintained. Pervious concrete has a very harsh mix as a result of the lack of sand, which has an adverse effect on mixing, delivery, and placement. Additionally, permeable concrete weighs little (between 1600 and 2000 kg/m3) because of its high void content (Concrete network, 2009).

The main components of this concrete are aggregate, Portland cement, admixtures, fine aggregate (if desired), and water. The percentage of void space in permeable concrete makes the biggest difference. According to NRMCA (2004), typical void space ranges are between 15 and 25 percent and roughly.08 in. and.32 in. (2 mm. and 8 mm.). The permeable concrete is layered on top of an aggregate base to create a permeable concrete pavement. Its thickness can range from 4 to 8 inches. This aggregate base's thickness is influenced by a variety of variables.

2. Brief History Pervious Concrete

Although its main use is in pavements, permeable concrete has a wide range of uses, including parking lots, tennis courts, residential roads, alleys and driveways; low volume pavements; low water crossings; sidewalks and pathways; parking areas; and slope stabilisation. With regard to managing runoff from paved surfaces, preventing run-off water contamination, and recharging aquifers, pervious concrete systems have advantages over impervious concrete. They also repel salt water intrusion, control pollution in water seepage to ground water recharge, which prevents subterranean storm water sewer drains, absorb less heat than conventional concrete and asphalt, which lowers the need for air conditioning. Concrete that is permeable has been used for centuries. The insulating qualities of structural pervious concrete were recognised by the Europeans for their structures. Permeable concrete has also been utilised in paving by Europeans. According to tales passed down through the years, troops in World War II didn't mind walking on pervious roadways since it meant their feet would be dry.

After World War II, pervious was introduced to the country. Florida and other southern coastal areas were where it initially appeared. It has gradually spread to other states, where it has experienced various triumphs. It had to prove itself, just like any new product does. The product was created by numerous well-intentioned ready mix makers, and it was installed by numerous well-intentioned contractors. Some fared well, while others did not. There is a science to it and a best manner to carry out the construction, as is true with every material and construction method. The secret to success is education and experience. Permeable concrete has been used in the coastal states for more than 20 years.

2.1 Indian Scenario

Permeable concrete is frequently used successfully in India for projects such as lots of parking, driveways, gullies or pathways, road platforms, and so on. There will most likely be plenty of dwellings being built there during the next 20 years. Water-pervious concrete can be utilised to surround apartments, residences, and a compound. Water problems are being caused by deepening ground water due to extensive urban mitigation in Indian cities. For instance, residents of states like Tamilnadu frequently pay to have water delivered, and it is normal for people to only get water for a few days of the week in many other sections of the nation. Urban regions frequently experience flooding and prolonged water logging due to the systematic conversion of all arid ground that couldn't store rainwater into lucrative real estate. As a result, the native flora has been covered by impermeable surfaces like roadways, roof tops, and parking lots.

Ironically, even CHERRAPUNJI, the wettest place on Earth, experiences drought despite experiencing flooding during the monsoon season. In addition, rainwater that lands on concrete and asphalt tends to contain a lot of pollutants, which eventually finds its way into our waterways. All of these negative consequences can be lessened with the use of pervious concrete. The vastly reduced cost of labour in India as compared to western nations is another important advantage. Even in remote regions, pervious concrete can be installed at a lesser cost because much of the construction is human and can be done without heavy machinery. However, there should be a word of caution because India has the highest level of airborne dust, which could cause the pervious concrete to become clogged. With some degree of blockage, pervious concrete can continue to function without maintenance. However, regular preventative maintenance is advised. In apartment complexes, resident associations might assume control of this, and those applications would be the ones that were tried first.

Future trends point to growing use of pervious concrete in India and other nations due to rising urbanisation, declining ground water levels, and an emphasis on sustainability.

2.2 Porous Concrete Pavement

Porous concrete is also known as pervious concrete, no-fines concrete, & permeable concrete. Porous concrete is a type of cementitious material that is constructed of gap-graded aggregates which has been coated with a thin layer of cement paste & bonded by the limited contact of the cement paste layers.

