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A COMPARATIVE STUDY ON PERVIOUS CONCRETE AND A WAY TO REDUCE ITS PERMEABILITY

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ABSTRACT

Pervious concrete (PC) is a highly porous concrete and one of the measures invented to address the environment related concerns like runoff and flash flood. Despite having many advantages, a concrete with a high void content can also be unfavorable when it comes to strength and serviceability requirements. For instance, when the fine aggregate gets washed down during a construction, a PC is formed instead of a conventional concrete (CC) and exhibits undesirable characteristics of a PC such as allowing seepage of water through the structure thereby deteriorating the reinforcements. This study presents a research programmed to evaluate the effect of decreasing the permeability of a PC with cement grout injection and compare the results with that of a PC without grout injection. Later, setting the reference concrete as the CC, these results were compared with it to identify the extent of improvement. The results obtained indicated that the void content and permeability were reduced (5.98% vs. 4.43% and 3.96mm/s vs. 1.99mm/s respectively) in the PC samples. Also, it was observed that these reduced parameters were still higher than that of the CC (3.41% and 0.73mm/sec). The study thus represents a probability of reducing the voids in a faulty concrete without having to reconstruct.

Keywords: *Pervious concrete, Grout injection, Permeability, Falling head permeability.*

1. INTRODUCTION

One of the unabating problems in concrete construction is the inadequate serviceability which often arises due to poor workmanship on site. Such a concrete, affected by improper workmanship and supervision, is termed as a poor quality or faulty concrete (Femi, 2014). A concrete is termed as a good or poor-quality basing on its performance and serviceability characteristics (Alam, Habib, Sheikh & Hasan, 2014). Water ingression in potentially vulnerable structures like swimming pool and basement is one of the performance issues regarding poor workmanship. Due to lack of proper proportioning and compaction by the workforce, voids, much greater than the maximum allowable of 4.5% (NPCA, 2012), are found to weaken the performance criteria as well as the serviceability (Barnes, 2013). A typical example of insufficient supervision is the formation of a highly porous concrete mix formed when the fine aggregates (FA) get washed down by rain on site. During such cases a structure becomes prone to water leakage by the permeable voids present in it and it is this fault that reduces service life of the structure as water moves in to deteriorate the reinforcement.

To reduce permeable voids in a structure by keeping it in functional stage is quite challenging and till date no such research has been made. In this paper such a case is studied and the porosity of a highly porous concrete is reduced by injecting cement grout into the hardened concrete.

In order to simulate a faulty concrete where water ingression remains a severe problem, three types of pervious concrete (PC) mix designs were prepared having different FA contents, namely 0%, 10% and 20% of the total aggregate. The aim of this study is to compare the rate of permeability, measured through Falling Head Method (FHM), of each of the PC samples with that of the CC samples. Later on, the PC samples were treated with cement grout injection and again tested for the rate of permeability to identify the degree of improvement.

2. METHODOLOGY

ASTM Type I Ordinary Portland Cement (OPC) was used as the binding material. The water to cement ratio (w/c) was kept to a constant of 0.4 throughout the study. Natural crushed stone as coarse aggregate complying to grading requirements by ASTM C33 (2018) size 67 (19.00 to 9.5mm) range and Sylhet sand as fine aggregate having a fineness modulus of 3.2 were used.

The PC samples were prepared according to ACI 211.3R-02 (2011) following a design void content of 15% which allows to maintain a minimum percolation rate of 0 inches per minute and consequently higher compressive strength. The CC samples were proportioned following ACI 211.1-91 (2002) specifications. Both the PC and CC were designed for a target strength of 3000 psi, Mix proportions of the various designs used in the study are summarized in Table 1 where PC0F=0% FA, PC10F=10% FA and PC20F= 20% FA. The conventional concrete is designated as NAC. The aggregates were used in saturated surface dry condition. The mix designs were used to cast cylinders having a diameter and height of 4 inch and 8 inches respectively. The casting was done according to ASTM C192 standard specifications (2016).

