ISSN (Online) 2456-1290
International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)
Vol 2, Issue 3, March 2017

Effect of Fine Aggregate on Performance of Pervious Concrete

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***Abstract:*— Due to rapid urbanization and development of smart cities, paved areas have been increased rapidly. Un-paved pervious areas are converting into impervious paved areas, which affects on many environmental factors, such as ground water table, average atmospheric temperature and green house effect, which are major current issues for environmentalists. Pervious concrete is one of the solutions to defeat this problem and research has been done by many researchers all over the world on the effective utilization of pervious concrete, especially in pavement sector. Due to complex behavior of pervious concrete, it is difficult to maintain proper balance between strength and permeability. In this paper property of hardened concrete with various percentage of fine aggregate has been determined experimentally in addition to various tests have been conducted to observe important properties, like compressive strength, density and permeability. Influence of fine aggregate on these properties is presented in this paper. As there is no approved standard method to determine permeability of pervious concrete, falling head permeability test method has been used by preparing own apparatus. Optimum strength and permeability results have been obtained on percentage of fine aggregate less than 15 percent.**

***Index Terms* - Pervious concrete, permeability, fine aggregate, compressive strength.**

I. INTRODUCTION

With the growth of smart cities and continual urbanization, cities are converting into impervious surfaces due to construction of buildings and impervious pavements. Due to lack of water permeability in the majority of pavements, the storm water is not able to percolate through these pavements. These impervious surfaces create the possibility of overloading on storm drainage system and flash flooding. With impervious surface, soil is not able to exchange heat and moisture with air and hence the temperature as well as humidity can't be adjusted. This is one of the main reasons of phenomenon of greenhouse and heat island effect.

Pervious concrete (PC) is a special type of concrete which not only posses strength but also porosity (up to 35%) through its interconnected voids present in it. PC is a mixture of cement, aggregate and a little or no fine aggregate with or without admixtures. PC has following benefits;

1. Recharge of ground water;
2. Control of pollution at source;
3. Controlling storm water runoff
4. Reducing glare on road surfaces to a great extent, especially when wet at night;
5. Reducing the interaction noise between tire and pavement;
6. Eliminating or reducing the size of storm sewer;
7. Reducing heat island effect.

For today's growing environmental demands, pervious concrete is one of the solutions, which is not only unique but also effective, especially in case of pavement application. Other than pavement application pervious concrete is also useful in many other engineering applications. Pervious concrete or no fine concrete is used in construction of floors in green houses, concrete blankets in dams, buildings walls, tennis courts and parking lots etc.

A proper selection of water-cement (w/c) ratio, even a proper balance of aggregate-cement (a/c) ratio and amount of fine aggregate is required to achieve the desired porosity and strength of pervious concrete. Many researchers have reported the properties of pervious concrete with variable water-to-cement ratio, aggregate-to-cement ratio, binder type, aggregate sizes, and compaction energy effect. A lot of research works have been done on PC to achieve a proper balance between porosity and strength for various applications in civil engineering structures.

Present work is based on the influence of fine aggregate on various properties like density, permeability and strength of PC. Samples were prepared with constant w/c ratio of 0.34 (typical range is 0.26 to 0.4) and a/c ratio of 4:1 with various percentage of fine aggregate ranges from 0% to

ISSN (Online) 2456-1290
International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)
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25%. No admixtures were used in the present study.

II. EXPERIMENT

A. Preparation of test specimens

In present study, six different concrete mixtures were prepared with different percentage of fine aggregates. For each type six cubes and three cylinders were casted, total 54 specimens were casted. Based on different percentages of fine aggregate ranging from 0% to 25% specimens were prepared on constant w/c ratio of 0.34 and a/c ratio of 4:1(Table I). Crushed basalt stone has been used as a natural aggregate (20mm IS sieve) and fine aggregate used in this investigation is river sand of grade-I, obtained from Wainganga river of Bhandara.

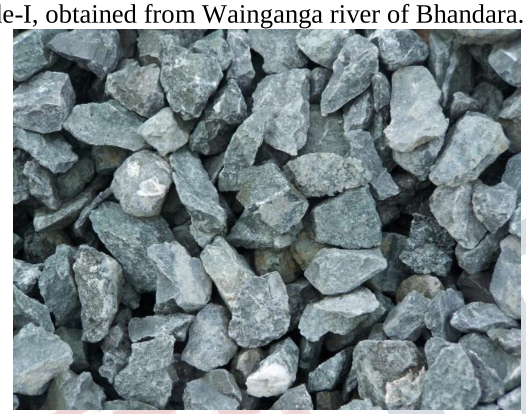

Fig.1. Aggregate.

