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Developing Pervious Concrete by Variations in Aggregate Size & Testing of Parameters

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ABSTRACT

Pervious concrete as a paving material has seen renewed interest due to its ability to allow water to flow through itself to recharge groundwater level and minimize storm water runoff. Pervious concrete mixtures are usually prepared by single sized coarse aggregate with negligible or zero percentage of fine aggregate. Our study includes the preparation of pervious concrete samples by varying the size of coarse aggregate used. The effect of variation in size of aggregate on compressive strength is studied and compared with conventional concrete. Coefficients of permeability for each mix are calculated and compared. The results and various reasons affecting the results are discussed by graphical presentation and conclusions are drawn.

Keywords: *Coefficient of Permeability, Compressive Strength, Pervious Concrete, Variation in Aggregate Size, Voids Ratio*

I. INTRODUCTION

In recent times, climate change is a huge problem. One of the effect of climate change is, major cities around the world are experiencing frequent flooding. The climate around the world is also changing due to increased urbanization, replacement of pervious natural surfaces and vegetation are being rapidly replaced with impervious materials such as pavements and structures which lead to an increase in runoff and pollution. As a result, the drainage system gets overloaded causing disruption to the road transport and flooding of basement parking. While constructing any project engineer should not only consider the economics of the project but also impact on the human and natural environment. Pervious concrete is also named as porous concrete or permeable concrete.

Fig. 1 Pervious Concrete

Pervious concrete has been gaining a lot of attention in recent years due to its various environmental benefits which include controlling storm water runoff, restoring groundwater supplies. It can be used for the construction of parking lots, low-volume roads, walkways, driveways, sidewalks and swimming pool decks. The permeability of the pervious concrete signifies its capacity to drain the ponding water from the concrete surface. The demonstration of drainage through pervious concrete is shown in Fig.1. The pervious concrete pavements also serve the purpose of reducing noise pollution to some extent so they are sometimes referred to as 'low-noise road surfaces'. The proper utilization of pervious concrete is a recognized Best Management Practice by the U.S. Environmental Protection Agency (EPA) for providing storm water management and suitable development. It is also recognized by United States Green Building Council (USGBC), which sets the green building rating system known as the LEED program (The Leadership in Energy and Environmental Design).

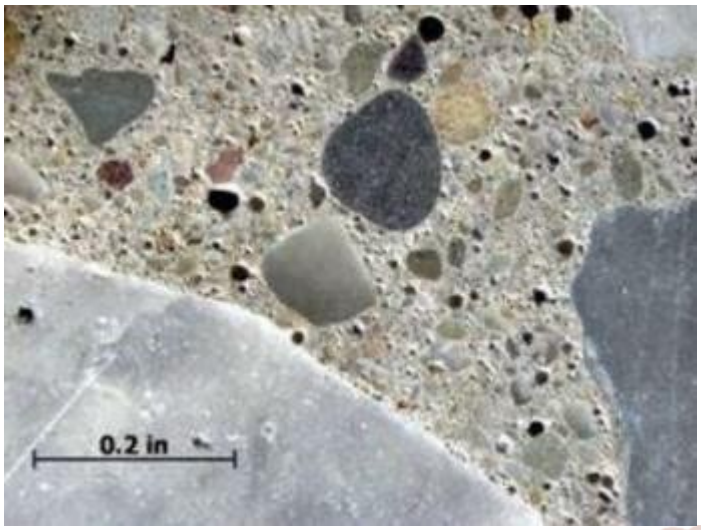


Fig.2 Conventional Concrete

Fig.2 Pervious Concrete

Pervious concrete can be produced using conventional concrete-making material such as cement, supplementary cementations materials, admixtures, single sized coarse aggregate, very little or no fine aggregates, and water [1]. Because pervious concrete contains little or no fine aggregates it is also referred to as 'no-fines concrete'. The lack of sand in pervious concrete results in a very harsh mix with a rough textured, and a honeycombed surface. Fig. 2 shows the microscopic view of the conventional concrete and Fig. 3 represents the pervious concrete in which the absence of sand has led to formation of voids. Use of small amount of sand can be proportionally improve the compressive strength but air void content will be reduced and permeability lowered.