Table 1: Mix proportioning of concrete for 1.00 m^3

Sample	**w/c ratio**	**Deign void content (%)**	**Mass of Cement (kg)**	**Mass of Water (kg)**	**Mass of Coarse Aggregate (kg)**	**Mass of Fine Aggregate (kg)**
PC0F	0.4	15	362.4	145	1567	0
PC10F	0.4	15	334.5	133.8	1472	145
PC20F	0.4	15	292.7	117.1	1361	301
NAC	0.4	-	475	190	1005	626

Permeability of the hardened concrete samples aged at 28 days was measured using the FHM. The gap between the inner surface of the apparatus and concrete sample was filled so that movement of water was confined in the vertical direction only. The samples were saturated before the test in order to get rid of the air trapped inside the voids. The time t required by the water column to fall through a specified height was recorded and the rate of permeability K was determined using the equation (1) below derived from Darcy's law. Void content analysis was made on samples after 28 days of casting according to ASTM C642 (2013).

$$K = \frac{A_1 l}{A_2 t} \log\left(\frac{h_2}{h_1}\right) \tag{1}$$

The equation (1) uses cross-sectional areas of the sample and the tube as A1 and A2 respectively and the initial and final height of the water column in the graduated cylinder as h1 and h2 respectively. The length of the sample here is denoted as l. Figure 1 represents the apparatus used for this test.

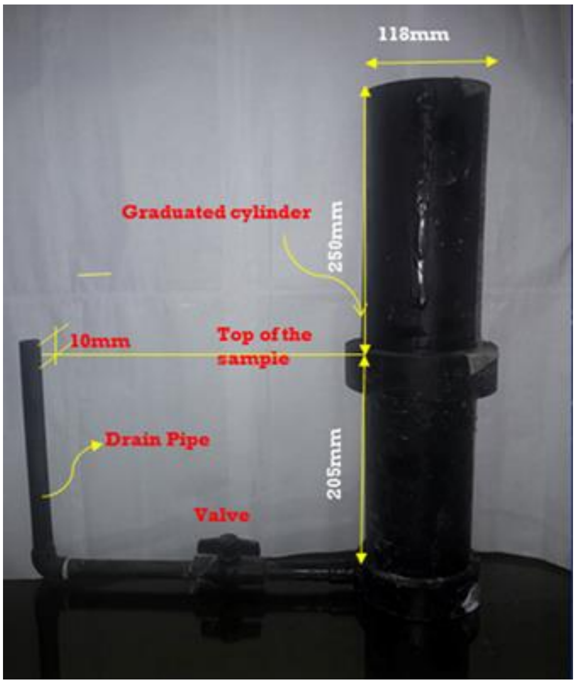

Figure 1 Falling Head Permeability Apparatus

To render the PC samples semi-pervious, the cylinders were injected with cement grout having a w/c ratio of 0.5. Before commencing the task, surface of the cylinders was cleaned to remove the adhering dust and impurities and applied two coats of a waterproofing solution: Nitobond EP, to seal the outer surface in order to contain the grout inside. Nitobond EP is a two-component solvent-free epoxy resin as a concrete bonding agent from FOSROC complying with ASTM C881 standards. This resin is basically used for binding wet cement with existing concrete surfaces and is found to be an excellent sealant to stop fluids inside from percolating out of the concrete. The cement grout was then injected in the PC samples with the help of a dual cartridge gun.

3. RESULTS AND DISCUSSIONS

A comparison made on compressive strengths of the PC samples represented (Fig. 2) indicates that there appears no particular trend in gaining or loosing compressive strength in the grout injected samples. However, there is a trend within the untreated samples showing that as the percentage of fines increased so did the compressive strength. The cement flows in to fill the voids in the fresh state but once it hardens it shrinks and does not form the required bond with the honeycombed matrix. This refers to the fact that cement grout did not impart any notable changes in strength of the PC samples.

