# MECHANICAL AND HYDRAULIC PROPERTIES OF PERVIOUS CONCRETE INCORPORATING WASTE PET PLASTIC

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**Abstract -** In modern times, human endurance is required for sustainable infrastructure development. In this regard, the concept of the blend of pervious concrete and Polyethylene Terephthalate plastic (PET) is a fascinating area of research. On the one hand, Pervious concrete helps to recharge groundwater levels by allowing water percolation through voids and reducing the surface runoff. Similarly, on the other hand, waste PET plastic, generated at a higher rate in today's time, gets reused in construction activities. This, in turn, provides two prominent advantages, i.e., alteration in the mechanical and hydraulic properties of concrete and effective plastic waste management. This paper examines the utilization of waste PET plastic fibers in the development of pervious concrete at different proportions to analyze the mechanical (compressive strength, flexural strength, tensile strength) and hydrological (permeability of concrete) variations in the resulting design. In this study, the natural coarse aggregates were replaced by different percentages of PET plastic fibers, viz. 0%, 5%, 10%, 15%, 20%, by volume at constant water-cement ratio of 0.34. Increasing the proportion of PET plastic in the concrete mix reduces the compressive strength, flexural strength, and split tensile strength. At the same time, the porosity, permeability, and abrasive resistance cited gradual rise. Based on the experimental outcomes, it was observed that the porous concrete with a w/c ratio of 0.34, aggregate to binder ratio of 4.81 with 10% replacement of coarse aggregate with PET plastic can be considered a better choice and sustainable also.

***Key Words*:** Pervious Concrete, Mechanical properties, Waste pet plastic.

## 1.INTRODUCTION

The rapid advancement and technological shift in today's contemporary world have pros and cons. Undoubtedly, the rise in infrastructural development is the most significant merit of rapid transformation. In contrast, the unprecedented surge in environmental threats due to these advancements proves to be the most concerning and alarming demerit. The lives of living beings are affected due to the problems such as environmental pollution, ineffective waste-management cycles, resource exploitation, etc. These problems have retarded the growth of eco-friendly infrastructure. To counter these stumbling blocks, the construction sector is shifting its focus entirely towards the concept of sustainability that promotes both construction and environmental safety.

Pervious concrete is a perfect and widely appreciated evidence of advancement in concrete technology. The porous concrete being stable in terms of infrastructure and eco-friendly serves twofold benefits, thus contributing to sustainable construction. It is validated as one of the most acceptable management practices by the U.S. Environmental Protection Agency (EPA). In addition to this, it also qualifies for LEED credits (Leadership in Energy and Environmental Design) by U.S. Green Building Council.

In India, many regions during the rainy season encounter serious problems, including water accumulation in potholes, widening of existing cracks, and ill-drainage patterns that fail during heavy precipitation periods. The country faces the scarcity of water and significant concerning issues like a substantial reduction in groundwater head mainly in the summer season or dry season.

This gap-graded concrete can cater to many problems like rising infrastructural defects, environmental misbalance, stormwater mismanagement, depleting groundwater level, water scarcity for irrigation, household motives; water-clogged water drains in rainy seasons, unaffordable drainage set-ups, etc., to a greater extent.

**Problem statement**

The vicious effect of rapid evolution and progress in the lifestyle of modern industrial society can be seen in the forms of the rising generation of waste and waste disposal crisis. The primary reason for this crisis is that plastic, being non-degradable, does not decompose for ages. Today, plastic wastes are simply dumped on open land and in flowing or stagnant water without proper management. The above-said reasons cause an unwanted rise in plastic waste over land and in water, causing a severe threat to the entire ecosystem. Land and water pollution are expected adverse outcomes of such dumping.

Polyethylene Terephthalate (PET) plastic is used to manufacture almost all plastic materials, including both household and commercial purposes, in one form and another. This is the primary source of increasing plastic waste. This is because the matter made from such plastic is mostly discarded after a single use. As a result, the uncontrolled rise of non-decomposable plastic waste is being cited at a higher rate. This shows a keen problem with plastic waste management today.

PET plastic mixed with pervious concrete seems to be an innovative idea to counter the issue of waste management. The same combination is used in this study to observe various related aspects. Moreover, the study examines the fusion of waste plastic fibres and porous concrete to analyse the resulting design's mechanical and physical variations. Also, the experimental research intends to devise new ways to enhance the element of sustainability in the concrete structures by providing adequate and cost-efficient waste management methods in present times.