Continuous voids that are intentionally integrated into concrete to create porous concrete. The physical features of this form of concrete are very different from those of regular concrete because it belongs to an entirely other group. Porous concrete was developed as a material for environmentally friendly construction in the 1980s. Because of the multiple environmental benefits it offers, such as reducing water and soil pollution, managing rainfall runoff, among recovering groundwater resources, it has been widely used in Japan, the US, and Europe. Porous concrete is frequently employed in road pavements due to its ability to permeate, sewer, and hold water. It is also used in a variety of applications that require energy efficiency or noise absorption. According to the Specifier's Guide on Pervious Concrete Pavement Design, the required structure vacuum of porous concrete is 15% minimum and 25% maximum. Several investigations have been conducted by various academics, and the typical percentage of voids varies between 15% to 30%. The durability of concrete that has been hardened tends to deteriorate for a variety of reasons. One of the causes is the occurrence of voids within the hardened concrete itself. The literature review also found that the strength of cured concrete decreases as the void percentage increases. Despite the fact that porous concrete has been used for a long time, its structural integrity still has many unresolved issues. Despite basic information such as the influence of the water-cement (W/C) ratio, void ratio, cement paste characteristic, volume ratio of coarse aggregate, size of coarse aggregate, and strength of porous concrete being studied, the ideal conditions for producing high-quality porous concrete have yet to be established.

3. LITERATURE REVIEW

SONIA RAHMAN, BSC, ANDREW B. NORTHMORE, MASC, EIT VIMY HENDERSON PHD, PENG AND SUSAN L. TIGHE, PHD, PENG. (2012)

The benefits of using older concrete pavement include helping to filter water, absorb heavy metals, reduce pollution, and lessen storm water runoff. Technology can produce environmentally friendly pavement and offer a framework for using old concrete into pavement infrastructure. Most old concrete pavement is still useful on routes with little traffic. There is an excessive amount of information about earlier concrete from parking lots, walkways and roads. Roads with an older concrete surface have advantages over low volume, everyday roads. Older concrete pavement is a strong alternative for low volume infrastructure's structural design and storm water management since it performs well with little upkeep.

MEI LIU XIAOMING HUANG GUOQIANGXUE (2014-2016)

The outcome of the double-layer, porous asphalt pavement's outdoor noise tests validates the virtual pavement models and the practical impacts of noise reduction. Asphalt pavement is intended to improve urban livability and reduce noise pollution from vehicular traffic. To create and test noise-reducing pavement for urban roadways, research the clogging of two-layer porous pavement, and evaluate the acoustical, structural, and clogging characteristics of pavement over time. Unwanted noise is noise that could pollute the environment and cause harm. The goal is to promote double-layered porous asphalt pavement that is both durable and keeps traffic noise at a minimum.

BASHAR S. MOHAMMED, MUHD FADHIL NURUDDIN AND YOGESWARY A/P DAYALAN (2016).

The goal of the project is to use pozzolanic ingredients to create high permeability concrete pavement. In this investigation, pozzolanic material is used in place of regular cement. High permeable concrete pavements are frequently utilized to lessen traffic noise and prevent slipping. When pozzolanic ingredients and regular cement are used, the compressive strength of high permeability concrete increases. This makes the pavement easier to use. According to the study's findings, replacing pozzolanic material with regular cement enhances the qualities of highly permeable concrete pavement. It is inexpensive and requires little upkeep. Pozzolanic material utilization reduces CO2 emissions.

EINSTINE M. OPISO, REINERIO P. SUPREMO, JEMIMA R. PERODES (2017)

High permeability concrete pavement utilizing pozzolanic materials is the goal of the research. Pozzolanic material is used in this study to substitute regular cement. In order to reduce traffic noise and prevent slipping, high permeable concrete pavements are frequently employed. When regular cement and pozzolanic ingredients are used, the compressive strength of the high permeability concrete increases. The pavement will be easier to work with as a result. According to the study's findings, high permeability concrete pavement qualities improve when pozzolanic material is substituted for regular cement. It requires little upkeep and is inexpensive. Less CO2 is released when pozzolanic material is used.

