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A Review on Mix Proportion and Performance Evaluation of Pervious Concrete

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Abstract: *Despite its many benefits, pervious concrete has downsides. These include sedimentation, maintenance, and application strength and load-bearing capability. Researchers keep working to improve pervious concrete's performance and acceptance. Finally, pervious concrete and mix proportioning research is extensive. Studies illuminate pervious concrete combination qualities, behaviour, and optimal design. These research improve pervious concrete technology and enable its use in many applications. Further study and mix proportioning refinements are needed to enhance pervious concrete's performance and durability in real building contexts. The present work has made an attempt to do a state of the art review for the national ad international work done so far on various aspects of pervious concrete.*

Keywords: *Pervious Concrete, Mix Design, performance and durability*

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1. Introduction

The literature focuses pervious concrete and mix proportions in influencing its performance. Research has focused on optimising mix proportions for permeability, strength, durability, and environmental sustainability in pervious concrete. Mix proportioning depends on aggregates, cement content, water-to-cement ratio, particles, admixtures, and SCMs. The desired qualities of pervious concrete depend on mixing, location, and compaction. As shown by the literature review, pervious concrete behaviour and mix proportioning have been extensively studied. Numerous research have examined how aggregate properties, cement content, water-to-cement ratio, particles content, and admixtures and SCMs affect pervious concrete performance. These research have revealed the best strength-permeability-durability ratios. Researchers have also examined pervious concrete's long-term effectiveness and durability in various environmental settings. Freeze-thaw cycles, abrasion, and chemical exposure tolerance of pervious concrete have all been researched. These research have identified ways to improve pervious concrete's durability in practical applications. While pervious concrete offers numerous advantages, it also has certain drawbacks that need to be addressed. These drawbacks include issues related to sedimentation, maintenance requirements, as well as concerns regarding its strength and load-bearing capacity. However, researchers are actively engaged in ongoing efforts to enhance the performance and acceptance of pervious concrete.

Significant research has been conducted on pervious concrete and mix proportioning, aiming to improve its qualities, behavior, and design. These studies have contributed to the advancement of pervious concrete technology and have enabled its use in a wide range of applications. However, there is still a need for further investigation and refinement of mix proportions to enhance the performance and durability of pervious concrete in real-world building contexts. Through continued research and refinement of mix proportioning, it is anticipated that pervious concrete will continue to evolve, addressing its limitations and enhancing its overall performance and durability. This will further expand the range of applications where pervious concrete can be successfully utilized in the construction industry.

2. Literature Review

The national and international scenario of the research work has been done in the field of Pervious Concrete and Mix proportion is detailed as under:

Liu P. et al. (2023); for decades, many IBA applications have proven viable in several countries. This research examined IBA-added pervious concrete as a highway subbase. Material qualities, mixing proportion, and in-situ testing. Mechanically, the IBA outperformed natural aggregates. IBA decreases compaction strength, according to mix design. Mixtures with less than 60% IBA substitution performed well and met criteria. IBA adds no volume to pervious concrete. In-situ measurements show that IBA test sections outperform bituminous concrete pavement in permeability and noise. IBA-paved test portions are equivalent to bituminous concrete pavement in roughness and rutting, but somewhat worse. IBA-containing pervious concrete demonstrated minimal Cu leaching in water samples, much below the regulatory limit. This study found that pervious concrete incorporating IBA as a highway foundation course is sufficient under the conditions.

Nasser Eddine Z. et al (2023); The study investigated the material properties, mixing proportions, and conducted in-situ testing to assess the performance of the IBA-incorporated pervious concrete. From a mechanical perspective, the inclusion of IBA in the previous concrete mix showed superior performance compared to natural aggregates. However, it was observed that the compaction strength decreased as per the mix design. Mixtures with less than 60% substitution of IBA performed well and met the required criteria for highway sub base applications. One significant advantage of using IBA is that it does not add any volume to the pervious concrete, allowing for effective water permeation. In-situ measurements demonstrated that the test sections incorporating IBA outperformed bituminous concrete pavement in terms of permeability and noise reduction. The IBA-paved portions exhibited comparable roughness and rutting characteristics to bituminous concrete pavement, albeit slightly worse in some aspects. Additionally, the study found that pervious concrete containing IBA showed minimal leaching of copper (Cu) in water samples, well below the regulatory limits. Based on these findings, it can be concluded that pervious concrete incorporating IBA as a highway sub base material is a viable option under the given conditions. The superior mechanical performance, effective water permeation, and minimal leaching of pollutants make IBA-added pervious concrete a suitable choice for sustainable and environmentally friendly highway construction. Further research and field studies can provide additional insights and optimize the mix design for maximizing the benefits of IBA-incorporated pervious concrete in various infrastructure applications.