**Objectives of study**

To examine the practical usage of PET plastic as a partial replacement of coarse aggregate in pervious concrete.

To study the mechanical properties of pervious concrete by replacing 0%,5%,10%,15%,20% coarse aggregate by volume with PET plastic.

To study hydraulic properties of the porous concrete with plastic replacement.

To determine the optimum volume fraction of PET plastic in pervious concrete as a replacement for coarse aggregates.

To enhance the overall properties of porous concrete.

**Literature Survey**

In the era of research and innovation, many studies and work related to pervious concrete are in progress to devise new usages of gap-graded concrete mix. The prime focus is to develop stable infrastructure patterns that are durable, economical, and eco-friendly. Today, new experiments and furtherance are carried out to modify the properties of pervious concrete to use it as per the requirement, suitability, and availability of resources.

In a study done by Karthik et al. [1], pervious concrete is defined as a particular type of concrete with high porosity used in flatwork applications that permit water from precipitation to pass through it and thus play a pivotal role in reducing the runoff and recharging groundwater levels. The study states that the void content of such concrete ranges between 18-35%, with variation in compressive strength recorded between 400 to 4000 psi (28 to 281 kg/cm2), and the infiltration rate lies at 2 to 18 gallons per minute per square foot (80 to 720 liters per minute per square meter). On the basis of previous research and experimentation, the paper mentions that pervious concrete requires little or no fine aggregates and just ample cementitious paste to coat the coarse aggregates while preserving the interconnectivity of the voids. The study also highlights the suitability of pervious concrete in India due to lower labor costs and manual organization of construction activity. Also, the pervious concrete recharges the groundwater level to fulfill the needs of a water-shortage state like Tamil Nadu. Moreover, this kind of concrete also helps reduce waterways pollution by restricting the entry of pollutants into it. As per the concluding statements of the work, the pervious concrete is suitable for construction parking lots, driveways, sidewalks, road platforms, etc.

In one study, Rahmani et al. [2] used PET processed particles to replace sand in concrete. The sand particles were replaced in volume of 5%, 10%, and 15% with different water-cement ratios. They investigated in their results that as the volume of PET increases for a constant water- cement ratio, the slump of the concrete decreases. PET particles having more surface area than the sand gives rise to more friction between the particles, thereby decreasing the workability of the concrete. Discussing the compressive strength, in the initial phase of replacement till 10%, strength increases to 15.26% and 17.49% with a water-cement ratio of 0.42, 0.54 respectively, but after 10%, it starts decreasing. Here also, the inter particle friction plays a vital role in strengthening the concrete. Still, in the latter stages of higher replacement level, the adhesion between the cement paste and the aggregate is not that much, thus lowering the strength. Flexural strength of the concrete was tested on beam specimen of size 500 mm x 100 mm x 100 mm. The results depicted a trend similar to compressive strength. In the initial phase, the strength increases but after that, with the replacement of 15%, the strength decreases. Split tensile strength decreases with the increment of PET volume. Apart from this, elastic modulus also decreases with the increment of the PET volume. Talking about the density of the concrete, PET particles have lower specific gravity making the concrete very lightweight. Also, the addition of PET in the concrete makes it more porous, resulting in a reduction in ultrasonic pulse velocity. One more result is given that strength of the control mix and the concrete with 10% PET replacement is the same, and the elastic modulus is reduced. It provides an important conclusion that a more ductile concrete can be obtained using PET particles. Overall, the author concluded that a 5% replacement of the fine aggregate with PET is the optimum replacement level. PET in concrete is a better solution for plastic waste management. Pervious concrete must conform to the terms of sustainability. The component of sustainability can be encouraged in pervious concrete by using materials like fly ash, waste plastics, etc. The work carried out by Abhishek et al. [03] grabs attention in this regard. This work used non-metalized waste plastic bag fiber (NMWPF) and fly ash (FA) in the concrete mix design. A total of ten design mixes were prepared out of these ten mixes. Five mixtures were prepared with OPC and NMWPF incorporation in the ratio of 0%, 0.5%, 0.75%, 1.00%, and 1.25%, whereas the other five mixes contained

80% OPC, 20% Fly ash, and the same volume fraction of NMWPF which was in the earlier mixes.

