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Effect of Aggregate Size on the Percolation Rate of Water through Permeable Concrete

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Abstract: *Permeable Concrete is a special type of Concrete having high water permeability in comparison to ordinary concrete. This type of concrete is mainly used for draining water from the ground surface, so that storm water runoff is reduced, and the ground water is recharged. The rate of permeability depends on various factors and aggregate size and grading is one of such key factors. In this study concrete cubes have been considered with different sizes of coarse aggregates ranging from 12-16mm, 12-10mm and 10-4.75mm down and then a comparison is made to select the suitable size of aggregate for better permeability. From the experimental result it has been obtained that concrete cube having 12-16mm size aggregates have higher permeability capability in comparison to the other two cases.*

Key words: Pervious Pavement, Aggregate, Cement-Aggregate Ratio, Compressive Strength, Percolation.

1. INTRODUCTION

Permeable concrete also known as no-fines or pervious concrete is a special type of concrete having the unique property of high porosity, hence considered as a good option for ground water recharge. It allows water from precipitation and other sources to pass directly through, thereby reducing the runoff from a site and allowing groundwater recharge.

Fig-1: Permeable Concrete Block[11, 12]

Initially studies related with the permeable concrete have been conducted approximately 50 years ago in the United Kingdom, United States, China and Japan[2]. But nowadays studies have been conducted across the globe and is becoming very popular in many countries like Scotland, England, Japan, etc. Permeable Concrete was first used in Europe in 1800s as pavement surfacing and load bearing walls. It again become popular in 1920s in England and Scotland for two storey houses. Even after World War-II, due to scarcity of cement, it gained more popularity. But its main utilization was made by the U.S. Environmental Protection Agency (EPA) for providing first flush pollution control and stormwater management. Even in India it is also gaining popularity after the year 2000[3]. Pervious Pavement i.e., road pavement made with Permeable Concrete is also very popular nowadays as the open cell structure of this concrete allow storm water to filter through the pavement and into the underlying soils[1]. As per Water Environment Research Foundation 2015, the Pervious Concrete Pavement has been recognized as one of the methods for allowing the rainwater to percolate in the soil below, recharge of the ground water aquifers, reducing the volume of direct water runoff from pavement and thus enhancing the quality of the storm water. As per ACI 522R-06[4], Permeable Concrete also known as Pervious Concrete consisting of Cement, Coarse Aggregate, Water, little or no-fine aggregate and admixture if properly mixed, placed, compacted and cured will produce a hardened material having permeability of 81 to 730 L/min/sec[2] and a moderate strength of 2.8 to 28 Mpa and durability. The drainage rate of this concrete varies with aggregate size and density of the mixture.

Fig-2 : Pervious Concrete Pavement[12]

The Famous "Sponge City" model of China is also based on the usage of Permeable Concrete. The sponge city is a construction model of urban areas for solving problems like waterlogging, water resources shortage, drainage problems and thus to improve the ecological environment and biodiversity by absorbing and capturing rain water[5].

The basic difference between Conventional Concrete and Permeable Concrete is that it doesn't contain any sand or very less amount sand. Because of absence of Sand particles, the voids between the coarse aggregate allows water to pass through it and hence making the concrete a Pervious one. Another aspect of difference is its compressive strength and its application. Permeable Concrete has less compressive strength than Conventional Concrete hence its application is limited to low traffic density areas like parking lot, sidewalks, low volume roads etc. where it provides a rigid structural surface to serve the basic structural functions and allow water to pass through it[6].

Compressive strength of concrete is an important factor which is generally affected by Proper Mix design, W/C ratio, aggregate-binding ratio, casting and compacting process, Curing conditions, etc. For a Permeable Concrete, it has been found in a study that, is compressive strength generally varies between 5 to 30 MPa[7,2]. In an experimental study it was found that with the decrease in W/C ratio, the Compressive Strength and Unit Weight of Permeable concrete increases but their permeability property decreases. But however, with the increase in coarse aggregate content, a reduction in the unit weight of the concrete mixture as well as increase in the void ratio and permeability was observed[8]. Neptune et. al[9]. claimed that there is an inverse relationship between permeability and strength properties of the Permeable Concrete. As per a research study it was found that Unit weight of Permeable concrete is approximately 70% of Conventional Concrete[1]. Many researches are presently going on across the globe to obtain an ideal Permeable Concrete without affecting its Compressive Strength.