Oinam Y. et al. (2022); Pervious concrete was utilised to solve urban floods, noise, and the urban heat island effect. This study replaced OPC with ground granulated blast furnace slag

(GGBFS). This replacement reduced building sector environmental effect. To maximise water permeability and compressive strength in pervious concrete, the mixture composition was carefully modified. The study compared OPC-only concrete to 60% and 100% GGBFS-replaced concrete. Modifying the binder-to-aggregate ratio reached two porosity objectives of 10% and 15%. CaO and CaCl2 accelerated GGBFS-only binder activation. Binder rheological characteristics also affected pervious concrete water permeability and compressive strength. Pervious concrete's permeability increased with porosity regardless of binder. CaO-activated GGBFS pervious concrete fulfilled the minimum strength requirement despite having lower compressive strength than the 60% GGBFS and OPC combination. Rheological studies showed that decreasing binder adhesion force decreased pervious concrete compressive strength and aggregate particle compression force. CT scan analysis showed that reduced binder adhesive forces increased local porosity (pore volume) at the specimens' bottoms. The study also found that the binder's increased plastic viscosity prevented bottom aggregate particle compression.

Wang C. et al. (2022); two realistic engineering aggregates were chosen to improve design occurrence and generate pervious concrete with required performance. Image ProPlus evaluated aggregate sphericity and computed pervious concrete skeleton structural characteristics. On the basis of aggregate sphericity, modifications were made to the mix proportion design approach for pervious concrete. Results show that the mix proportion design method of pervious concrete based on aggregate sphericity can be applied to aggregates with low sphericity and a broad size range, improving its accuracy and reliability, which has important engineering applications.

Vinay V. et al. (2022); Due of its high porosity and low compressive strength, pervious concrete (PC) is widely employed. PC's outdoor applications remain unclear after intensive investigation. Field-installed PC pavement WAC was measured in this investigation. A PC footpath with compressive strength of 24 MPa and permeability of 1.56 cm/s was made utilising the appropriate mix proportions from a prior research (40% 20 mm, 30% 12.5 mm, and 30% 10 mm aggregate, 10% Fly ash with 90% OPC and a w/c ratio of 0.35). 15 10-cm-deep 1.2 × 1.2 m panels. Soil parameters are examined before installing PC panels. PC Walkway WAC depends on seasonal lateral and vertical flows. August 2018 WAC was 3315.7 litres/m3, January 2019 was 3064.56. 400.73 millimetres of precipitation and 44.028 kilogrammes of silt may explain the WAC decline from season 1 to 2. Time and discharge water contaminants effect PC water absorption.

Tang C.W. et al. (2022); This study examined lightweight coarse aggregate fiber-reinforced pervious concrete (LPC) design and performance. Testing had two steps. After a rheological test, the matrix was mixed with various proportions of lightweight coarse and fine aggregate to generate the LPC mixture. Taguchi experimental design using a four-controllable three-level orthogonal array (L9(34)) reduced experimental effort. The research showed that LPC's mechanical performance was largely affected by material selection and combination amounts. This study's LPC specimens had compressive, flexural, and split tensile strengths of 4.80–7.78 MPa, 1.19–1.86 MPa, and 0.78–1.11 MPa, respectively. Silica fume, ultrafine silica powder, and polypropylene fibres made these advances. LPC specimen mechanical characteristics improved throughout processing. This study showed that selecting appropriate materials and optimising mixture proportions improves the mechanical performance of lightweight coarse aggregate fiber-reinforced pervious concrete. The findings improve LPC design and use in building projects.

Karawi R.J.A. (2021); No-fines Porous concrete quickly absorbs liquids. Testing concrete's compressive, flexural, and fracture tensile strengths is frequent. This study tested fracture tensile strength with various combination components. Two penetrable concrete series tested two parameters. One sample in the first group lacked grit, therefore SBR was added at 5–8% cement weight. The second group replaced 15%, 30%, and 45% coarse aggregate with sand. Water-to-cement was 0.38–0.42. Sand strengthens pervious concrete more than SBR.

