Comparison of Pervious Concrete with Conventional concrete Made of Local Materials

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Abstract - *Pervious Concrete which is also known as porous concrete, permeable concrete or zero fines concrete is a specialized classification of concrete characterized by its high permeability, allowing liquid to pass through it directly. The composition of pervious concrete involves primarily large aggregates with minimal fine aggregates, resulting in a concrete paste that coats the aggregates and permits water permeation through the slab. Its popularity is growing due to its capacity to reduce drainage system overload, with flow rate of water that is around 0.34 cm per second. Pervious concrete is commonly utilized in several applications, including parking pavements with low loading intensity, pathways, walkways, and roads. Pervious concrete acknowledged by EPA which is known as Environmental Protection Agency for its application in sustainable development, storm management and pollution control is created by a proper combination of cement, sand and gravel or cursed stone. Its light color and open-cell structure help mitigate heat absorption from the sun, subsequently reducing heat emission into the atmosphere and minimizing environmental heating. Notably, pervious concrete offers cost-effective installation and acts as a filtration system for storm water, diminishing the influx of pollutants into rivers and ponds. Moreover, it supports tree growth by facilitating better water infiltration into the soil. This study conducted experimental analysis on the behavior of pervious concrete, specifically investigating its workability, compressive strength, split tensile strength, and permeability. The analysis was carried out using 3 different w/c ratios of 0.35, 0.40 and 0.45.*

***Key Words*: Pervious concrete, Mix proportion, Porosity, Compressive Strength, Tensile Strength**

1.INTRODUCTION

Over time, construction technology has undergone significant advancements, enabling the swift completion of various structures within a month using modern techniques. It's widely acknowledged that concrete is indispensable for economical construction. "Concrete" is derived from the Latin word “concretes” meaning to grow together [1,14]. Constituting cement, aggregate, and water, concrete undergoes a chemical process called hydration upon mixing and placement, solidifying into a durable material. Concrete serves myriad purposes in construction, from pavements to architectural structures, foundations, overpasses, and parking structures. Though rigid with high compressive strength, concrete lacks in tensile strength, which is often bolstered by reinforcing bars [15]. Concrete properties both in initial and hardened states, are controlled by the relative proportions of cement, aggregate and water. Notably, this water-cement ratio significantly influences concrete strength, with an increase leading to excessive bleeding and reduced strength [3].

High-performance concrete commonly utilizes standard Portland cement and includes other cementitious elements as by-products, which is a prevalent technique in the industry. Pervious concrete is an unconventional material composed of large pieces of aggregate, cement, water, and very little or no sand [2]. It is characterized by a structure that has empty spaces or openings, allowing for the passage of air or water [4]. This composition facilitates natural water drainage and groundwater replenishment, distinguishing it from conventional concrete or asphalt. Commonly referred to as zero fines concrete, pervious concrete exhibits a void space of almost 15%-30%, with pores ranging from 0.08inchs-0.32inches (2mm-8mm), allowing water passage without compromising the concrete matrix [9,12]. In light of climatic imbalances leading to land drying up, there's a growing trend towards adopting pervious concrete or porous pavement in communities, municipalities, and businesses [5,6]. This material possesses the durability and cost-effectiveness of conventional concrete while also having the potential to deal with storm water runoff and restore local watershed systems [3].

1.1 Materials

Laboratory testing according to relevant codes is important to measure the properties of materials used in various mixes of concrete. In this study, binding materials such as cement, coarse aggregate such as stone chips and fine aggregates such as sand were examined to ensure compliance with standards and facilitate mix design of concrete for the appropriate strength requirements [7].

Ordinary Portland cement (OPC): OPC, a crucial cement type, is finely ground Portland cement clinker and is classified into three grades based on 28-day strength: 33 grade, 43 grade, and 53 grade. Quality improvements in cement production, including the use of high-grade limestone, modern equipment, and finer grinding, enhance cement qualities.

The use of higher grade cement offers advantages in producing stronger concrete. Throughout the investigation, 53 Grade OPC (Seven Ring Cement) was utilized, carefully stored to prevent moisture-induced property deterioration. Cement underwent various tests including initial and final setting time, specific gravity, fineness, and compressive strength [10].

