Experimental Study on Pervious Concrete with Pebbles as a Coarse Aggregate

Maheswaran. S
UG Student
Department of Civil Engineering
KPR Institute of Engineering and Technology

Nandhagopalaguhan. B
UG Student
Department of Civil Engineering
KPR Institute of Engineering and Technology

Niveditha. P
UG Student
Department of Civil Engineering
KPR Institute of Engineering and Technology

Pasupathi. K
UG Student
Department of Civil Engineering
KPR Institute of Engineering and Technology

Elango. K .S
Assistant Professor
Department of Civil Engineering
KPR Institute of Engineering and Technology, Coimbatore, Tamil Nadu

Abstract

The present study aims to evaluate the properties of pervious concrete (PC) using pebbles as coarse aggregates (CA) and Portland Pozzolana Cement (PPC) as binder. Properties such as compressive strength, split tensile strength, flexural tensile strength, coefficient of permeability, percentage of voids and dry density properties were examined and relationships between testing age vs. strength parameters and permeability parameters were drawn to evaluate the effect of pebbles aggregate in pervious concrete. Furthermore, durability studies such as salt resistance and sulphate resistance were also carried out to evaluate the chemical resistance property of PC. The results are compared with conventional control mix made of Ordinary Portland Cement (OPC) binder. The results indicated that using of pebbles as coarse aggregate shows sufficient strength, permeability and durability properties. The strength parameters and permeability parameters met the requirements and pervious concrete made with pebbles as a coarse aggregate can be used for sustainable pavement construction.

Keywords: Air voids, Dry density, Compressive strength, Permeability, Pervious Concrete, Split tensile strength

I. INTRODUCTION

Pervious concrete is a structural concrete pavement with a large volume (15 to 35 percent) of interconnected voids [1,2]. It is made from a mixture of cement, coarse aggregates, and water. However, it contains little or no sand, which results in a porous open-cell structure that water passes through readily (figure 1). Portland Pozzolana Cement is a kind of blended cement which is produced by either inter grinding of OPC clinker along with gypsum and pozzolanic materials in certain proportions or grinding the OPC clinker, gypsum and Pozzolanic materials separately and thoroughly blending them in certain proportions. Pozzolana is a natural or artificial material containing silica in a reactive form [3].

Numerous sources have affirmed how population growth, urbanization and wasteful consumption of natural resources are leading to worldwide global warming. Due to a lack of permeability in common concrete pavement, storm water cannot easily penetrate through to the ground beneath. Over the past few decades, this has resulted in increased runoff and pollution from urban storm water. Groundwater is a natural thermostat, adjusting the heat and moisture in cities and a lack of groundwater can lead to greenhouse and hot land effects. Several researchers have documented the negative impact that a lack of groundwater can have on streams. For over thirty years, in the US and Japan, pervious concrete has been used to reduce surface runoff by permitting rain water to drain into the ground. The low strength of pervious concrete limits its uses to applications, such as sidewalks, parking lots, recreation squares and as a sub-base for conventional pavement. In addition to recycling old concrete pavement, many projects have demonstrated how buildings and other structures may provide an additional resource for recycled aggregate [4].

Pervious concrete is an alternative paving material that may alleviate many of the environmental problems caused by urban runoff from developed areas. This research shows that there is a vertical distribution of porosity in slabs placed with certain placement techniques. The vertical variation of porosity can affect the strength distributions within the material and the permeability of the system and its potential for clogging. This studies indicate that for slabs approximately 15 cm (6 in.) in height and placed with an approximately 10% surface compaction technique, the porosity increases significantly from top to bottom. A series of vertical porosity distribution equations have been developed to effectively model this using the percent compaction and average cored porosities [5-8].