Bin Y. (2021); this orthogonal testing research examined the mechanical characteristics, permeability, and frost durability of 15% porous pervious concrete. The study tested three main factors: silica fume (at mass fractions of 3%, 5%, and 7%), metakaolin (at 8%, 10%, and 12%), and polypropylene fibre (at volume fractions of 1%, 2%, and 3%). The freeze-thaw cycle test's ideal mix ratio was found by range analysis of these parameters.The mechanical properties of pervious concrete were mainly impacted by silica fume and metakaolin, whereas polypropylene fibre affected compressive strength and continuous porosity. 7% silica fume, 10% metakaolin, and 2% polypropylene fibre made the best blend. The study also discovered that pervious concrete's relative dynamic modulus and compressive strength declined as freezing-thawing cycles increased, while mass loss and continuous porosity increased. Pervious concrete's dynamic elastic modulus and relative residual compressive strength declined parabolicly when frozen-thawed. This study can assist engineers use pervious concrete in cold areas.

Understanding different components and their ideal mix proportions can help implement pervious concrete in such locations, considering its mechanical performance and frost damage resistance.

Srikanth N., Dakshina Murthy N.R. (2021); only concrete has grown in popularity in building engineering during the previous decade. Rapid urbanisation has increased building material demand, depleting natural resources daily. Porous concrete, sometimes called no-fines concrete, allows water to soak through it, minimizing external discharge and raising the ground water table. The cementitious paste fills the spaces between coarse aggregate particles in pervious concrete since there is little to no fine aggregate. Only no-fines concrete's perviousness implies penetrability. Infiltration rate relies on coarse aggregate pore sizes, shape, and interconnectivity, hence it accurately depicts pervious concrete performance. Pervious concrete may be used as a sustainable building material to protect the water quality for future generations. In this investigation, water-to-cement ratios, cement-to-aggregate ratios, and aggregate dimensions were varied. 150 150 mm standard cubes were compressively tested. The falling head permeability instrument measures sample permeability. By performing permeability experiments on pervious concrete, 11 cm diameter and 18 cm depth cylinder-shaped moulds were utilized to evaluate infiltration rates. Sustainable pervious concrete meets infiltration and strength standards.

Zhang Y., Xu X. (2021); Pervious concrete plays a crucial role in facilitating water infiltration into the underlying sediments, making it a viable solution for sustainable urban drainage systems. However, the process of designing concrete mixes typically involves extensive trial batching and time-consuming experiments. Fortunately, recent advancements in machine learning have shown promise in reducing experimental efforts by developing robust models. By leveraging the GPR model, it becomes possible to accurately and reliably estimate several important parameters of pervious concrete quickly and cost-effectively. This approach offers significant advantages over traditional trial-and-error methods, saving valuable time and resources in the concrete mix design process. Overall, the application of machine learning techniques, particularly the GPR model, holds great potential for streamlining the design of pervious concrete mixes. This approach enables rapid and cost-efficient estimation of various concrete properties, contributing to more efficient and sustainable construction practices in urban permeable pavement systems and drainage solutions.

Abdulwahid M.Y. (2021); this work analyses how partial coarse aggregate substitution with various stone particles affects pervious concrete strength and porosity. This study employed stones from Koya, Iraqi Kurdistan, near Haibat–Sultan Mountain. Mudstone, sandstone, marlstone, and limestone replaced 7% coarse aggregate. Each mixture had 1:4.5:0.4 weights of cement, coarse aggregate, and water. All combinations lowered porosity and enhanced compressive and fracture tensile strength. Fine stone infill improved pervious concrete with adequate porosity. Sandstone and marlstone particles also strengthen pervious concrete.

Zhang Q. et al. (2020); RSM is used to create recycled aggregate pervious concrete mix proportions in this study. The study examines the internal structure of recycled permeable concrete and how paste properties, paste coating thickness on aggregate, and aggregate void content affect its strength and porosity. RSM quantifies and optimises IPT, ACT, and TVC. The Box-Behnken Design (BBD) examines IPT and ACT responses to three admixtures. On the other hand, TVC is analyzed in response to different recycled aggregate gradations using the simplex centroid design. To facilitate practical use, three response surface models are developed and optimized. These models enable the identification of appropriate aggregate gradations and optimal admixture doses for achieving desired concrete properties. The efficiency of the models is validated through experimental testing. Overall, this research demonstrates the effectiveness of RSM in designing mix proportions for recycled aggregate pervious concrete. By considering key factors and optimizing the variables, the study provides a valuable framework for achieving desired strength and porosity characteristics in such concrete mixtures. The findings contribute to advancing the use of recycled materials and promoting sustainable practices in concrete production..

Alshareedah O. et al. (2020); Compaction greatly impacts pervious concrete (PC) mechanical characteristics, yet field density and strength need unknown levels of compaction. Expensive test panels detect compaction. This study investigated compaction force, cemented porosity, and compressive strength (fc). A lab-based lightweight deflectometer (LWD) crushed three PC mix proportions with varied paste contents at four compaction settings. Each compaction level's cylinders were porosity and 7-day fc evaluated. First 15 LWD lowers impacted and fc more than successive compaction. The field-equivalent force of a rotating roller-screw was calculated using the LWD-recorded compaction force. Regression-based algorithms estimated PC's 7-day and fc from compaction force and paste content. The suggested models calculate the compaction force needed given PC mechanical parameters in the field.