Aggregates: Aggregates, constituting the bulk of concrete, provide dimensional stability. Employing aggregates in multiple sizes enhances mix density, with fine aggregates crucial for workability and mixture uniformity. They aid cement paste in suspending coarse aggregate particles, ensuring plasticity, and preventing segregation during transport. Aggregates contribute significantly to concrete's properties and must meet specific requirements for workability, strength, durability, and economy. Coarse aggregates, retained over a 4.75mm IS sieve, were used, including crushed gravel or stone, uncrushed gravel, and partially crushed gravel. Table 1 and Table 2 shows the locally available coarse aggregates with a maximum size of 20mm were utilized, washed to remove impurities and tested as per IS: 383-1970 for properties such as specific gravity. Sieve analysis was conducted to assess particle size distribution. In Table 3, the mixer proportion of concrete showed.

Table -1: Summary of Aggregate Properties

Topic	ASTM Specifications	Aggregate (Black Stone)
Absorption Capacity (%)	C127	4.5
Loss Angeles Abrasion (%)	C131 (Grade B)	20.63
Specific gravity (SSD)	C127	2.76

Table 2: Coarse Aggregates properties

Characteristics	Value
Shape	Angular
Color	Grey
Flakiness index, (%)	26.9%
Water absorption, (%)	0.50%
Elongation index, (%)	10.60%
Maximum Size, (mm)	20 mm
Specific Gravity	2.76

Table 3: Mixture Proportions of Pervious Concrete

Mixture ID (Water cement ratio)	Aggregate Type			
	Black Stone			
	Unit Content (kg/m³)*			TV* %
	C	W	CA	
0.45	600	197	1050	21.6
0.40			1150	24.7
0.35			1020	25.4

**W= Water, C= Cement, CA= Coarse Aggregate and TV= Theoretical Void*

1.2 Sample Preparation and Curing procedure

Mixing concrete was done with a pan-type mixer with a capacity of 200 liters. The quantities of materials used to cast cylinders and other specimens were determined and measured with an automated weight balance. Under the specifications set by ASTM C192, concrete cylinder specimens with dimensions of 100 mm x 200 mm were manufactured. These specimens were saturated surface dry (SSD) and manufactured with 100 mm x 200 mm dimensions. A 200 liter pan-style concrete mixer was used to mix the concrete [11]. The amounts of materials needed for casting cylinders and other samples were measured using a weighing scale. The mix included aggregates (CA) in a surface dry (SSD) condition. Concrete cylinder samples measuring 100 mm x 200 mm were produced following the ASTM C192 guidelines. Once compacted the formed concrete samples were placed under damp jute bags for a day. Afterward they were taken out of the molds and stored under wet jute bags. The concrete specimens were submerged in water a day before testing. Before testing began the samples were taken out of the water any surface moisture was. They underwent the inspections. In total 72 concrete cylinder specimens were created for this research study.

1.3 Research Methodology

Compressive and split-tensile tests were performed on the applicable samples in accordance with the ASTM C39 and ASTM C496 standards, respectively [13]. In order to evaluate the voids inside the concrete, a cylindrical sample was immersed in a container of water that had been marked with a measuring scale. The subsequent rise in the volume of water was then measured. The cylinder was gently agitated to remove any air bubbles. The following formula was used to determine the interconnected porosity:

$$Vo = \frac{V1 - V2}{V1} * 100\% \dots\dots\dots\dots (1)$$

Here, 'V_0' represents the air void percentage in concrete, 'V_1' is the volume of the cylinder including the voids and 'V_2' is the volume of the water container that is increased due to the immersion of the cylinder.

Due to the complex and linked pore structure in pervious concrete, traditional techniques used to measure the hydraulic conductivity in conventional concrete may not be directly applied. A falling head permeability cell was created by Hossain et al. (2010) to determine the hydraulic conductivity of pervious concrete [8]. The value of the coefficient of permeability (k) was determined by using the equation:

$$k = 2.303\frac{aL}{At}log_e\frac{h1}{h2} \dots\dots\dots\dots\dots\dots (2)$$

Where 'a' and 'A' indicates the cross-sectional areas of the sample and the tube, respectively, 'L' indicates the specimen's length, 'h_1' and 'h_2' denote the initial and final head levels and 't' is the time taken for the water to descend from the initial head to the final head.