Results showed that the addition of NMWPF decreased the workability of the concrete. It is because of the hindrance to the mixing provided by plastic waste. Therefore, the superplasticizer dosage was increased to maintain the required workability. At the same time, Fly ash-based concrete reduced the superplasticizer dosage. It is because of the improved workability. The compressive strength of the plastic waste-based concrete decreased by about 35%, whereas for fly ash-based concrete, it decreased to 41.79%. Results for the flexural strength reveal that for the plastic-based concrete, it increased to 0.75% addition, and after that, it fell due to the uneven distribution of plastic waste. However, the flexural strength is more remarkable for the plastic induced concrete than for the control mix, and fly ash blended concrete did not affect the flexural strength much. Water absorption of the concrete (NMWPF based) increased to 156.61% for a1.25% volume fraction, while for concrete with fly ash, it increased to 139.61% only for the same volume of plastic fiber. In addition, fly ash-based concrete reinforced by NMWPF reflected substantially better resistance to impact and drying shrinkage because of enhanced density rather than regular OPC-based concrete. The concluding statement of the work stated that the use of NMWPF and fly ash could considerably improve the properties of porous concrete. Moreover, this combination can also be used to cater to issues related to the disposal of NMWPF and fly ash in the contemporary world.

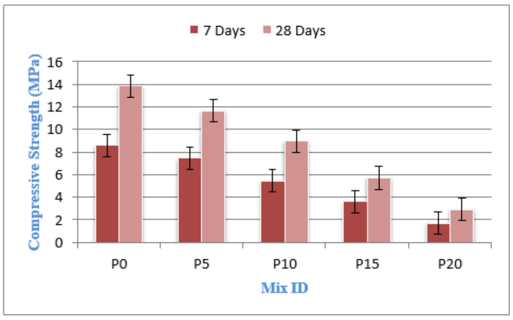
## Methodology

The whole experimental work is carried out in an organized way to achieve the study's objectives. This chapter includes all the required materials, their basic properties, and the preliminary test results of the materials. It also provides mix design, preparation, casting, curing of samples of different batches, and details of all the tests carried out on hardened concrete.

## Results and Discussions

Compressive strength of different mixes

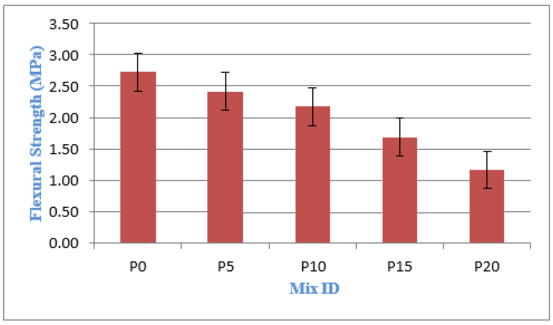
| MIX ID | Plastic (%) | 7 Days (MPa) | 28 Days (MPa) |
|---|---|---|---|
| P0 | 0 | 8.59 | 13.81 |
| P5 | 5 | 7.44 | 11.64 |
| P10 | 10 | 5.45 | 8.96 |
| P15 | 15 | 3.62 | 5.71 |
| P20 | 20 | 1.72 | 2.92 |




Compressive strength of all the concrete mixes at different plastic replacement

Flexural strength of different mixes

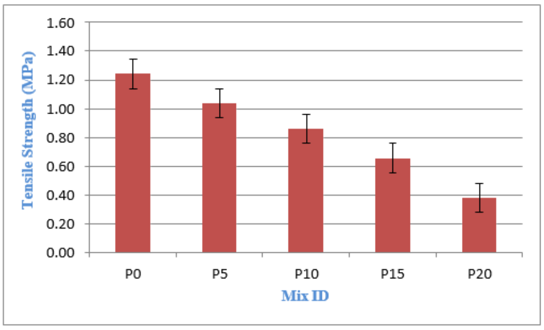
| MIX ID | Plastic (%) | Flexural Strength (MPa) |
|---|---|---|
| P0 | 0 | 2.73 |
| P5 | 5 | 2.42 |
| P10 | 10 | 2.18 |
| P15 | 15 | 1.69 |
| P20 | 20 | 1.17 |




Flexural strength of all the concrete mixes at different plastic replacement

Split tensile strength of different mixes

| MIX ID | Plastic (%) | Tensile Strength (MPa) |
|---|---|---|
| P0 | 0 | 1.24 |
| P5 | 5 | 1.04 |
| P10 | 10 | 0.86 |
| P15 | 15 | 0.66 |
| P20 | 20 | 0.38 |




Split Tensile strength of all the concrete mixes at different plastic replacement