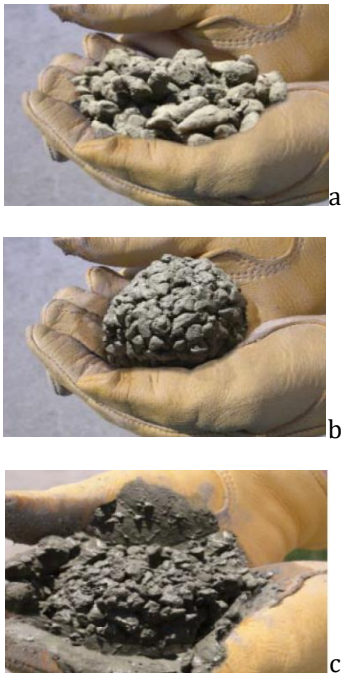

Fig-3 : Workability Assessment of Permeable Concrete Manually[12]

a: Too less water added b: Proper Amount of Water added c: Too much water added

Apart from the Compressive Strength, another important factor of a Permeable Concrete is the time required for complete drainage of water through the pores present in it or in simple the permeable capacity of the concrete. There are many factors on which this capacity depends, and aggregate size is one such important factor. S.O. Ajamu et al.[1] conducted an experimental study with aggregate size of 3/4" and 3/8" with Aggregate/Cement (A/C) ratios of 6:1, 8:1 and 10:1. Author conducted the falling head permeability test to calculate the coefficient of Permeability (K) value and it was found that aggregate size of 3/4" is having higher K value than 3/8" aggregate size.

2. EXPERIMENTAL PROCEDURE

All the Preliminary experiments of Cement and Coarse Aggregate was initially conducted in the lab like Consistency Test of Cement, Initial and Final setting time of Cement, Sieve Analysis of Coarse Aggregate, Fineness of Cement, Compressive strength of cement, etc.

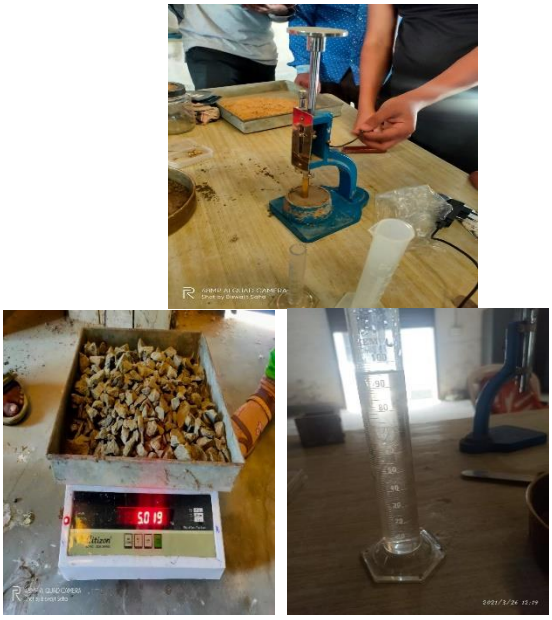

Fig-4 : Preliminary Experiments of Materials

With the results obtained from the preliminary experiments, a typical Mix design of grade M35 concrete was done in accordance with the IS 10262:2009; considering Specific Gravity of Cement to be 3 and Coarse Aggregate to be 2.78. Locally available PSC cement was considered for the experiment. No sand and admixture were considered, and all the experiments were conducted in the room temperature.

Table -1: Proportions of Materials used in experiment

Sl. No.	Materials	Proportions
1	Cement: Fine Aggregate: Coarse Aggregate	1:0:3.35
2	Water-Cement Ratio	0.32
3	Admixture	Nil

The Value of Water-Cement ratio and aggregate size has been considered as per American Concrete Institute (ACI) 522R-10[10]. As per ACI, Water-Cement ratio should range between 0.26 to 0.40 and aggregates should be rounded and crushed. It should be either single sized or grading between 3/4 to 3/8 inch. In this work, we have considered coarse aggregate of three different sizes 16-12mm, 12-10mm and 10-4.75mm. Three samples of Concrete cubes of size 150 x 150 x 150 mm were made with the results obtained from mix design. Sample-1 Concrete Cube having coarse aggregate of 16-12 mm size, Sample-2 Concrete Cube having coarse aggregate of 12-10mm and Sample-3 Concrete Cube having coarse aggregate of 10-4.75mm size. Rest parameters are same for all the three cubes.


a.
b.
c.