2. Results and Discussion

According to earlier studies, the best compressive strength in duration of 28 days and better permeability are achieved in porous concrete when fine particles are absent (Yang & Jiang, 2003). In this study with no amounts of fine aggregates, the specimens that underwent compressive strength split tensile and permeability tests contained water-cement ratios of 0.35, 0.40 and 0.45 showed in Chart 1, Chart 2 and Chart 3. It is reasonable to state that the compressive strengths of conventional concrete cannot be surpassed by pervious concrete as given by the experiments. Pervious concrete has a significant porosity, which lowers the values of compressive strength. The compressive test results exhibited similar patterns of values irrespective of the duration of the weeks the specimens are cured. In Chart 1(a) and Chart 1(b), on the 7th and 14th days of curing, conventional concrete displayed the highest values of compressive strength for a w/c ratio of 0.40, measuring 15 N/mm² and 18 N/mm² respectively. Whereas the pervious concrete showed higher values for w/c ratio of 0.35 measuring 12.5 N/mm² and 15.5 N/mm² on the 7th and 14th day respectively. It can be seen that as time went on, the strength differential gap gets reduced. For w/c ratios of 0.35, 0.4 and 0.45, the differences between compressive strengths of conventional concrete and pervious concrete are 10.71%, 20% and 37.03% respectively measuring in 7 days. And in 14 days, the differences are 6.06%, 16.67% and 26.47% respectively for the three w/c ratios. In span of 7 days, the strength gain for pervious concrete is seemingly higher. Analyzing the compressive test results of specimens of 28 days shown in Chart 1(c), both conventional and pervious concrete specimens showed higher strength for w/c ratio of 0.40. 20 N/mm², 22.5 N/mm², 21 N/mm² were the compressive strength values for conventional concrete and 16 N/mm², 21.2 N/mm², 20.8 N/mm² were the compressive strength values for pervious concrete for w/c ratios of 0.35, 0.40 and 0.45 respectively. So, the differences between compressive strengths of conventional concrete and pervious concrete are 0.95%, 5.78% and 20% for the three water cement ratios of 0.35, 0.4 and 0.45 respectively. Here the differential gap is rather less and as water cement ratio is lowered pervious concrete gains more strength. For w/c ratio of 0.35 both the concrete specimens exhibited approximately similar values of strength results.

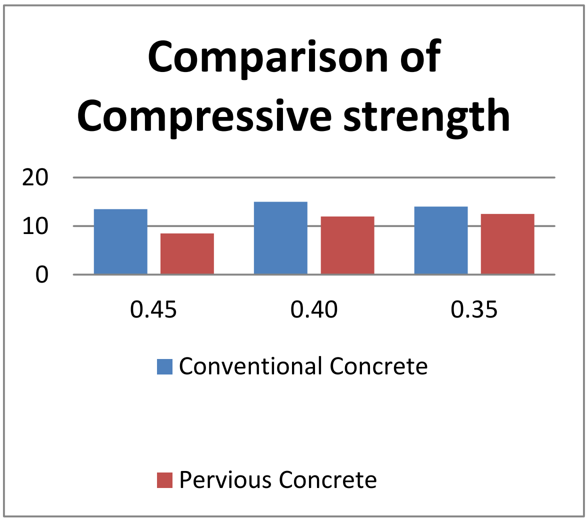

Chart -1(a): Comparison of Compressive strength for 7 days (N/mm²)

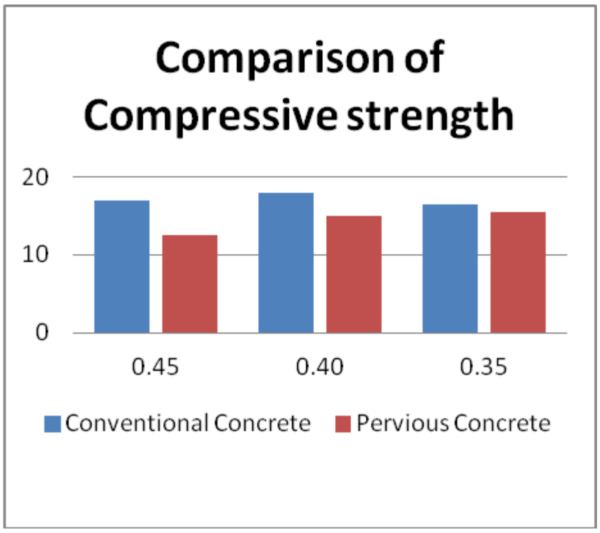

Chart -1(b): Comparison of Compressive strength for 14 days (N/mm²)

