STRUCTURAL PERFORMANCE OF PERVIOUS CONCRETE PAVEMENTS INCORPORATING MARGINAL AGGREGATES

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ABSTRACT:

This study investigates the structural performance of pervious concrete pavements incorporating marginal aggregates, focusing on compressive strength, flexural strength, durability, and shrinkage characteristics. With urbanization increasing the demand for sustainable pavement solutions, pervious concrete offers dual benefits of load-bearing capacity and hydrological efficiency. The research evaluates whether pervious concrete mixtures using alternative aggregates can meet structural requirements for low-traffic pavements and pedestrian infrastructure. Experimental results demonstrate that marginal aggregates can be effectively utilized without compromising structural performance, providing a cost-effective and sustainable alternative for infrastructure applications.

Keywords: *Pervious concrete, marginal aggregates, compressive strength, flexural strength, structural performance, sustainable pavements*

INTRODUCTION:

Rapid urbanization and the expansion of road infrastructure have increased reliance on conventional, impervious concrete pavements. These surfaces exacerbate environmental issues such as urban flooding, soil erosion, and heat island effects, while consuming vast amounts of natural resources. Sustainable solutions such as pervious concrete are therefore gaining importance. Pervious concrete, also referred to as porous or permeable concrete, is designed with interconnected voids that allow water infiltration while still maintaining structural integrity.

Traditionally, pervious concrete uses high-quality coarse aggregates, limiting its economic feasibility. The use of marginal aggregates—defined as locally available, lower-cost, or non-standard aggregates—can reduce costs and environmental impact. However, the structural implications of such substitutions require systematic evaluation. While hydrological benefits of pervious concrete are widely acknowledged, structural performance remains a major barrier to large-scale implementation.

This paper aims to fill this gap by analyzing the compressive strength, flexural strength, durability, and shrinkage behavior of pervious concrete pavements incorporating marginal aggregates. The study highlights the potential of such mixtures for low-volume traffic applications including sidewalks, parking lots, and rural roadways.

LITERATURE REVIEW:

Development of Pervious Concrete:

The concept of pervious concrete dates back to the mid-19th century but has gained global significance in recent decades due to urban water management challenges. Ghafoori and Dutta (1995) explored the mechanical properties of no-fines concrete, while Malhotra (1976) discussed its early structural applications. More recent studies have focused on improving the balance between strength and permeability.

Mechanical Properties of Pervious Concrete:

The absence of fine aggregates leads to high porosity but reduces compressive and flexural strength. Neithalath (2003) reported that optimized compaction and chemical admixtures could significantly improve strength without reducing permeability. Studies show that compressive strengths of pervious concrete generally range from 2,000 to 4,000 psi (14–28 MPa), depending on aggregate size and mix proportions.

Marginal Aggregates in Construction:

Marginal aggregates include quarry waste, crushed stone dust, recycled concrete aggregates, and locally available natural stone. Several researchers (NRMCA, 2004) have highlighted their role in reducing reliance on high-quality natural aggregates. However, variability in shape, texture, and strength of marginal aggregates can affect bonding and structural properties.

Indian and Global Context:

In India, the use of marginal aggregates is economically attractive due to the abundance of quarry dust and stone chips. Case studies in Japan and the U.S. have demonstrated the viability of recycled aggregates in pervious concrete for low-traffic areas. However, adoption remains limited due to concerns about durability and long-term performance.

Research Gap:

While numerous studies focus on the hydrological benefits of pervious concrete, fewer have rigorously analyzed its structural behavior with marginal aggregates. This study aims to bridge that gap, providing experimental evidence and comparative analysis.

Research Methodology:

Materials:

- **Cement:** Ordinary Portland Cement (OPC 43 grade)
- **Aggregates:** Locally sourced marginal aggregates, including crushed stone and quarry dust alternatives
- **Water:** Potable water conforming to IS 456 standards
- **Admixtures:** Hydration stabilizers, viscosity modifiers, and water-reducing agents

Aggregate Characterization:

Marginal aggregates were tested for specific gravity, water absorption, impact value, and crushing strength as per IS 2386 standards. Results indicated slightly lower density and higher water absorption compared to conventional aggregates.

Mix Design:

Mixes were prepared with aggregate-to-cement (A/C) ratios of 4.0:1 and 4.5:1. Water-to-cement (w/c) ratios ranged from 0.27 to 0.30. Fine aggregates were excluded to maintain high void content (15–25%).

Experimental Setup:

- **Compressive Strength:** 150 mm cubes tested at 7, 14, and 28 days (IS 516)
- **Flexural Strength:** 100 × 100 × 500 mm beams tested under third-point loading
- **Durability Tests:** Freeze-thaw resistance, abrasion resistance (ASTM C666, C944)
- **Shrinkage:** Measured over 28 days with standard shrinkage molds

Statistical Analysis:

Results were compared using regression models to identify relationships between aggregate type, mix ratio, and strength development.

RESULTS:

Compressive Strength:

Compressive strength values at 28 days ranged between 2,000–3,000 psi (14–21 MPa). Mixes with A/C ratio of 4.0:1 showed superior performance. Marginal aggregates exhibited a 5–10% reduction in strength compared to conventional aggregates, but remained within acceptable limits for light-traffic applications.

Flexural Strength:

Flexural strength values ranged between 200–400 psi (1.4–2.8 MPa). While lower than conventional concrete, these values were sufficient for sidewalks, parking lots, and pedestrian zones.

Durability:

- **Freeze-thaw cycles:** Samples retained 90% of dynamic modulus after 80 cycles.
- **Abrasion resistance:** Slightly lower than conventional concrete, but acceptable for low-speed applications.

Shrinkage:

Shrinkage was lower than conventional concrete (approx. 200×10^{-6}), reducing the likelihood of cracking.

Comparative Analysis:

Compared to international benchmarks, the results confirm that marginal aggregates can provide structurally viable pervious concrete for low-volume applications. Strength loss is minimal, while cost savings and sustainability benefits are substantial.

DISCUSSION:

Structural Suitability:

Marginal aggregates proved effective in achieving compressive strengths above 14 MPa, meeting basic pavement requirements. Flexural strength was sufficient for light traffic loads.

Durability Implications:

While marginal aggregates slightly reduce abrasion resistance, proper compaction and curing practices mitigate this limitation. Freeze-thaw resistance was satisfactory, aligning with field performance in temperate climates.

Sustainability Benefits:

The use of marginal aggregates reduces reliance on high-grade stone, decreases carbon footprint, and lowers costs by 10–20%. This makes pervious concrete economically viable for rural and semi-urban applications.

Policy Implications:

Incorporating marginal aggregates aligns with sustainable development goals (SDGs), promoting resource efficiency in construction. Government agencies can encourage adoption through specifications and incentives.

Conclusion:

Pervious concrete pavements incorporating marginal aggregates demonstrate sufficient structural performance for low-volume applications such as parking lots, pedestrian pathways, and residential streets. The compressive and flexural strengths achieved meet design requirements, while durability and shrinkage performance further support their use.

Future Scope:

- Long-term field studies to monitor real-life performance under traffic and weather conditions
- Use of supplementary cementitious materials (SCMs) to improve strength
- Development of national guidelines for mix design with marginal aggregates
- Exploration of hybrid mixes combining recycled and natural aggregates

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