PERFORMANCE STUDY ON NO FINES CONCRETE

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ABSTRACT

In this study an attempt has been made to improve the performance of no fines concrete in terms of compressive strength, porosity and permeability. The effect of aggregate gradation and use of fine aggregate in the mix proportion was also studied to evaluate the performance. Cylinders of 4"×8" sizes were investigated for 28 days compressive strength and constant head water permeability test for selecting suitable type of gradation. The well graded sample was found suitable among the types of gradation. After that 0%, 2%, 4%, 6%, 8% and 10% fine aggregate (sand) was added in the well graded sample having water/cement ratio and aggregate/cement ratio as 0.40 and 4.5:1, respectively. Again cylinders of 4"×8" sizes were investigated for 28 days compressive strength and constant head water permeability test to examine the performance of no fines concrete. The compressive strength, water permeability and porosity were found to be varied from 6 to 14 MPa, 10.51 to 1.45 mm/s and 5.26to 26.89%, respectively. It was found that the addition of fine aggregate (sand) up to 10% increases the compressive strength about 56% but decreases porosity and permeability about 85% and 76%, respectively. Linear correlations have been proposed for compressive strength, porosity and water permeability to obtain suitable amount of fine aggregate for different types of tasks related to no fines concrete.

Keywords: *Aggregate gradation, compressive strength, porosity, water permeability*

1. INTRODUCTION

No Fines concrete is a mixture of cement, water and coarse aggregate, with little or no fine aggregate, combined to produce a porous structural material. It has a porous structure with relatively large interconnected voids that confers to it acoustic and thermal insulation characteristics, water permeability, and economy in terms of material cost. No fines concrete has many different names including zero-fines concrete, pervious concrete and porous concrete. This form of concrete has the ability to allow water to permeate the material which reduces the environmental problems associated with asphalt and conventional concrete pavements because of its higher void ratios. In the absent of fine aggregates, pervious concrete has connected pores size range from 2 to 8 mm, and the void ratio usually ranges from 15% to 25% with compressive strength of 2.8 MPa to 28 MPa (however strength of 2.8 to 10 MPa are common).

Figure 1: No fines concrete draining water

No fines concrete is increasingly being installed to improve storm water quality and reduce runoff produced by urban settings. During the last few years, no fines concrete has attracted more and more attention in concrete industry due to the increase awareness of environmental protection. Many studies revealed that unlike conventional concrete, the performance of no fines concrete is highly dependent on both concrete materials and construction techniques (Schaefer, Suleiman & Wang, 2006; Delatte and Schwartz, 2007). The principal focus of pervious concrete technology is the balance between the compressive strength and permeability because of their inversely proportional relationship.

2. METHODOLOGY

- Selection of suitable type of gradation for coarse aggregate.
- Determination of water-cement ratio and selection of aggregate-cement ratio.
- Casting of cylinders (4"×8")
  - Well graded, gap graded and uniform graded sample.
  - For uniform graded sample a single size aggregate (#4 retained) was used.
  - For well graded sample the maximum size of aggregate was 3/4" down.
  - For gap graded sample a single size of 3/8" retained aggregate was omitted.
  - Adding 2%, 4%, 6%, 8% and 10% of sand as fine aggregate (by weight) in the proportion mix.
- Determination of compressive strength, porosity and water permeability by laboratory performance.
- Explanation and comparison of various test results.
- Concluding remarks.

3. EXPERIMENT

3.1 Selection of Suitable Type of Gradation

Stone chips were used as coarse aggregate in this study. Three types of gradation such as well graded, gap graded and uniform graded were used to investigate the effect on compressive strength, porosity and permeability of no fines concrete. The maximum size of aggregate was 3/4" down. For uniform graded sample, a single size of aggregate retained on no. 4 sieve was used. For gap graded aggregate, a single size of 3/8" aggregate was omitted from the well graded sample.

3.2 Determination of Water-Cement Ratio

It is recommended that workability for no fines concrete should be assessed by forming a ball with the hand to established mouldability of pervious concrete (Tennis et. al, 2004). The water/cement ratio was determined by a trial test which consisted of forming a concrete ball with hand, as shown in Figure 2.1. Water/cement ratio of 0.40 was found to be suitable to produce moldable no fines concrete. Hence, for all concrete mixes this water/cement ratio was used.

(a) 0.30 (b) 0.35 (c) 0.40

Figure 2: Determination of water/cement ratio

3.3 Selection of Mix Proportion

From the review of literature, suitable aggregate/cement ratio was found 4.5:1 for no fines concrete. Hence, Aggregate/cement ratio was taken as 4.5:1 for this study. 0%, 2%, 4%, 6%, 8% and 10% fine aggregate (sand) was added in the well graded sample having water/cement ratio and aggregate/cement ratio as 0.40 and 4.5:1, respectively. Table 1 shows the mix proportion of no fines concrete when fine aggregate was added:

Table 1: Mix proportion of no fines concrete while adding fine aggregate

Mix	FA (%) (by weight)	CA:FA:Cement	Water:Cement
1.	0	4.5:0:1	0.40
2.	2	4.41:0.09:1	0.40
3.	4	4.32:0.18:1	0.40
4.	6	4.23:0.27:1	0.40
5.	8	4.14:0.36:1	0.40
6.	10	4.05:0.45:1	0.40

3.4 Casting of Cylinders

Three sets (each set contains 6 nos.) of cylinders of 4"x8" sizes were casted for 28 days compressive strength and constant head water permeability test for selecting suitable type of gradation. The well graded sample was found suitable among the three types of gradation. After that 0%, 2%, 4%, 6%, 8% and 10% fine aggregate (sand) was added in the well graded sample. Again five sets (each set contains 6 nos.) of cylinders of 4"x8" sizes were casted for 28 days compressive strength and constant head water permeability test to examine the performance of no fines concrete.