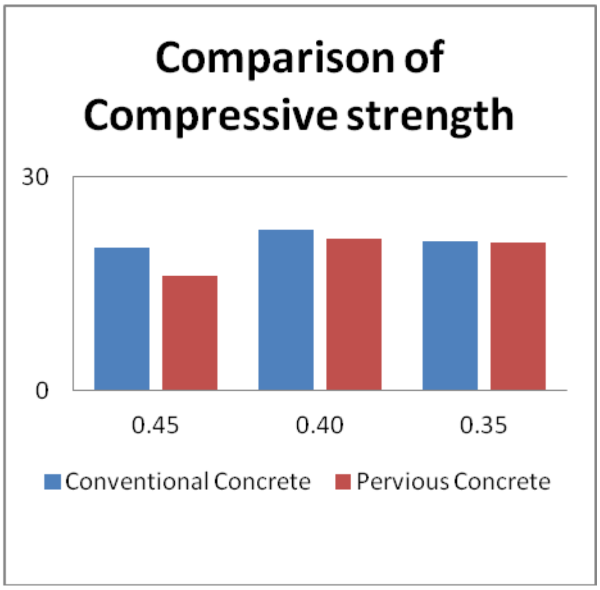

Chart -1(c): Comparison of Compressive strength for 28 days (N/mm²)

The findings of the split tensile tests showed a similar trend, indicating higher strengths for conventional concrete with a w/c ratio of 0.4%. For pervious concrete, results came quite same for both the w/c ratios of 0.40 and 0.35. In 7 days, shown in Chart 2(a), the split tensile values for conventional concrete and pervious concrete are 1.86 N/mm² and 1.54 N/mm² respectively with a gap of 17.2% for w/c ratio of 0.4%. The 14 days cured specimens had split tensile values for conventional concrete and pervious concrete of 2.19 N/mm² and 2 N/mm² respectively with a gap of 8.67% for 0.40 w/c ratio and 2.04 N/mm² and 2.01 N/mm² with 1.47% gap for 0.35 w/c ratio shown in Chart 2(b). While The 28 days cured specimens, shown in Chart 2(c), had split tensile values for conventional concrete and pervious concrete of 2.54 N/mm² and 2.41 N/mm² respectively with a gap of 5.12 % for 0.40 w/c ratio and 2.47 N/mm² and 2.4 N/mm² with 2.83% gap for 0.35 w/c ratio. The split tensile strength for pervious concrete increases in 28 days but the least gap of values between conventional concrete and pervious concrete was achieved with 0.35 w/c ratio. Therefore, a water-cement ratio of 0.35 contributed to improved outcomes in both split tensile and compressive tests for pervious concrete.

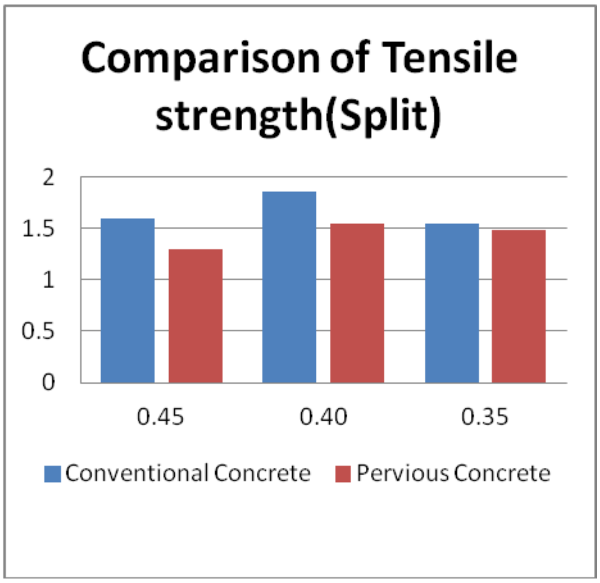

Chart -2(a): Comparison of Split Tensile strength for 7 days (N/mm²)