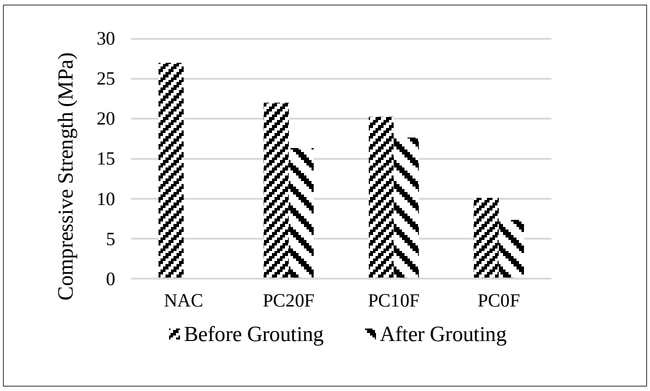

Figure 2: Effect of cement grout injection on compressive strength of PC samples

The following figures 3 and 4 represent the results obtained for the rate of permeability tested on samples before and after grout injection. It shows that, before the samples were injected, both the rate of permeability and void content is highest in PC0F and lowest in NAC. The results are then compared with that of PC samples injected with cement grout and it is seen that the rate of permeability decreased to about 50% in PC10F and 38% in PC20F whereas the void content reduced by 26% in PC10F and 4% for PC20F. PC0F samples were too delicate as there was inadequate bond due to having no fine particles to provide the bulk and so pressure grouting was not attainable.

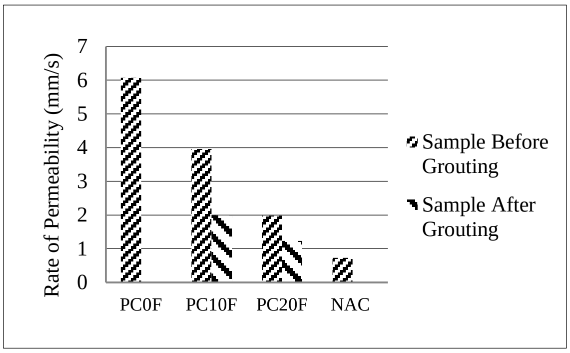

Figure 3: Rate of permeability in PC and CC samples

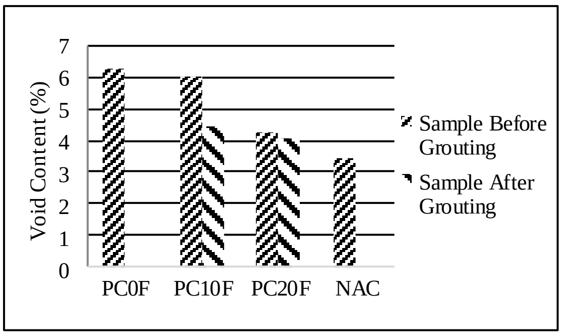

Figure 4: Void content in PC and CC samples

Hence it can be inferred that the void content and rate of permeability decreases with the increase in amount of fine aggregate in the mix. Inclusion of cement grout within the porous structure of PC samples did reduce the permeability and percentage of void content but it is still no match for the parameters that was found in the case of CC samples.

4. CONCLUSIONS

In this paper, effects of cement grout injection in a faulty concrete, as signified by its high porosity, is studied. Faulty concrete is modeled here as PC [Alam, #16]and the probability of a low cost renovation technique is evaluated. Three different mix designs were incorporated for the PC test specimens. Tests were carried out and changes in physical properties (compressive strength, rate of permeability and void content) of the samples were noted. A falling head apparatus was fabricated specifically for this research. Further, the properties tested for both grouted and un-grouted samples were compared with that of a control specimen (CC).

The results of this study conclude that when percentage of fine aggregate in the PC was lowest (0% of the total aggregate), both void content and rate of permeability was the highest and lowest when fine aggregate content was greatest (20% of the total aggregate). The cement grout injection facilitated a decrease of void content and permeability in the PC samples. These findings, when compared with that of the control specimen (CC), helped to identify the extent of reduction in voids and permeability in the grout injected PC samples.

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