COMPRESSIVE AND FLEXURAL STRENGTH BEHAVIOR OF PERVIOUS CONCRETE WITH MARGINAL AGGREGATES

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Abstract

Pervious concrete is increasingly being adopted as a sustainable pavement material due to its ability to facilitate groundwater recharge and reduce surface runoff. However, the scarcity of high-quality aggregates and the rising cost of conventional materials have encouraged the exploration of low-quality or marginal aggregates in its production. This study investigates the compressive and flexural strength characteristics of pervious concrete prepared using low-quality aggregates. Various concrete mixes were developed by partially or fully replacing conventional aggregates with marginal aggregates, and their mechanical performance was evaluated through standard laboratory tests. The results indicate that although the use of low-quality aggregates leads to a reduction in strength compared to conventional mixes, optimized mix proportions can still achieve acceptable structural performance for low to moderate load-bearing applications. Additionally, the study highlights the balance between strength and permeability, emphasizing the importance of proper gradation and binder content. The findings suggest that the use of marginal aggregates in pervious concrete can be a cost-effective and environmentally responsible alternative, particularly in regions where high-quality materials are limited.

Keywords: *Pervious concrete, low-quality aggregates, compressive strength, flexural strength.*

INTRODUCTION

Among the various sustainable construction solutions, Concrete that has been pervious pavement is increasingly viewed as the most viable option when considering structural performance, hydrological benefits, and cost-effectiveness. The investigation into permeable pavement materials began in technologically advanced nations like the United States and Japan during the 1980s. Concrete that has been pervious typically comprises Portland cement, water, coarse aggregates, and occasionally, chemical additives. The exclusion of fine aggregates results in the creation of voids within the concrete, facilitating the infiltration of water through the pavement and into the ground. Due to its relatively rigid mix, it requires specific techniques for placement and compaction.

In California, Concrete that has been pervious is most commonly used for parking lot construction, according to Youngs. Nevertheless, he also observes a growing trend in using this material for residential streets, sidewalks, and golf cart lanes. Additionally, a rising number of homeowners are selecting Concrete that has been pervious to address surface water issues, reduce erosion, and avoid the costs associated with connecting to municipal stormwater infrastructure. Common residential applications include its use in driveways, footpaths, poolside surfaces, and patio areas. Below are examples of projects nationwide that demonstrate how Concrete that has been pervious is used to manage runoff, preserve aquatic habitats, and support irrigation systems: The use of pervious pavement technologies to control rainwater and protect the habitats of endangered salmon species in Puget Sound is being investigated by the Washington State Aggregates and Concrete Association. Finley Stadium in Chattanooga, Tennessee, built its parking lots with permeable concrete so that rainwater could be collected and used to water the field.

Figure 1: Pervious Concrete

Table 1: Applications for Concrete that has been pervious

Category of Application	**Illustrative Uses**
Residential and Light-Duty Pavements	Local access streets, narrow service lanes, and domestic driveways
Pedestrian and Non-Motorized Zones	Footpaths and pedestrian walkways
Parking and Recreational Installations	Car parks, sports surfaces such as tennis courts, and outdoor seating areas
Surface and Stormwater Management	Shallow stream crossings, drainage at pavement perimeters, and poolside deck surfaces
Base Courses	Supportive sub-layers beneath traditional concrete pavement systems
Coastal and Ecological Structures	Marine-based artificial reef systems, shoreline stabilization using groins and seawalls
Soil Retention and Drainage	Soil slope reinforcement systems and linings for wells
Urban Environmental Enhancements	Tree surround installations incorporated within city sidewalks
Commercial and Institutional Foundations	Structural floors and bases for greenhouses, aquatic breeding centers, zoos, and water parks
Water Infrastructure	Engineered components in hydraulic applications
Acoustic Mitigation Structures	Sound-dampening walls designed for noise control
Load-Bearing and Structural Walls	Vertical concrete elements, including walls designed for structural support

REVIEW OF LITERATURE

Serifou, M (2024): Traditional concrete typically consists of cement, water, gravel, and sand, but some studies investigate the use of waste materials as aggregate replacements. In this research, used tires were employed as a substitute for gravel. The properties examined included tensile strength, Strength at Compression, and porosity, evaluated at curing ages of 7.0, 14.0, and 28.0 days. Results indicated that aggregates derived from used tires are suitable for concrete production and can act as substitutes for natural gravel.

Arnaud, K (2023): This research examines the use of waste-derived plastic aggregates to address issues of shrinkage and expansion in concrete. Plastic aggregates made of high-density polyethylene (HDPE) and polyvinyl chloride (PVC) were used to replace natural aggregates at 0%, 5%, 10%, 20%, and 30% by volume. The investigation involved tests on drying shrinkage, water absorption, and expansion due to internal sulfate attack (ISA), which was accelerated via a controlled heat treatment process followed by drying and immersion. Image correlation was applied for expansion measurements.

