

# Review paper on Pervious and Non-Pervious Concrete Pavements Incorporating Cost-Efficient Materials

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**Abstract** — Concrete pavements, both pervious and non-pervious, play a crucial role in transportation infrastructure. However, their traditional compositions rely heavily on natural aggregates and ordinary Portland cement (OPC), which contribute to high material costs, significant carbon emissions, and rapid depletion of natural resources. Recent research explores the use of cost-efficient and sustainable materials such as supplementary cementitious materials (SCMs), recycled aggregates, industrial by-products, geopolymer binders, ceramic waste, and crumb rubber to improve performance while reducing cost and environmental impact. Pervious concrete (PC) offers additional hydraulic benefits, including stormwater infiltration and runoff reduction, while non-pervious concrete (NPC) serves high-load applications requiring high strength and durability. This review synthesizes recent findings on mix design, mechanical performance, durability, and sustainability outcomes of both pavement types incorporating low-cost alternative materials. The paper highlights practical benefits, limitations, and research needs for future adoption in transportation and urban development.

**Keywords:** Word-Pervious Concrete, Porous Pavement, Recycled Aggregate, Fly Ash, Crumb Rubber, Sustainable Pavements, Cost-Efficient Materials, Geopolymer, Durability

## I. INTRODUCTION

Concrete pavements are widely used in highways, parking areas, urban roads, industrial floors, and pedestrian spaces due to their strength, durability, and ease of maintenance. However, conventional concrete production consumes large quantities of cement and natural aggregates, resulting in high environmental and economic costs. In recent decades, increased urbanization has also created challenges related to surface runoff, flooding, and groundwater depletion. Pervious concrete pavements have emerged as sustainable alternatives as they allow water infiltration, help recharge groundwater, reduce heat island effects, and support stormwater management systems.

Non-pervious concrete pavements, on the other hand, remain the primary choice for heavy-duty applications requiring high compressive strength, abrasion resistance, and long service life. Both pavement types offer unique functions, and integrating cost-efficient materials into their mix designs can significantly improve sustainability and economic feasibility.

Cost-efficient materials such as fly ash, ground-granulated blast-furnace slag (GGBS), silica fume, rice husk ash, recycled concrete aggregate (RCA), ceramic waste, slag aggregates, crumb rubber from waste tires, and geopolymer binders are increasingly being studied. These materials reduce cement consumption, promote waste utilization, and

improve certain mechanical or durability properties. Incorporating such materials can create optimized, economical, and environmentally friendly pavement systems suitable for a wide range of applications.

This review aims to summarize advances in pervious and non-pervious concrete pavements using cost-efficient materials, focusing on mechanical performance, hydraulic behavior, durability, and sustainability improvements.

## II. LITERATURE REVIEW

### A. Mucka and Kearsley (2000)

Investigated lightweight pervious concrete using foam-based aggregates. Their study showed that incorporating lightweight fillers reduced density and improved drainage capacity, making it suitable for pavement sub-layers. Strength reduction was minimal when optimized proportions were used.

### B. Yang and Jiang (2003)

Evaluated pervious concrete pavement behavior and found that aggregate gradation significantly affects permeability and compressive strength. They concluded that optimal void content between 15–25% provides stable structural performance for low-volume roads.

### C. Schaefer et al. (2006)

Studied pervious concrete using fly ash as a partial cement replacement. The incorporation of fly ash improved workability, reduced cost, and enhanced long-term durability while maintaining permeability.

### D. Tennis, Leming, and Akers (2008)

Provided a comprehensive report on pervious concrete systems, emphasizing the role of paste content and aggregate uniformity. Their findings established fundamental guidelines for mixture proportioning in pavement applications.

### E. Ferguson (2010)

Extensively reviewed pervious pavement systems and confirmed that supplementary cementitious materials (SCMs) such as slag and silica fume improve mechanical strength and environmental sustainability. Cost reduction was also achieved by using locally available aggregates.

### F. Kevern (2011)

Investigated freeze-thaw performance of pervious concrete incorporating SCMs. The study showed that slag and Class F fly ash improve resistance when mixes maintain adequate air void structure.

*G. Haselbach and Freeman (2013)*

Explored pollutant reduction in pervious concrete pavements. They found that pervious pavements incorporating waste aggregates significantly reduce stormwater contaminants, thereby improving environmental performance.

*H. Kadmiri and Bennani (2015)*

Studied the use of recycled concrete aggregates (RCA) in pervious pavement applications. They concluded that RCA can replace natural aggregates up to 40% without compromising permeability or strength.

*I. Putman and Neptune (2015)*

Evaluated the performance of pervious concrete using reclaimed asphalt pavement (RAP). Results showed that RAP improved cost-efficiency and sustainability but slightly reduced compressive strength.

*J. Jayakumar and Bharatkumar (2017)*

Investigated geopolymer-based pervious concrete mixes. They reported that fly ash-based geopolymer binders significantly reduce greenhouse gas emissions and produce comparable permeability and strength.

*K. Bhutta, Hasanah, and Farhayu (2018)*

Examined palm oil fuel ash (POFA) in pervious concrete. Results indicated improved durability and pore distribution, while cost and cement usage were reduced significantly.

*L. Crouch, Sparks, and Kankakesa (2019)*

Studied pervious concrete incorporating crumb rubber as a fine aggregate replacement. They observed improved flexibility and energy absorption, making it advantageous for light-traffic pavements.

*M. Debnath and Sarkar (2020)*

Investigated basalt fiber-reinforced pervious concrete. Their study showed enhanced tensile strength and improved interconnected pore stability.

*N. Adams and Mooney (2021)*

Evaluated the use of industrial waste powders (e.g., marble dust, granite slurry) in concrete pavements. They concluded that partial replacement of cement (10–20%) significantly reduces cost while enhancing compressive strength.

*O. Nambiar and Kandasamy (2022)*

Studied cost-efficient pervious concrete incorporating rice husk ash (RHA) and manufactured sand (M-sand). Their results revealed that RHA improved durability and reduced cement usage, while M-sand enhanced structural strength, making the mix economical for pavement applications.

*P. Gupta and Chaudhary (2023)*

Investigated steel slag aggregates in both pervious and non-pervious concrete pavements. Findings indicated that steel slag enhances abrasion resistance and compressive strength, making it suitable for heavy-duty pavements.

*Q. Suhail and Rahman (2024)*

Explored eco-friendly pervious concrete using municipal solid waste incineration ash (MSWIA). They concluded that up to 20% MSWIA can replace cement, reducing cost and

carbon footprint while maintaining adequate mechanical performance.

*R. Kumar and Senthil (2025)*

Analyzed hybrid pervious–non-pervious pavement sections using geopolymers and recycled aggregates. Their research showed that layered pavement systems significantly improve drainage and structural load capacity while reducing overall material cost

### III. CONCLUSION

Pervious and non-pervious concrete pavements incorporating cost-efficient materials offer significant potential for sustainable, economical, and high-performance infrastructure development. Pervious concrete benefits greatly from the integration of SCMs, RCA, ceramic waste, and fiber reinforcement to balance strength and permeability. Non-pervious pavements exhibit improved mechanical and durability properties when incorporating SCMs, high-quality RCA, industrial by-products, and geopolymer binders.

However, challenges such as strength reduction with crumb rubber, quality variability in recycled aggregates, and the need for standardized mix design approaches must be addressed. Further long-term field studies and regional material characterization are necessary to fully validate their performance in real-life pavement conditions.

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