M. KAYHANIAN, HUI LI, JHON T. HARVEY AND X. LIANG (2019)

Future sustainable transport plans with full depth permeable pavement (FDPP) will include accessible pavement. Full depth permeable pavement is also frequently constructed by adding a pervious friction course (PFC), a thin (5–10 cm) permeable layer on top of an existing impermeable layer of pavement. PFC pavement is frequently used in metropolitan areas to reduce noise, improve storm water quality, and improve safety during heavy downpours. Permeable pavement usage is anticipated to rise as "Urban surface evolution" progresses. By transitioning from grey to green infrastructure. By allowing water to percolate, permeable pavement minimizes runoff while yet preventing soil erosion.

F. G. PRATICO, P. G. BRIANTE, G. COLICCHIO AND R. FEDELE (2019)

The internal elements are related by the volumetric qualities and the asphalt's complementary surface in the illustration. As a result, the external influences that affect its intricate process throughout time and its causes. It has an impact on the budget, noise, and security. The purpose of the paper is to approach the crack percentage and acoustic features of porous asphalt design. A thorough analysis of the goal and the materials mentioned therein, such as the variance in air spaces, texture and friction, and location work on the roadway, is crucial as it deteriorates over time. It relies on the roots, their strong penetrating power, and how many drivers are clogged by degradation.

MOHSEN SARTIPI, FARID SARTIPI (2019)

Because of the impermeable pavement utilized in urban areas, there is a lot of storm water runoff. The urban storm water runoff is bigger than the natural storm water runoff as a result of the usage of impermeable pavement. Less water is absorbed by the ground as a result. The goal is to deploy permeable concrete pavement in Sydney's western suburbs to reduce storm water runoff. Numerous advantages of this research include lowered storm water discharge and water resource restoration. The geography of the area is crucial for the implementation of permeable concrete pavement. In topography, ground slopes and local rainfall are taken into account for storm water retention. The water catchment need determines how the permeable concrete pavement is designed. As a result, if permeable concrete pavement is used, storm water retention capacity will be increased and slippery surfaces during the rainy season will be avoided.

GUOYANG LU, YUHONG WANG, HUI LI, DAWEI WANG, MARKUS OESER (2019)

Permeable pavement and conventional pavement are contrasted in the study. The heat island effect is caused by the expanding road system in urban areas and the usage of traditional paving. The roughness of the road increases fuel consumption while driving on it. This study includes an assessment of several pavement types based on environmental factors. For permeable and conventional pavement, the LCA framework is used to estimate the environmental impact. The most environmentally friendly pavement surface material is polyurethane-bound porous pavement, which is superior to porous asphalt pavement. This makes permeable paving concrete an environmentally friendly material with many benefits over traditional pavement.

I.M.H PERERA, C. J. ATHAPAPATHTHU, PROF. W. K. MAMPEARACHCHI (2019)

The design of the cover slab's porous concrete layer, building processes, and real-world problems with application and mitigation strategies were covered. According to study findings, covered drainage slabs for pedestrian walkways should be composed of a reinforced concrete composite section and porous concrete for draining. Porous concrete with the highest permeability & lowest clogging propensity can be used as a beneficial drainage layer. Use a plate vibrator to create a more comfortable walking surface. Even with a high initial infiltration rate, severe blockage, especially during road building, will result to an enormous decrease of infiltration potential. As a result, heavy traffic should be avoided. When using porous concrete to cover slab for long-term performance, effective maintenance is critical. This is because, in the long term, the capacity for infiltration should be far more than the capacity required to infiltrate the rainfall.

SHADI SAADEH, AVINASH RALLA, YAZAN Al-ZUBI, RONGZONG WU, JOHN HARVEY (2019)

The University of California Pavement Research Centre (UCPRC) implemented a revolutionary design technique for totally permeable pavements through the building of two test sections constructed of asphalt and concrete at California State University Long Beach (CSULB). Pressure cells and strain gauges were installed throughout the pavement construction to determine the stress on the highest point of the subgrade and the strain felt at the bottom of the topmost layer on both test sections. The research also determined the volume of traffic. Graphs were constructed to study the patterns in the data sets after the information collected from pressures cells and strain meters was analyzed using the MATLAB tool. The graphs revealed that the asphalt test component had more stress and strain than the concrete test portion. In terms of distresses, both test segments performed consistently. The data gathered is being used to evaluate the results of both exam segments. Based on the performance evaluation results, the entirely permeable pavement layout can be produced and implemented as a component of sustainable highway traffic.