Ubi, S.E (2022), Polystyrene, widely recognized as a common plastic material used for packaging, is characterized by its resistance to biodegradation and can take several centuries to decompose when disposed of in landfills. Moreover, alternative disposal or treatment techniques for polystyrene pose environmental risks. Nonetheless, this polymer exhibits favorable characteristics such as acoustic insulation, lightweight nature, and high thermal conductivity, which make it a suitable additive in concrete formulations.

Danso, H. (2021), One intriguing approach to sustainable building methods is the use of palm kernel shells (PKS) in place of traditional building materials. The performance characteristics of lightweight concrete built using PKS of different particle sizes—6 mm, 8 mm, 10 mm, and 12 mm—as well as a mixed type made up of 25% of each—were investigated in this work. These PKS sizes replaced traditional coarse aggregates in concrete specimens cured over 7, 14, 21, and 28 days. Evaluations were carried out on dry density, compressive and flexural strength, along with EDS and SEM analyses.

METHODOLOGY

The research methodology for this study focuses on preparing and testing pervious concrete made with low-quality aggregates to evaluate its compressive and flexural strength. Initially, different concrete mixes are designed by partially or fully replacing conventional aggregates with low-quality aggregates. Standard materials such as cement, water, and aggregates are proportioned carefully to maintain the desired porosity. The concrete samples are then cast into standard molds for compressive strength and beam molds for flexural strength testing. After casting, the specimens are cured under controlled conditions for specific durations, typically 7 and 28 days. Once cured, compressive strength is measured using a compression testing machine, while flexural strength is determined through a loading test on beam specimens. The results obtained are compared with conventional pervious concrete to understand the performance and suitability of low-quality aggregates in structural applications.

RESULTS

Fly ash was tested at 5% intervals to evaluate mechanical qualities up to 20% in concrete that had been previously mixed. Adding up to 15% fly ash made standard concrete that was permeable stronger over time. After that, the strength properties got worse. It was found that adding 15% fly ash to S1, S2, and S3 material mixes made the fly ash mixed concrete that was permeable stronger by 14.37 MPa, 13.78 MPa, and 13.08 MPa, all at the compression level. For S1, S2, and S3 aggregate mixes, concrete that had been previously mixed without fly ash (FA00 and FA15) increased in strength at compression by 16%, 17%, and 24%, respectively. Adding materials with a high specific area made a thick paste around the pebbles, which helped make the concrete stronger.

Table 1: Strength properties of Concrete that has been pervious

Mix	Comp. strength (MPa)	Split tensile strength (MPa)	Flexural strength (MPa)	Mix	Comp. strength (MPa)	Split tensile strength (MPa)	Flexural strength (MPa)
A3CS1	15.87	1.70	3.21	FA15S2	13.78	2.15	3.65
A4CS1	12.28	1.53	2.86	FA20S2	12.15	1.95	3.16
A5CS1	8.56	1.40	2.62	FA00S3	9.01	1.30	2.62
A6CS1	6.46	1.29	2.22	FA05S3	10.73	1.42	2.86
A7CS1	5.94	1.17	1.93	FA10S3	12.27	1.63	3.06
A3CS2	13.73	1.66	2.96	FA15S3	13.08	2.01	3.56
A4CS2	10.07	1.47	2.81	FA20S3	11.32	1.77	2.96
A5CS2	6.89	1.32	2.37	MK00S1	12.81	1.67	3.23
A6CS2	5.64	1.23	2.02	MK05S1	13.87	2.02	3.82
A7CS2	5.05	1.15	1.88	MK10S1	15.75	2.48	4.40
A3CS3	12.44	1.57	2.86	MK15S1	14.10	2.23	3.88
A4CS3	9.13	1.44	2.47	MK20S1	13.59	2.05	3.65
A5CS3	6.79	1.25	2.07	MK00S2	10.34	1.61	2.73
A6CS3	5.47	1.17	1.83	MK05S2	13.24	1.86	3.70
A7CS3	4.90	1.12	1.63	MK10S2	15.14	2.30	4.08
FA00S1	11.33	1.92	3.11	MK15S2	13.39	2.09	3.65
FA05S1	12.49	2.29	3.36	MK20S2	12.04	1.86	3.23
FA10S1	13.90	2.64	3.65	MK00S3	9.57	1.40	2.57
FA15S1	14.37	3.00	3.85	MK05S3	10.21	1.68	3.22
FA20S1	13.10	2.48	3.41	MK10S3	13.10	2.00	3.82
FA00S2	10.44	1.46	2.81	MK15S3	11.85	1.83	3.22
FA05S2	11.85	1.52	2.96	MK20S3	10.06	1.67	3.05
FA10S2	12.98	1.80	3.26				