Kant Sahdeo S. et al. (2020); Pervious concrete pavement (PCP) can reduce urban heat island effects and improve stormwater flow, drawing scholarly interest. The pavement uses unique concrete with microscopic particles and linked spaces. PCP mixes must be balanced by considering aggregate gradation, water-to-cement (w/c) and cement-to-aggregate ratios, and compaction techniques of variable effort. Thus, this study examines how aggregate gradations and w/c ratios affect PCP mixture production and structural, functional, and long-term performance. G1, G2, G3, G4, and G5 aggregate gradations and w/c ratios were tested. G4 and G5 had 5% and 10% natural particles, while G1 and G2 were well-graded. G3 aggregates were 30% 10 mm and 70% 4.75 mm. G3 was the most balanced PCP mixture in lab tests. The study recommends binary mixed single-sized aggregates at 0.35 w/c ratio for pervious concrete pavement mixtures that fulfil criteria. This research gives insights into selecting aggregate gradations and w/c ratios for PCP blends based on performance metrics. The results improve pervious concrete pavement designs.

Arifi E. et al. (2020); Pervious concrete lowers urban surface discharge. To assess surface discharge problems, pervious concrete's void ratio is affected by various components. Pervious concrete has numerous ingredients. In studies, aggregate sizes, cement additives, recycled coarse aggregate as an alternative to natural coarse aggregate, and fibre use were used to determine the void ratio, which greatly affects pervious concrete's ability to manage urban surface drainage. The study found that aggregate size impacts pervious concrete void ratio more than cement additives. Recycled coarse aggregate pervious concrete exhibited more lacunas than natural coarse aggregate. The mix's fibre lowered pervious concrete's void ratio.

Nguyen T.S. et al. (2020); Pervious concrete aids flood-prone areas. 15–25% porous concrete aids drainage. They lack compressive and tensile strength. This article describes a design method for concrete mix proportions with 20-30 MPa compressive strength, 5-7 MPa tensile strength, and mineral flour and geotextile grid enhancements. Discussed include pervious concrete structures and infrastructure utilisation.

Guo L. et al. (2020); Recycled aggregate (RA) from pulverised and sifted concrete pavements was tested and analysed. This inspired pervious concrete (PC) compound proportions. Results showed: Increased RA replacement ratio decreased RPC density. Single-gapgraded RA (10-20 mm particle size) provided a denser RPC than double-gapgraded. Porosity raised RPC permeability. RPC compressive and fracture tensile strengths linked strongly. Porosity weakened RPC compression. Regression study indicated compressive strength enhanced RPC impact and attrition resistance. RPC samples passed tensile and permeability tests. This study theoretically supports RPC.

Malayali A.B. et al. (2019); GGBS-based Geopolymer Pervious Concrete (GGPC) with different aggregate sizes was tested for mechanical, thermal, and moisture properties. Inquiry maintains 12 M NaOH. Eliminating fine particles keeps mixture pervious. Three coarse aggregate diameters—6mm, 12mm, and 20mm—are employed to assess GGPC properties. The liquid-to-solid ratio is 0.45 and the sodium silicate-to-sodium hydroxide ratio is 2.5 throughout the investigation. After 28 days, the 12 mm aggregate had the best compressive strength. 6–20 mm aggregate size increases k.

Chen X. et al (2019); Cement material rheology affects pervious concrete's mechanical characteristics and permeability. Modifying water-reducing agent and tackifier amounts affects cement paste fluidity and plastic viscosity. Pervious concrete samples with preset cement-to-aggregate ratios are made for comparison. The pull-off bond strength test and optical microscope are used to quantify the paste coating on aggregate particles in pervious concrete. The paste's rheological characteristics are associated with the pervious concrete's mechanical properties (compressive, flexural, and permeability coefficient). The paste's fluidity and plastic viscosity affect pervious concrete's mechanical properties and permeability. Fluidity and plastic viscosity initially increase mechanical characteristics but subsequently diminish. Higher paste plastic viscosity enhances concrete permeability, whereas higher mixture fluidity lowers it. The study determined that the mechanical properties and permeability of pervious concrete are primarily influenced by cement paste rheology, bond strength, and paste coating thickness on aggregate particles. By adjusting the cement paste rheology during mix percentage design, a balance can be achieved between the mechanical qualities and permeability of pervious concrete. This research emphasizes the importance of considering cement material rheology to optimize the mechanical properties and permeability of pervious concrete, ultimately enabling more effective mixture design.