Using smaller sized aggregate, silica fume (SF), and super plasticizer (SP) in the previous concrete can enhance the strength of pervious concrete greatly. The pervious pavement materials that composed of a surface layer and a base layer were made. The compressive strength of the composite can reach 50 MPa and the flexural strength 6 MPa. The water penetration, abrasion resistance, and freezing and thawing durability of the materials are also very good. It can be applied to both the footpath and the vehicle road. It is an environment-friendly pavement material [9].

The effects of some factors such as gradation and particle size of aggregate, mass ratio of aggregate to cement, mass ratio of water to cement, admixtures and mixing process on the properties of porous pervious concrete including porosity, permeation coefficient and compressive strength were studied. The results indicate, gradation and particle size of aggregate, mass ratio of aggregate to cement are the key factors affecting porosity, permeation coefficient and compressive strength of PC. Mass ratio of water to cement has minor effect on properties of PC. Admixtures such as water-reducing admixture, silica fume and polymer latex improve properties of PC [10]. The mixing process of cement paste encapsulating aggregate method could improve the compressive strength of PC and reduce its porosity while keeping its permeation coefficient stable [11- 15].

Fig. 1: Pervious Concrete

II. MATERIALS AND METHODS

A. Materials

Portland Pozzolana Cement conforming to IS: 1489 (1) -1991 was used in this study. Pebbles as a coarse aggregate are obtained from sand quarry at Coimbatore, Tamilnadu and is shown in figure 2. The physical properties of coarse aggregates are presented in table 1. Mixing water used in the study satisfied the quality standards of drinking water and it was taken from KPR Institute of Engineering and Technology, Coimbatore, Tamilnadu.

Fig. 2: Pebbles

Table – 1
Properties of CA

Properties	*Results*
Specific gravity	*2.8*
Water absorption (%)	*11*
Impact value (%)	*18.25*
Crushing value (%)	*22.65*
Abrasion Value (%)	*25.86*

B. Mix Design

To prepare the mix, cement content of 400 kg/m^3 and aggregate to cement ratio of 4.75:1 was maintained. The water cement ratio was maintained as 0.34 for entire study (Uma maguesvari & her associate, 2013). Natural coarse aggregates (blue granite metal) are replaced with pebbles aggregate. Proper care was taken to maintain the workability in pervious concrete for easy and proper mixing. The typical mix proportions arrived for all the mixes and the same is exposed.

C. Testing Methods

Totally six cubes of size 150 mm were casted to study the compressive strength properties, six cylinders of size 150 mm diameter and 300 mm height were cast to find split tensile strength properties and six prism specimens of size 100 mm x 100 mm x 500 mm were cast to find flexural tensile strength at the age of 7 and 28 days. The permeability test, percentage of air voids and dry density test was determined at the age of 28 days. To evaluate the permeability of PC, falling head permeability apparatus was fabricated at concrete laboratory. Cylinder of size 150 mm diameter and 150 mm height was casted for doing permeability test and it was placed between two acrylic tubes as shown in fig. 3. The coefficient of permeability (k) was calculated using Darcy's law equation as given below,

$$k = \frac{A_1 l}{A_2 t} \log\left(\frac{h_2}{h_1}\right) \text{---------- (1)}$$

Percentage of voids and dry density properties of pervious concrete were evaluated by using cube of size of 70 mm x 70 mm. Furthermore, nine cubes of size 100 mm was cast to determine the durability properties such as salt resistance, sulphate resistance and water absorption.

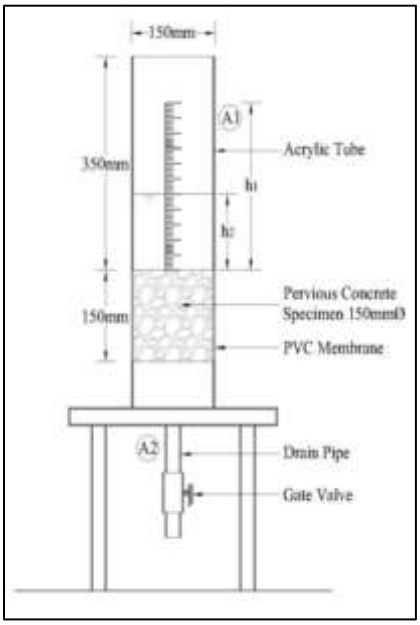

Fig. 3: Falling head permeability test setup

III. RESULTS AND DISCUSSIONS

A. Mechanical Properties

The compressive strength, split tensile strength and flexural strength test results of pervious concrete are presented in table 2 and graphically represented in figure 4-6.