The sized aggregate are bonded together by a paste formed by the cement and water. It is important to maintain the proper volume of paste in the mix design so that the aggregate is equally coated but the excess of paste should not fill the void space within coarse aggregate. Therefore a lower water-cement ratio between 0.26 and 0.5 is regulated to create channels through which water can freely flow [2]. Coarse aggregate sizes suggested for pervious concrete range from 9.5 to 19 mm [2]. To achieve the permeability pervious concrete can be designed such that mutually connected voids account for 15 to 35 % of the total hardened concrete volume [2]. As a result of this composition, pervious concrete made without additives has a relatively low compressive strength varying from 2.8 to 28 MPa [2]. To avoid the formation of cement paste lower water-cement ratio between 0.26 and 0.50 has been suggested [2].

II. OBJECTIVES

In this paper the effect on compressive strength and permeability of pervious concrete is studied by varying the size of coarse aggregate used. The different size of aggregates used are 10 mm, 13 mm, 16 mm. Eight number cubes of 150 × 150 × 150 mm are prepared for each aggregate size. Six samples of readings for each compressive strength test and permeability are recorded. The results obtained are compared with each other and the various reasons affecting the results are studied. One slab model of 450 mm × 450 mm is prepared for each size of aggregate.

III. EXPERIMENTS

1. Materials and Equipment Specifications

- Standard aggregate with specific gravity 2.97, available for regular construction works were used.
- Ordinary Portland cement specific gravity 3.15, of 53 grade was used.
- Portable water is used for preparation of mixture and curing.
- No admixtures and fine aggregates were used.
- Curing is performed in the curing tank.
- Concrete mixture is mixed in the rotating mechanical mixture.
- Cubical size metallic moulds of 150 mm are used for test cubes.
- Wooden mould is used for casting of model.
- Steel tamping rod of16mm diameter 0.6m long along with bullet ends used for tamping.
- Universal testing machine (1000KN) is used for testing compressive strength.

2. Mix Design and Preparation of Mix

Proportions of pervious concrete mixture are done to produce concrete having adequate workability, strength, permeability and void ratio. Aggregate content is usually around 1200 kg/m^3 to 1800 kg/m^3 [3]. The water-cement ratio is also prescribed in the range of 0.26 and 0.5 [2]. In earlier studies the mix design with aggregate and cement ratio of 3 was found to have the maximum strength [4].

The following contents of materials were used for the M30 mix of the pervious concrete.

Table 1 Contents of the constituents per cubic meter

Constituent element	Content
Cement	394 Kg/m^3
Aggregate	1168 Kg/m^3
Water	197 Kg/m^3

Water-cement ratio of 0.35
Aggregate-cement ratio of 3
i.e. 1:0:3 with 0.35 w/c

Weight batching is used for proportionating the quantities of materials. The mechanical mixer was used. Initially the dry constituents were mixed for 2 minutes. After gradual addition of water the wet mixture was mixed for minimum 4 minutes and until the homogenous mixture is obtained.

Table 2 Pervious concrete mix and the aggregate size used

Name of the mix	Aggregate size used
L	16 mm
M	13 mm
S	10 mm

3. Casting and Curing

The prepared mix is poured into the mould and light tamping is done so as to maintain the void content in the concrete and achieve the required strength. After 24 hours of casting. The sample is kept into curing tank for 28 days curing.

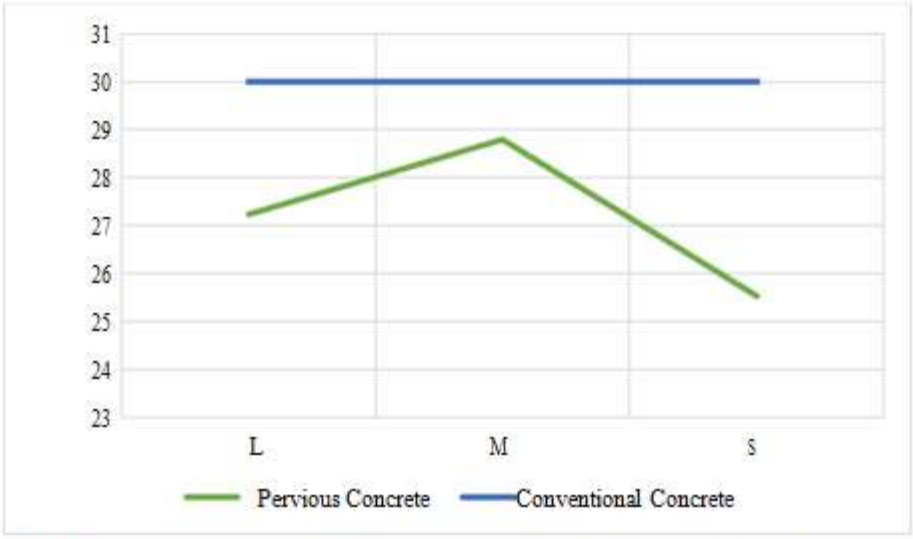
4. Testing

Compressive Strength and Permeability of the pervious concrete are the parameters under study in this paper.