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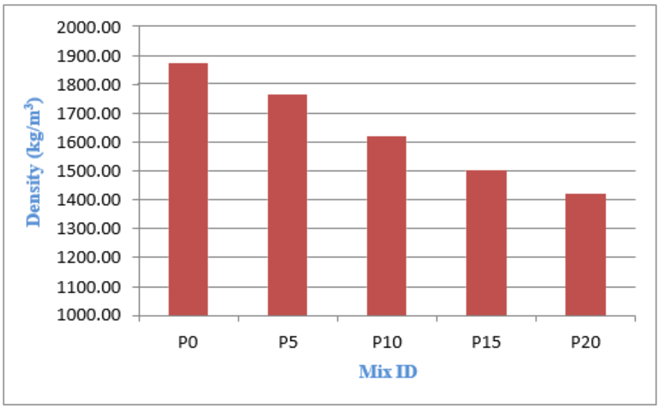
Density of different mixes

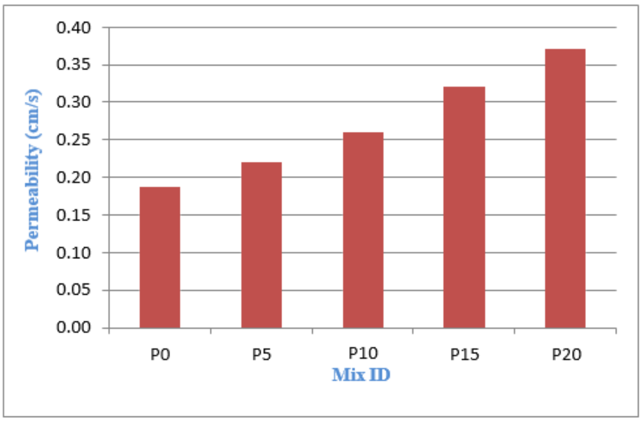
| MIX ID | Plastic (%) | Density (kg/m³) |
|---|---|---|
| P0 | 0 | 1872.10 |
| P5 | 5 | 1764.40 |
| P10 | 10 | 1621.30 |
| P15 | 15 | 1502.35 |
| P20 | 20 | 1420.05 |




**Density of different concrete mixes**

Permeability coefficients for different mixes

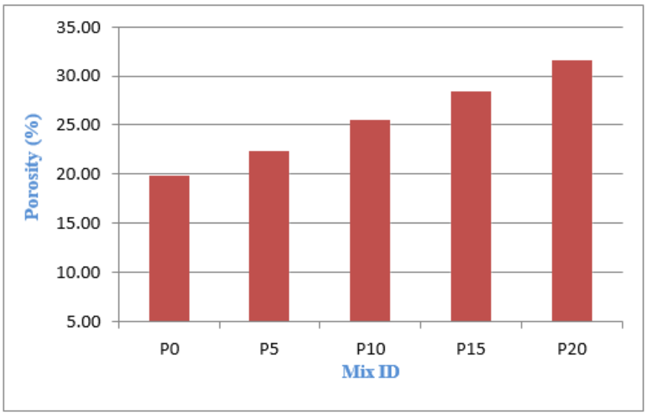
| MIX ID | Volume (mL) | Time (s) | Area (cm²) | Length (cm) | Δ h (cm) | K (cm/s) |
|---|---|---|---|---|---|---|
| P0 | 2275 | 60 | 100 | 10 | 20.2 | 0.19 |
| P5 | 2660 | 60 | 100 | 10 | 20.2 | 0.22 |
| P10 | 3150 | 60 | 100 | 10 | 20.2 | 0.26 |
| P15 | 3880 | 60 | 100 | 10 | 20.2 | 0.32 |
| P20 | 4485 | 60 | 100 | 10 | 20.2 | 0.37 |



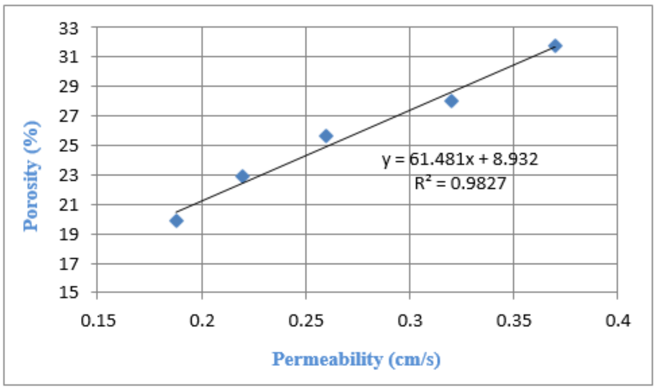

**Permeability coefficients of concrete mixes**

Porosity values of different mixes

| MIX ID | Plastic (%) | Porosity (%) |
|---|---|---|
| P0 | 0 | 19.84 |
| P5 | 5 | 22.41 |
| P10 | 10 | 25.58 |
| P15 | 15 | 28.40 |
| P20 | 20 | 31.58 |