YAZHEN SUN, RUI GUO, XIAOCHEN WANG, XIHONG NING (2019)

If the water supplied was regulated properly, the maximum flow capacity while avoiding surface ponding may be reached. Then, using porous media theory & Biot's theory, finite element models of asphalt pavement with hydro mechanical coupling were provided. The topmost height of a pavement influences the increase in pore water pressure generated by void reduction and an elevated degree of clogging, resulting in a peak value for pore water pressure. As a result of vertical tensions in the pavement structure, the upper layer shows a considerable shift. Under the action on clogging and driving load, an acceptable top layer thickness and drainage evaluation should be taken into account to promote road safety.

LU-MING CHEN, JUI-WEN CHEN, T. LECHER, TING-HAO CHEN AND P. DAVIDSON (2020)

As it is frequent in materials trapping voids, the pavement allows storm water to enter the porous area, which decreases the effectiveness of the paving system. It also looks at how two pavement methods affect onsite permeability changes. It investigates the permeability between pervious concrete (PC) and the JW-Ecosystem (JW). By defining the anticipated permeability and the breadth of the system, the paper aims to close any gaps in the field of science. The results of experiment 1 show that for the majority of test sites, both JE and PC maintain comparable and efficient permeability.

4. Major Application of Permeable Concrete

- Low-volume pavements
- Residential roads, alleys, and driveways
- Sidewalks and pathways
- Parking areas
- Low water crossings
- Tennis courts
- Subbase for conventional concrete pavements
- Slope stabilization
- Well linings
- Hydraulic structures
- Swimming pool decks
- Pavement edge drains and Tree grates in sidewalks
- Groins and seawalls
- Noise barriers
- Walls (including load bearing)

5. Advantages

- The U.S. has recognized pervious concrete as a best management practice for its appropriate use, providing first-flush pollution prevention and storm water management.
- Pervious concrete is a creative material for construction with many economic, environmental, and structural advantages.
- Property owners and builders can lower costs and increase profits through the use of pervious concrete, which typically lasts 20 to 40 years with little to no maintenance.

3. CONCLUSIONS

Pervious concrete is a practical and environmentally favorable technique to assisting with sustainable construction. Because of its ability to absorb storm water, restore ground water, and reduce storm water flow, pervious concrete may have an important role. Because of its ability to reduce runoff, it is commonly used as a pavement material. The higher the compressive force and permeability rate that may be created, the smaller the dimension of the coarse aggregate. Higher aggregate/cement ratios, such as 8:1 and 10:1, are regarded to be advantageous for pavements that require high permeability as well as low compressive strength. The perfect permeable concrete mix is anticipated to have the highest compressive strength and optimal infiltration rate. One of the top materials employed by the concrete industry as part of "green" industrial practices for offering pollution prevention, storm water management, and sustainable Design is pervious concrete.

REFERENCES

[1]ACI Committee 522, “Permeable concrete”, American Concrete Institute, Farmington Hills, Michigan, 2006.

[2]Alshareedah, O., Nassiri, S., Chen, Z., Englund, K., Li, H., & Fakron, O., (2019). Field performance evaluation of pervious concrete pavement reinforced with novel discrete reinforcement. Case Studies in Construction Materials, 10, e00231.

[3]Arambula, E., Caro, S., Masad, E., 2009. Experimental measurement and numerical simulation of water vapour diffusion through asphalt pavement materials. J. Mater. Civil Eng. 22,588-598.

[4]Chen Lu-Ming, Chen Jui-Wen, Lecher Timothy, Chen Ting-Hao, Davidson Paul., 2020. “Assessment of clogging of permeable pavement by measuring change in permeability.” Science of Total Environment 749 (2020) 141352.

[5]Chen Lu-Ming, Chen Jui-Wen, Lecher Timothy, Chen Ting-Hao, Davidson Paul., 2020. “Assessment of clogging of permeable pavement by measuring change in permeability.” Science of Total Environment 749 (2020) 141352.