Table I Materials Proportion.

Tag name	w/c ratio	a/c ratio	20 mm aggregate	Fine aggregate
M1	0.34	4:1	100%	0
M2	0.34	4:1	95%	5%
M3	0.34	4:1	90%	10%
M4	0.34	4:1	85%	15%
M5	0.34	4:1	80%	20%
M6	0.34	4:1	75%	25%

Fig.2. Sand.

Ordinary Portland cement (OPC) 53 grade was used in this investigation. Mixing was done using pan mixer.
Specimens from M1 to M6 were prepared (Table I) accordance with ASTM C305, the designation corresponds to concrete mixture M1 to M6.
The PC mixtures were prepared according to the following procedure: 1) as per aggregate cement ration of 4:1, mass of each item i.e. aggregate, cement and sand in required proportions were taken; 2) as per water cement ratio of 0.34 weight of water was calculated; 3) void ratio of 20% was assumed in the concrete mixture; 4) fraction of aggregate were first mixed with cement for 3min in the pan mixer; 5) water was subsequently added and mixing continued for another 5min. 6) six cubes and three cylinders were casted by providing 25blows with temping rod in three layers for each type of mix; 7) all specimens were extracted from moulds 24h after the casting and placed in a water tank for 28 days at a temperature of 20±5oC accordance with standard code.

Fig.3. Pan concrete mixer.

B. Testing of hardened concrete specimens

At 7 days and 28 days, the mechanical properties of hardened concrete were tested as per relevant code. Compressive strength, density and porosity were tested in this study. Compressive strength was tested on cube specimen of 15cm edge length with a constant rate of loading of 0.22Mpa/sec accordance with ASTM C109. Density was tested on the same specimen using the basic fundamental equation of weight to volume ratio.

Fig.4. Comperssion testing machine.

ISSN (Online) 2456-1290
International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)
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As there is no standard apparatus available for permeability test, permeability of sample was calculated from the falling head permeability test apparatus of our own. The falling head permeability apparatus is consists of a stand pipe with graduation and sample is kept at the bottom of pipe. Test sample was sealed in the apparatus and water was allowed to pass through the sample (Fig.5). Initial height from which water is allowed to fall is recorded and time of fall up to a particular height is also recorded. The coefficient of permeability is then calculated for each sample by using (1). Three different samples of same mix were used in this test and average value of coefficient of permeability is then calculated.

$$K = \left(\frac{aL}{At}\right) \ln \frac{h1}{h2} \quad (1)$$

Where, K is the coefficient of permeability, a is the cross sectional area of the water inlet pipe, L is the length of sample, A is the cross sectional area of specimen, t is the time in seconds from h1 to h2, h1 is the initial water level, and h2 is the final water level.

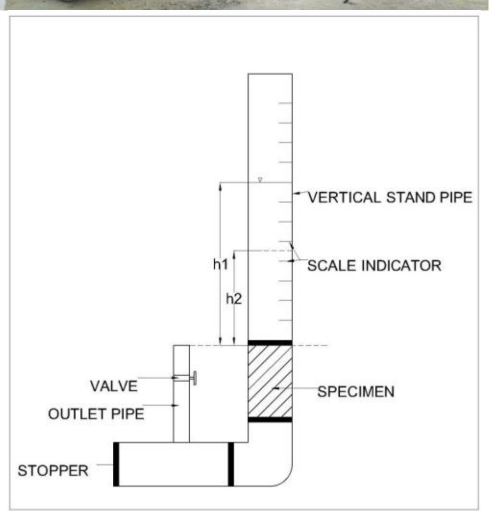

Fig.5. Permeability testing apparatus.

III. RESULTS

A. Density verses percentage fine aggregate

Density is an important characteristic of concrete, as density increases strength of the concrete also increases. Following Table II shows the effect of fine aggregate for 20mm size aggregate PC on density with constant w/c ratio of 0.34 and a/c ratio of 4:1.