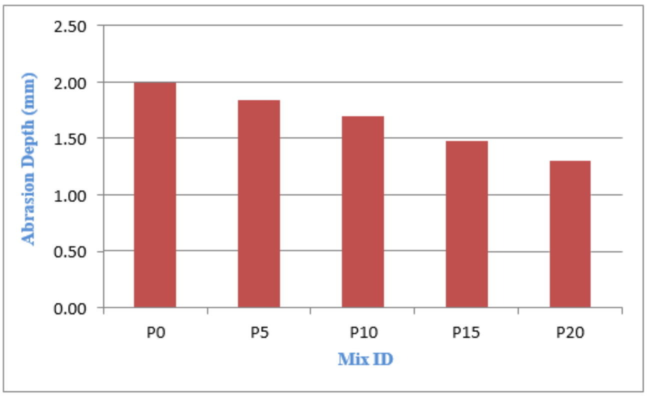

**Porosity of different concrete mixes**




**Correlation between porosity and permeability**

Depth of wear of different mixes

| MIX ID | Plastic (%) | Depth of wear (mm) |
|---|---|---|
| P0 | 0 | 1.99 |
| P5 | 5 | 1.84 |
| P10 | 10 | 1.70 |
| P15 | 15 | 1.48 |
| P20 | 20 | 1.30 |




**Abrasive resistances of different concrete mixes**

## Conclusions

This study replaces 20 mm single-sized coarse aggregates with PET waste plastic fibers. The effect of PET plastic fibers on the mechanical and hydraulic properties of porous concrete was investigated experimentally. In this regard, compressive strength, tensile strength, flexural strength, permeability, porosity, density, and abrasion resistance tests were carried out to understand the impact of plastic.

Based on different trial mixes in the initial stages of the experiment, the water-cement ratio and aggregate to binder ratio for all the batches were decided. In this experimental study, replacement of the coarse aggregate has been done to a maximum value of 20 % only. It is because beyond this value, the volume of PET becomes very large, and this much volume is not capable of forming a uniform concrete. There is no binding between aggregates and PET, and the concrete keeps on segregating itself.

So, the effect of PET as an alternative sustainable solution for the replacement of coarse aggregate can be seen in the following:

- The weaker binding of PET plastic fibers with cement paste resulted in decreased compressive strength of the porous concrete. It reduced significantly from 13.81 MPa for the control mix to 2.92 MPa at 20 % PET replacement.
- The flexural strength and split tensile strength also get reduced with the increased percentage of PET fibers in the porous concrete. The reduction in the values is more significant after the 10 % replacement level, so up to 10 % replacement, it can be efficiently used as per requirement.
- The density of pervious concrete keeps on decreasing with the addition of more volume of PET. The low specific gravity of PET fibers and porous concrete's porous nature lead to lightweight concrete confining the density values from 1872 kg/m3 (0 %) to 1421 kg/m3 (20 %).
- The inclusion of PET fibers increases the permeability of pervious concrete. The smooth surface of PET fibers provides a better pathway inside the concrete composite, resulting in a 97.14 % increment of permeability coefficients with a 20 % replacement level of PET.
- The amplification of porosity values with the increase in PET fibers volume fraction is also one of the important conclusions. The higher porosity values are within the permissible limits and are the leading cause of higher permeability coefficients.
- The porous concrete's abrasion resistance improves with the increase in PET fibers. The property of high toughness and good resistance to wear of PET results in a low depth of wear.
- Overall, it can be concluded that when water drainage is a significant concern and strength is not a matter of priority. The porous concrete with a w/c ratio of 0.34, an aggregate to binder ratio of 4.81, and a 10 % replacement of coarse aggregate with PET plastic can be considered a better choice and sustainable.

## Future Scope

Although a lot of studies have been done on the pervious concrete and the replacement of its constituents with PET, further studies can be done on its durability properties. Being pervious, it has a very large amount of porosity, and ingress of water in the concrete makes it necessary to investigate the impact of acid attack, sulphate attack, chloride penetration, etc. Further microstructure analysis of the concrete blended with PET can be carried out to understand PET's effect on mechanical and durability properties.

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