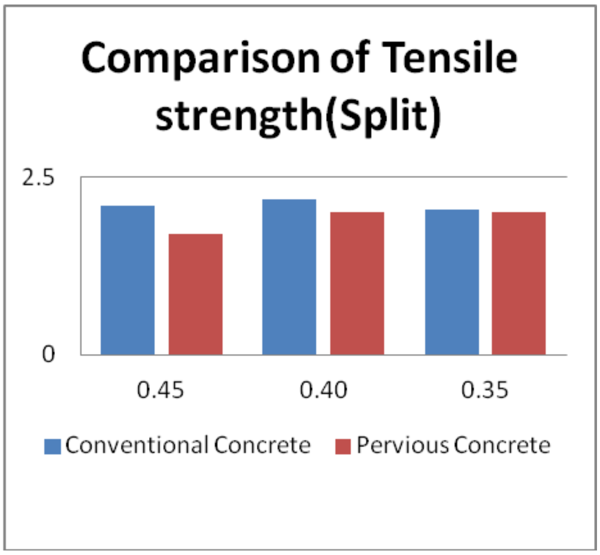

Chart -2(b): Comparison of Split Tensile strength for 14 days (N/mm²)

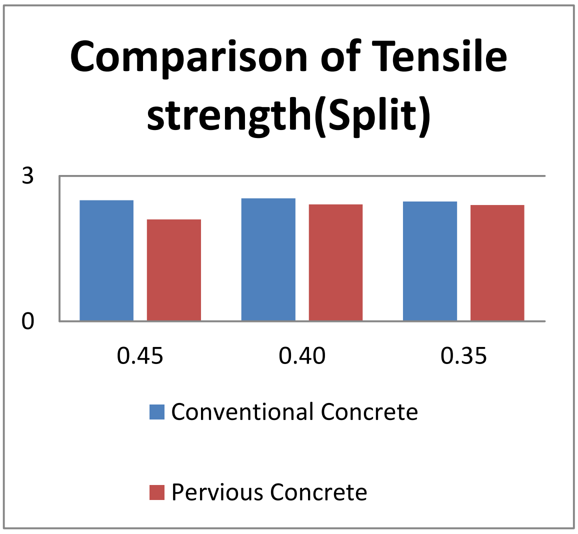

Chart -2(c): Comparison of Split Tensile strength for 28 days (N/mm^2)

For w/c ratios of 0.35, 0.40 and 0.45 the durations of passing time of 1L water are 8.5, 10 and 12.5 seconds for pervious concrete shown in Chart 3. The lowest values of water passing time are seen at w/c ratios of 0.35, suggesting that reducing w/c ratios can enhance the quality of pervious concrete's water permeability.

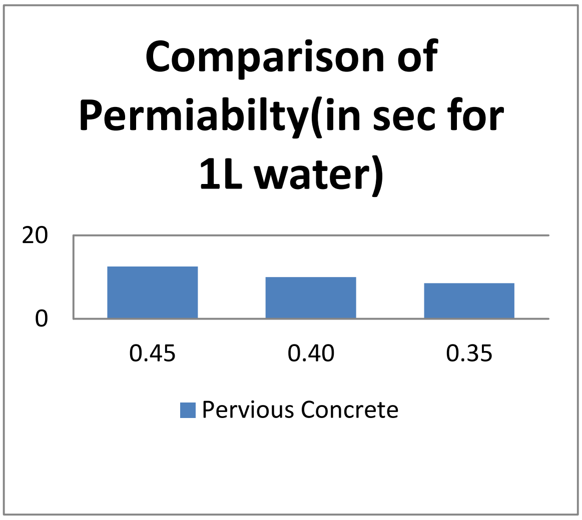

Chart -3: Comparison of Permeability for 28days (in sec for 1L water)

3. CONCLUSIONS

After the investigation of this study following statement can be drawn:

1) Cases, under investigation, adhere to the ACI specifications concerning strengths such as compressive strength, split tensile strength, void percentage, and permeability.
2) In comparison to conventional concrete, much better result can be found for pervious concrete.
3) For permeability case, same better result can be found for lower w/c ratio.
4) Pervious concrete is suitable for applications such as parking areas, pathways, and roadways designed for light vehicles such as passenger cars, rickshaws, and auto-rickshaws.
5) Analyzing all the results, in w/c ratio of 0.35, found the best result in each and every sector in comparison of other w/c ratios for pervious concrete type.

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