Table II
Percentage fine aggregate effect on PC Density

Specimen	% Fine Agg.	w/c ratio	a/c ratio	Density in Kg/m³
M1	0%	0.34	4:1	1910.81
M2	5%	0.34	4:1	2149.83
M3	10%	0.34	4:1	2200.49
M4	15%	0.34	4:1	2299.16
M5	20%	0.34	4:1	2141.83
M6	25%	0.34	4:1	2072.69

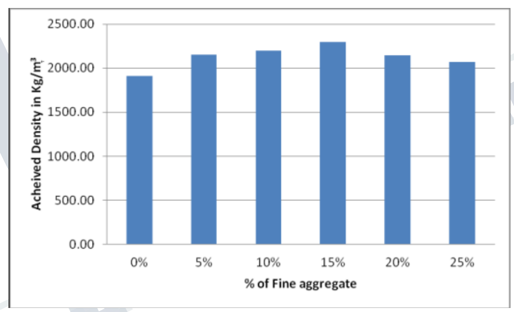

Fig.6. Percentage fine aggregate and density of PC.

B. Compressive strength

The compressive strength of the specimens was determined at the age of 7 days and 28 days. The compressive strength was determined on cube samples, three samples of each type i.e. M1 to M6 was tested accordance with ASTM C39.

Table III Percentage fine aggregate effect on 7 days compressive strength

Specimen	% Fine agg.	w/c ratio	a/c ratio	7 days Compressive Strength in Mpa
M1	0%	0.34	4:1	7.86
M2	5%	0.34	4:1	15.44
M3	10%	0.34	4:1	17.19
M4	15%	0.34	4:1	27.70
M5	20%	0.34	4:1	15.05
M6	25%	0.34	4:1	7.86

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International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)
Vol 2, Issue 3, March 2017

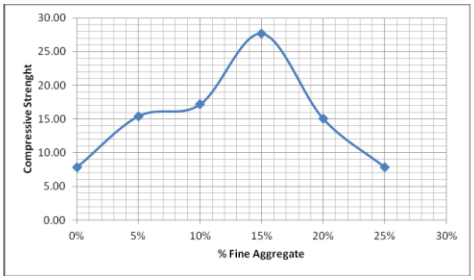

Fig.7. 7 days compressive strength.

Table IV Effect of percentage fine aggregate on 28 days compressive strength

Specimen	% Fine agg.	w/c ratio	a/c ratio	28 days Compressive Strength in Mpa
M1	0%	0.34	4:1	8.02
M2	5%	0.34	4:1	16.35
M3	10%	0.34	4:1	24.76
M4	15%	0.34	4:1	30.43
M5	20%	0.34	4:1	22.15
M6	25%	0.34	4:1	13.17

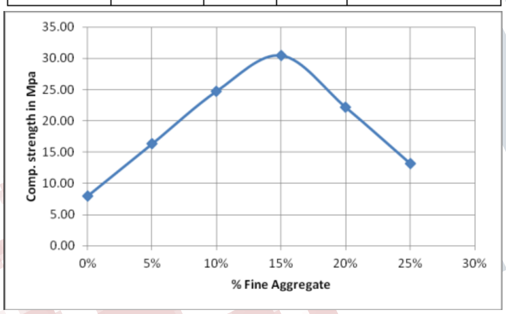

Fig.7. 28 days compressive strength.

C. Permeability

Results of permeability test of PC are shown in Table V. Pervious concrete with high percentage of fine aggregate shows high permeability value.

Table ○ Effect of percentage fine aggregate on coefficient of permeability.

Specimen	% Fine agg.	w/c ratio	a/c ratio	Permeability in mm/s
M1	0%	0.34	4:1	28.81
M2	5%	0.34	4:1	17.30
M3	10%	0.34	4:1	11.28
M4	15%	0.34	4:1	7.12
M5	20%	0.34	4:1	5.30
M6	25%	0.34	4:1	4.23

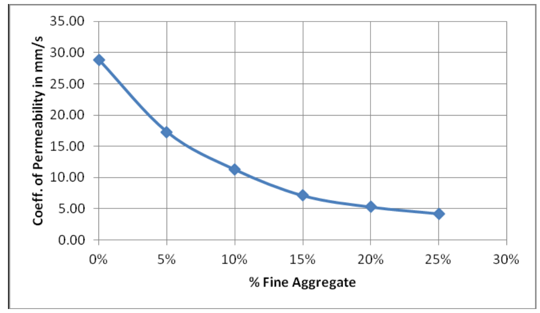

Fig.7. Coefficient of permeability.

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ISSN (Online) 2456-1290
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