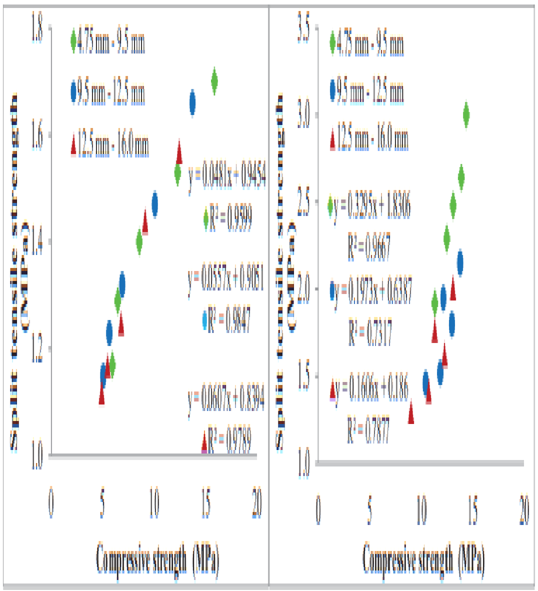

Figure 1: Compressive and split strength of FAPC

It shows how split tensile strength and strength at compression are related in regular concrete that has already been mixed. If you look at Strength at Compression, the split tensile strength goes up slowly from the S3 aggregate mix to the S1 aggregate mix. It displays the split tensile strength findings for the FAPC mix as a function of strength at compression.

Most of the time, the strength when compressed is six times the strength when stretched. The stronger link between split tensile strength and strength when compressed can be seen in the picture.

As shown in Fig. a consistent association between flexural strength and strength at compression was found for all aggregate gradations. For all mixtures, the aggregate mix's flexural strength is directly correlated with its strength during compression. Compared to the other two aggregate mixes, the big size aggregate mix has a superior relationship.

It compares the flexural strength and strength at compression based on the various aggregate gradations of FAPC mixtures. FAPC mixtures have four times the strength during compression compared to their flexural strength.

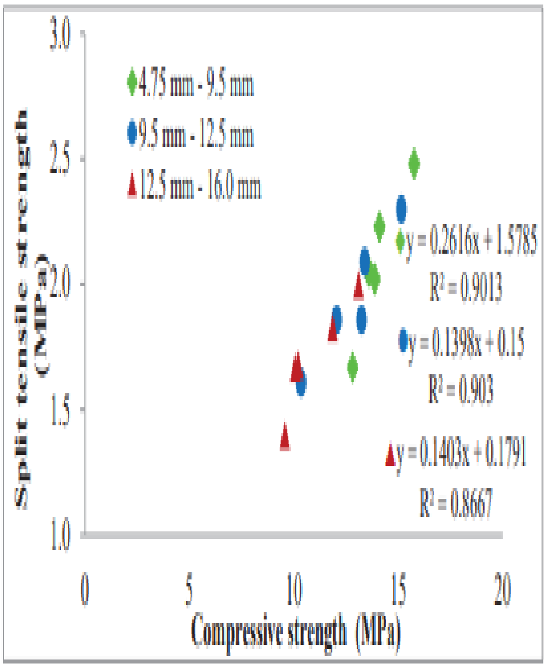

Figure 2: Compressive and split strength of MKPC

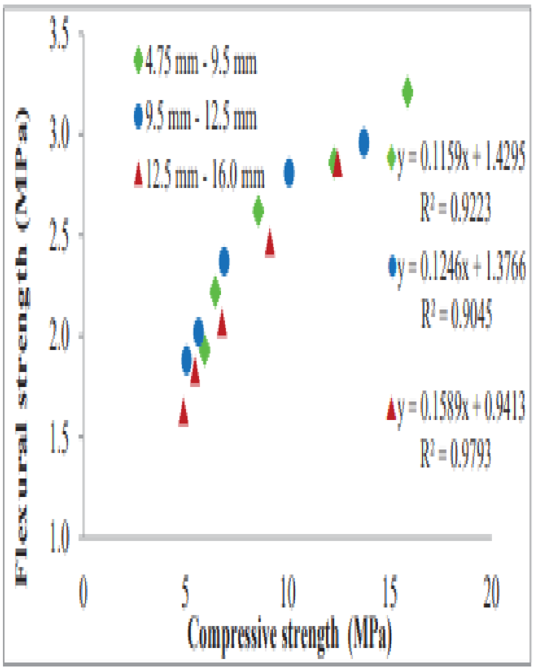

Figure 3: Compressive and flexural strength of NPC

CONCLUSION

The study concludes that compressive strength has a strong and consistent relationship with split tensile and flexural strength in pervious concrete. As compressive strength increases, both tensile and flexural strengths also improve, though at a lower rate. Typically, compressive strength is about six times the split tensile strength and four times the flexural strength. Among different aggregate gradations, larger-sized aggregates show a better strength relationship. The inclusion of fly ash significantly enhances strength up to an optimum level of 15%, beyond which the strength starts to decline. The improvement is mainly due to the formation of a denser paste around aggregates. Therefore, optimized aggregate grading and controlled fly ash content improve overall mechanical performance.

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