[6]Ferguson, B.K., “Porous Pavements”, New York: Taylor and Francis Group, 2005, 577 pages Mathis, D. E. "Permeable bases - An update,” PCA, No. 8., Nov., 1990, pp. 3-4.

[7]Hatanaka, s., Kamalova, Z., and Harada, M. (2019). Construction of a nonlinear permeability model of pervious concrete and drainage simulation of heavy rain in a residential area. Results in materials, 3, 100033.

[8]I.M.H Perera, C.J. Athapapaththu, Prof. W.K. Mampearachchi (2019). “Design of a porous concrete mixture for drainage coverslab in pedestrian walkway”. Paper presented at World Conference on Transport Research – WCTR 2019

[9]Kajio, S., Tanaka, S., Tomita, R., Noda, E., Hashimoto, S., “Properties of Porous Concrete with High Strength”, Proceedings 8th International Symposium on Concrete Roads, Lisbon, 1998, pp 171-177

[10]Kayhanian Masound, Hui Li, Liang Xiao, Harvey Jhon T., 2019. “Application of permeable pavement in highway for stormwater runoff management and pollution prevention: California research experience.” International Journal of Transportation Science and Technology 8 (2019) 358-372.

[11]Kayhanian Masound, Hui Li, Liang Xiao, Harvey Jhon T., 2019. “Application of permeable pavement in highway for storm water runoff management and pollution prevention: California research experience.” International Journal of Transportation Science and Technology 8 (2019) 358-372.

[12]Lu, G., Wang, Y., Li, H., Wang, D., & Oeser, M. (2019). The environmental impact evaluation on the application of permeable pavement based on life cycle analysis. International Journal of Transportation Science and Technology, 8(4), 351–357.

[13]Mallisa, H., Turuallo, G., 2017. The maximum percentage of fly ash to replace part of original Portland cement in producing high strength concrete. Proceedings of the 3rd International Conference on Construction and Building Engineering (Iconbuild) 2017: Smart Construction towards Global Challenges. American Institute of Physics, Palembang, Indonesia.

[14]Mei Liu Xiaoming Huang Guoqiangxue, effect of double layer porous asphalt pavement of urban streets on noise reduction, received 6 June 2014; accepted 12 February 2016. Anderse

B. kragh, J. Bendsten, H 2005 Acoustic performance of low noise road pavement. Sustainable road surfaces for traffic noise control. Gulf organization for research and development page no 183-196.

[15]Mohammed, B. S., Nuruddin, M. F., & Dayalan, Y. (2016). Properties of High permeable concrete utilizing pozzolanic materials. ARPN Journal of Engineering and Applied Sciences, vol. 11, no. 3. NRMCA, "What, Why, and How? Permeable concrete," Concrete in Practice Series. CIP 38, 2004.

[16]Pratico Filippo G., Briante Paolo G., Colicchio Giuseppe, Fedele Rosario., 2019. "An experimental method to design porous asphalts for surface requirements." Journal Of Traffic And Transportation Engineering (2019).

[17]Sartipi, M., & Sartipi, F. (2019). Stormwater retention using pervious concrete pavement: Great Western Sydney case study. Case Studies in Construction Materials, 11, e00274.

[18]Shadi Saadeh, Avinash Ralla, Yazan Al-Zubi, Rongzong Wu, John Harvey (2019). "Application of fully permeable pavements as a sustainable approach for mitigation of stormwater runoff". International Journal of Transportation Science and Technology 8 (2019) 338–350.

[19]Sonia Rahman BSc, Andrew B. Northmore, MASC, EIT, Vimy Henderson, phD, PENg and Susan L Tighe, phD, PENg. Henderson V. Evaluation of the performance of the previous concrete pavement in Canadian climate, phD, Thesis department of civil and environmental engineering, university of Waterloo, Ontario, Canada 2012.

[20]Sprouse, C.E., Hoover, C., Obritsch, O., & Thomazin, H. (2020). Advancing Pervious Pavement through Nomencleture, standards, Holisticgren design. Sustainability, 12(18), 7422.

[21]Stormont, J.C., Zhou, S.X., 2001. Improving Pavement Sub-Surface Drainage Systems by Considering Unsaturated Water Flow. University of New Mexico, NM. Report to the U.S. Department of Transportation Cooperative agreement.