Tarangini D. et al. (2019); This article examines pervious concrete with varied aggregate sizes for permeability, porosity, density, strength, and durability. Open-graded hydraulic cement, coarse particles, additives, and water make pervious concrete viable. Zero-slump concrete is called no-fines concrete. Research includes mixing coarse particles of different sizes. The water-cement ratio and aggregate-cement ratio remain at 0.31 throughout the study. To evaluate performance and attributes, pervious concrete samples are evaluated at 7, 28, and 56 days. The study examines how coarse aggregate mix percentage affects pervious concrete properties. Measuring permeability, porosity, density, strength, and durability. The experiment data is analysed and graphed to show the link between coarse aggregate mix percentage and pervious concrete quality. This study examines how aggregate sizes affect pervious concrete qualities to determine the best mix design. Understanding the link between aggregate sizes and pervious concrete properties may help create more efficient and effective combinations, increasing its usage as a sustainable material in drainage systems and other uses.

Malayali A.B., Chokkalingam R.B. (2018); This study examines sodium hydroxide and sodium silicate solution-activated geopolymer pervious concrete manufactured from Ground Granulated Blast Furnace Slag (GGBS). Five combined quantities of GGBS are 450, 460, 470, 480, and 490 kg/m3. According to a literature analysis, all formulations have 1:3 cement-to-aggregate and 0.3 activator solution-to-GGBS ratios for compressive strength. 1% GGBS is added to all combinations for workability. GGBS boosted strength in all GPPC blends.

Yanya Y. (2018); Resource-saving recycled pervious concrete satisfies China's circular economy and environmental protection regulations. Due to insufficient study, recycled pervious concrete is underused. This study recovered aggregate by crushing and screening discarded precast concrete beams. Recycled coarse aggregate formed pervious concrete. Replaceability and particle size grade established five mix percentage groupings. Physical, mechanical, and permeability performance and relationships were tested. Replacement rate increased concrete compressive strength. 30% replacement rate maximised improvement. Double particle grade aggregate increased compressive strength by 35.4%, although permeability decreased...

Veerakumar R. (2018); for concrete flat work, high-porosity porous paver concrete lets water pass through directly, reducing site runoff and replenishing groundwater. A dense void network generates porosity. Porous concrete contains no fine aggregate and enough cement to cover coarse aggregate particles and maintain cavity interconnectivity. Its interconnected pore structure and 15–35% volume void content/porosity separate it from other concretes. Pervious concrete reduces flooding, storm-water runoff, automobile tyre noise, glare, and sliding during rainy seasons by letting water permeate its pores and recharge the groundwater. Road conditions dictate minimal permeable paver concrete. Mix proportions were evaluated for Compressive Strength, Void Ratio, and Infiltration.

3. Findings from Literature

Significant research has been conducted on pervious concrete, as evidenced by the availability of over 1300 Scopus documents containing the keywords "Pervious Concrete." While India ranks third in terms of the number of documents listed on Scopus, behind the United States and China, standardisation is still required in this field. Specifically, the proportioning of constituents for various categories of concrete must be refined and standardized.

Characterizing pervious concrete is highly dependent on the source and materials employed, resulting in variations in its properties. The present study seeks to contribute to resolving these gaps and challenges by addressing the aforementioned points. By conducting a thorough investigation, the study aims to determine and finalise the optimal constituent ratios for various grades of pervious concrete. The goal is to establish a standard approach that can be broadly implemented in the construction industry.

This research seeks to provide valuable insights into the optimal mix proportions by synthesising existing knowledge, undertaking experimental analyses, and assessing the performance of pervious concrete mixes. This research will contribute to the formulation of guidelines and recommendations for the production of pervious concrete with consistent and desirable properties.

Through this research, it is anticipated that the standardisation of pervious concrete mix proportions will increase its practical applicability and encourage its wider adoption in construction projects. This study will contribute to the advancement of pervious concrete technology in India and beyond by resolving the variability in material characterization and refining the proportioning process.

4. Conclusion

In summary, although there has been considerable research on pervious concrete and India has made significant contributions in this field, there is still a need for standardization of mix proportions. This study aims to fill this gap by conducting a comprehensive investigation that will contribute to the standardization process. The findings of this study will help promote the widespread adoption of pervious concrete in the construction industry by providing clear guidelines for mix proportioning. By establishing standardized mix proportions, pervious concrete can be more readily implemented in various construction projects, leading to its increased acceptance and utilization.

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