Fig-5: Permeable Concrete Cubes

a: 16-12mm aggregate used, b : 12-10mm aggregate used, c : 10-4.75mm aggregate used

After the materials were properly mix, placed inside the cube and compacted and were cured for 7 days inside the water, the cubes were left in open atmosphere for 1 day to make the surface dry. A random 200ml of water was poured above all the sample of cubes.

Fig-6: Arrangement of Supply of Water in the Concrete Cube

The head and rate of flow of water above the cubes were kept constant with some small arrangements using a stand and perforated bottle. Total time for the water to completely percolate through the concrete cube was recorded with the stopwatch.

3. RESULTS & DISCUSSION

Table -2: Final Calculation of Time of Water Percolation

Sample Name	Aggregate Size	Size of Permeable Concrete Cube	Amount of Water Supplied	Time Required for Percolation
Sample-1	16-12mm down mix	150x150x150 mm	200 ml	27.13 sec
Sample-2	12-10mm down mix	150x150x150 mm	200 ml	40.12 sec
Sample-3	10-4.75mm down mix	150x150x150 mm	200 ml	58.90 sec

After conducting the experiment, it was found that the time required for 200ml of water to pass through a 150 x 150 x 150mm cube completely is 27.13 sec for Sample-1 Concrete Cube having aggregate size 16-12mm, 40.12 sec for Sample-2 Concrete Cube having aggregate size 12-10mm and 58.90 sec for Sample-3 Concrete Cube having aggregate size of 10-4.75mm.

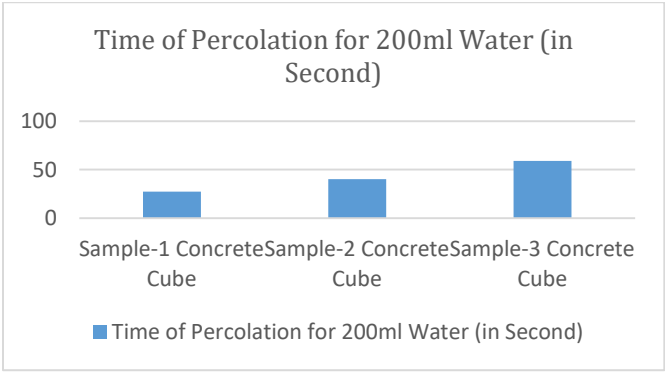

Fig- 7: Graphical Representation of Time of Water Percolation through different Concrete cube samples

Thus, from the result obtained it is clearly seen that concrete cube having aggregate size of 16-12mm takes minimum time for the water to pass through it completely and concrete cube having aggregate size of 10-4.75mm takes maximum time for the water to pass through it. If more time is taken for complete percolation of water through the concrete surface, it will create problems of water logging, hence our focus should be on quick percolation of water through concrete surface. In all the three Permeable Concrete Cube Samples some minimal amount of water might remain on the inner surface of the aggregates while the water percolates through the cubes.

4. CONCLUSION

As per the result obtained, it can be concluded that large size aggregate allows water to quickly get permeable in comparison to smaller size aggregates. In our work concrete cubes with aggregate size 16-12mm will allow water to permeable quickly in comparison to concrete cubes having aggregate size of 12-10mm and 10-4.75mm. As water logging is a serious issue, hence more quickly the water passes through the concrete, lesser will be chances of water logging. Apart from the aggregate size, there are other parameters also like aggregate shape, C/A ratio, chemical admixtures etc. on which the percolation rate of water depends. Many researches are going on various aspects of Permeable Concrete as it has various advantages specially from environment point of view. Metro Cities of India like Kolkata, Mumbai, etc. has a serious problem of water logging in the monsoon season due to lack of proper drainage system and other geographical factors. Just like Sponge City concept of China, this concrete can be used in low traffic roads and parking lots also. As Permeable Concrete do not possess high strength, hence more research has to be made in this area to increase its strength parameters. Furthermore, in this experiment work, the cubes can be tested for Compressive Strength and Flexural Strength result also and make a comparative study.

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