4.1 Compressive Strength Test

6 cubes of each type of concrete mix were tested for compressive strength after 28 days of curing in the curing tank. The compressive strength tests were performed on the universal testing machine available in the college. The cubes are placed on universal testing machine such that the cast surfaces are in contact with the platens of the machine i.e. in the right angled position to that of casting. The compressive load on the cube should be applied at the constant rate between 0.2 to 0.4 MPa/sec [5]. Table 3 presents the average value of compressive strength recorded for each type of mix. All the tests were performed according to IS 516:1959. Table 3 Compressive strength of each mix

Mix	Compressive Strength
L	27.23 MPa
M	28.80 MPa
S	25.53 MPa
Conventional Concrete	30 MPa



Graph 1 Relation between compressive strengths of various mix used and conventional impervious concrete

The failure pattern of cube is observed and results of compressive strength of Pervious Concrete cube are presented in chapter below.

4.2 Permeability Test

6 permeability tests were performed on 2 cubes for each type of the mix. The permeability test was performed on the 27th day of the casting [6]. Table 4 presents the average value of coefficient of permeability for each type of mix. All the tests were performed according to IS 516:1959.

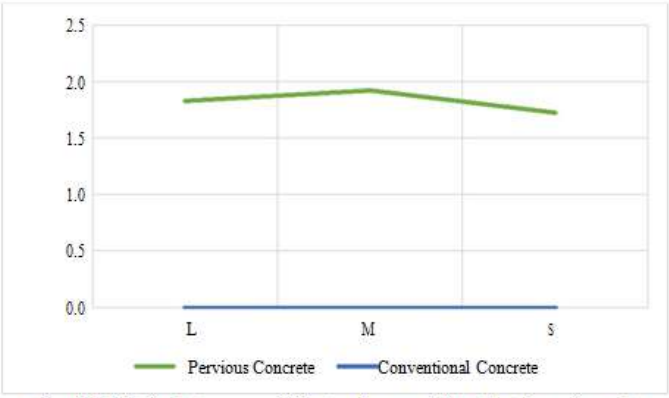
Coefficient of permeability can be calculated by the formula stated below [7, 8].

$$k = \frac{a.L}{A.t} . log_e \left(\frac{h_1}{h_2}\right)$$

where, a → cross-sectional area of standpipe
L → length of the sample
A → cross-sectional area of the specimen
t → time for water to drop from h1 to h2

Table 4 Coefficient of permeability of each mix

Mix	Coefficient of Permeability
L	1.83 cm/sec
M	1.92 cm/sec
S	1.73 cm/sec
T	0



Graph 2 Relation between coefficients of permeability of various mix used

IV. FUTURE SCOPES

Only coarse aggregates were used in this study. Future studies can be performed on improvement of compressive strength of pervious concrete by adding various percentages of sand. But it should be noted that increase in content of fine aggregate will reduce the permeability of pervious concrete.

V. CONCLUSIONS

After the study of the pervious concrete pavement we can conclude that pervious concrete pavements are suitable to reduce the storm water runoff, to increase the ground water level, to eliminate the costly storm water management practices. The above experimental work included the compressive strength tests and permeability tests for varying size of aggregate. We can conclude that maximum compressive strength of 28.8 MPa is achieved for the mix consisting of 13 mm aggregates. 16 mm aggregate has a slightly less strength as there are more number of voids generated

due to bigger aggregate size. The compressive strength of mix having aggregate size 10mm has the least compressive strength among the 3 samples. Highest compressive strength of pervious concrete can be achieved by using optimum size of aggregate.

The permeability of the concrete with 13 mm aggregate is found to be highest due to the optimum balance between number and size of voids and the aggregate size. The coefficient of permeability in this case was found to be 1.92 cm/sec. The concrete sample with larger 16 mm aggregate develops the slurry of cement at the bottom which slightly reduces the permeability. Due to smaller size aggregates the pores will be of smaller size and lesser interconnectivity, as a result the concrete mix with 10 mm size aggregate has the least coefficient of permeability.

Pervious concrete pavements are extensively used worldwide these days because of their environmental benefits, hydraulic and durability properties. Optimum size of aggregate can be used to achieve the maximum strength and permeability parameters of pervious concrete. Thus economy in design and most efficient use of resources can be achieved.

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