Table – 2
Physical properties of pervious concrete

Age of Test (Days)	*Compressive Strength (MPa) at 28 days*		*Split tensile Strength (MPa) at 28 days*		*Flexural Strength (MPa) at 28 days*	
	OPC	*PPC*	*OPC*	*PPC*	*OPC*	*PPC*
7 days	*10.84*	*8.46*	*1.10*	*0.95*	*2.30*	*2.05*
28 days	*13.35*	*11.84*	*1.36*	*1.25*	*2.57*	*2.44*

The test results indicated that, at the age of 28 days pebble aggregate showed the compressive strength as 11.84 MPa, split tensile strength as 1.25 MPa and flexural strength as 2.44 MPa respectively. It was found that, when compared to conventional control mix, pervious concrete made of PPC binder showed 11.3% lesser compressive strength. Further, 8% reduction of split tensile strength was noticed in PPC binder pervious concrete when compared to conventional control mix. It was observed that, 5.5% decreased flexural strength in PPC binder pervious concrete when compared to control mix OPC.

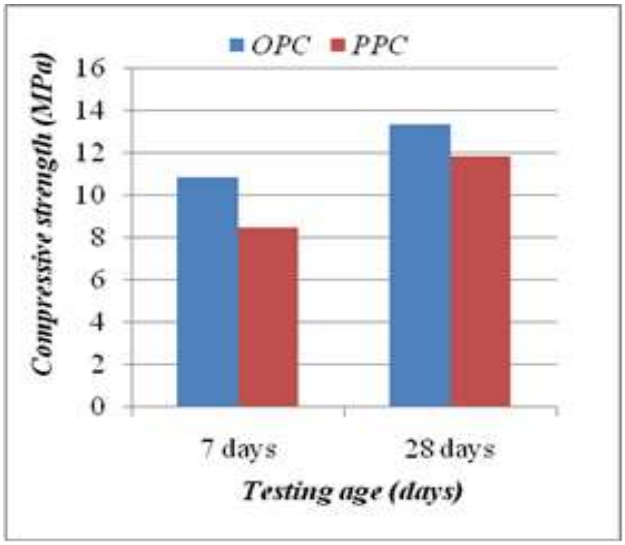

Fig. 4: Compressive strength

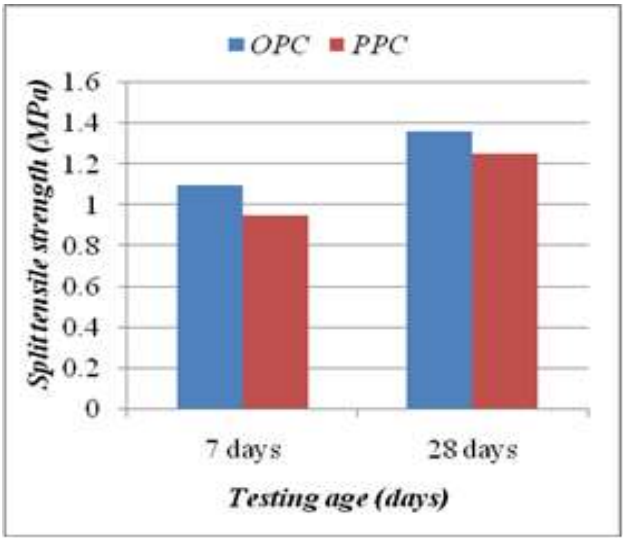

Fig. 5: Split tensile strength

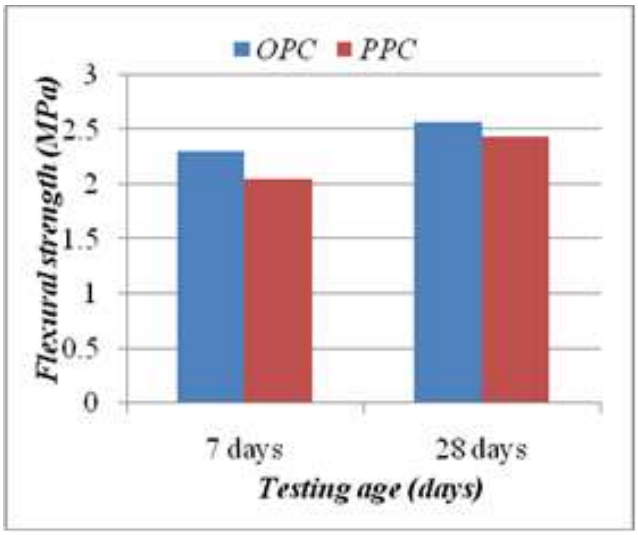

Fig. 6: Flexural strength

B. Physical Properties

The permeability, porosity and dry density test results of pervious concrete are presented in table 3.

Table - 3
Physical properties of pervious concrete

Aggregate size	*Permeability (k) at 28 days (cm/s)*		*Porosity at 28 days (%)*		*Dry density at 28 days (Kg/m^3)*	
	OPC	*PPC*	*OPC*	*PPC*	*OPC*	*PPC*
16-20 mm	*1.75*	*1.92*	*32*	*35.7*	*1850*	*1810*

From the test results, it was observed that PPC mix pervious concrete possesses 11.5% increased porosity when compared to control mix pervious concrete. Furthermore, 9.7% increased permeability was noticed in PPC mix when compared to control mix. In the case of dry density, 2.2% decreased density was observed in PPC mix when compared to control mix.

C. Durability Properties

Table 4 shows the effect of weight change and loss in strength of OPC and PPC mix pervious concrete specimens immersed in sodium chloride (NaCl) and magnesium sulplate ($MgSO_4$) solution in the concentration of 3% and 5% at the age of 28 days. Test results shows that OPC and PPC binder pervious concrete specimens shows better resistance against chemical attack. Furthermore, visual observation reveals that minor physical deterioration has occurred at the edges and slight whitish formation was appeared on the surface of the specimens. In the case of water absorption PPC specimens exhibited less water absorption when compared to conventional control mix OPC.

Table - 4
Durability properties of pervious concrete

Solution	*Weight loss (%)*		*Strength loss (%)*	
	OPC	*PPC*	*OPC*	*PPC*
NaCl	*10.5*	*9.8*	*6.9*	*5.5*
$MgSO_4$	*9.9*	*9.3*	*6.7*	*5.2*

IV. CONCLUSION

Properties such as compressive strength, split tensile strength, flexural strength, permeability, porosity dry density and chemical resistance were found and based on the test results the following conclusions can be drawn.

1) The compressive strength, split tensile strength and flexural strength of PPC mix specimens are slightly lesser than OPC mix specimens due to less heat of hydration.
2) PPC mix specimens shows higher porosity and permeability when compared to conventional control mix, whereas the density values are vice versa. This is because, greater the porosity reduces the density of the mix.
3) PPC mix specimens shows better resistance against chemical solution because pozzolanic material present in PPC results in pore refinement.
4) Pervious concrete made with pebbles as coarse aggregate results in superior permeability property due to its round shape nature.
5) Pervious concrete made with PPC as binder and pebbles as a coarse aggregate satisfies the pervious concrete requirements with adequate properties and it can be used for sustainable pavement construction.

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