3.5 Compressive Strength Test

Compressive strength test was performed according to ASTM C29. For no fines concrete, three cylindrical specimens four inches in diameter and eight inches in height were used. The specimens were cured in water for 28 days. The compressive strength reported was the average of three results taken from three identical cylinders.

Figure 2: Compressive strength test of no fines concrete

3.6 Porosity

The porosity of the hardened concrete was calculated from the oven-dry and saturated weights, using the following Equation (Park and Tia, 2004).

$$V_r = \left[1 - \frac{(W_2 - W_1)V}{\rho_w}\right] \times 100 \tag{1}$$

Where,
V_r = porosity
W_1 = weight under water (gm)
W_2 = oven dry weight (gm)
V = volume of sample (cm^3)
ρ_w = density of water (gm/cm^3)

Figure 3: Weight in water of no fines concrete

3.7 Water Permeability Test

For no fines concrete, constant head permeability test method was used to measure the water permeability. Water head of 375 mm were adopted for the test. Due to the large specimen size, a new experimental set up was invented as shown in Figure 4. The cylinders were surrounded by a hard plastic pipe and to prevent water leakage from the adjacent sides between the pipe and the concrete at both top and bottom were blocked by silica gel. Under a given water head, the permeability was carried out when a steady state of flow was reached. The amount of water flowing through the specimen over 15 seconds was measured and the permeability coefficient was calculated using Darcy's First Law as given below:

$$K = \frac{Q\,L}{A\,t\,h} \tag{2}$$

Where, K = water permeability coefficient (mm/s)
Q = quantity of water collected (mm^3)
L = length of the specimen (mm)
A = cross sectional area of cylinder (mm^2)
t = time (s)
h = water head (mm)

Figure 4: Constant head water permeability test

4. RESULTS AND DISCUSSIONS

4.1 Effect of Aggregate Gradation on Compressive Strength, Porosity and Water Permeability

Figure 5 shows effect of aggregate gradation on compressive strength, porosity and permeability of no fines concrete. It is clear that among the three types of aggregate gradation, compressive strength is found higher in well graded sample, whereas porosity and permeability are observed higher in uniform graded and gap graded sample, respectively. In well graded sample porosity and permeability are observed 80.5% and 90.1% of highest value, respectively.

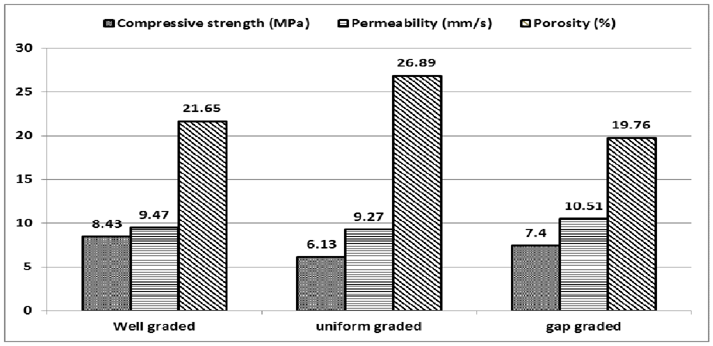

Figure 5: Effect of aggregate gradation on compressive strength, porosity and permeability

4.2 Effect of Adding Fine Aggregate on Compressive Strength

Figure 6 shows the effect of adding fine aggregate on compressive strength. Addition of fine aggregate reduces pore spaces between the aggregates thus increases compressive strength. From the figure, when no fine aggregate was added compressive strength was found 8.43 MPa and up to 10% addition of fine aggregate it was increased to 13.13 MPa.

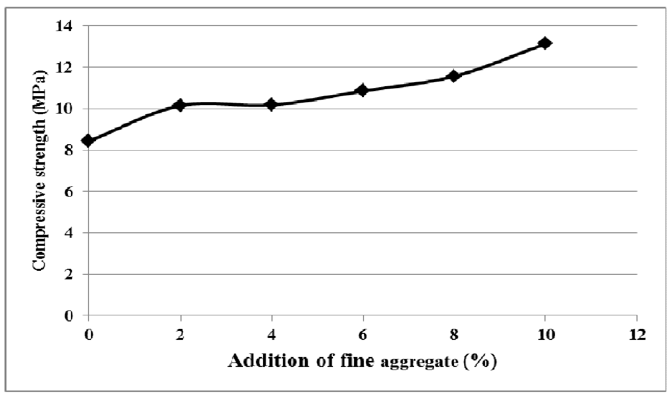

Figure 6: Effect of adding fine aggregate on compressive strength

4.3 Effect of Adding Fine Aggregate on Water Permeability

Figure 7 shows the decrease in water permeability when fine aggregate was added in the proportion mix. Addition of fine aggregate reduces pore spaces thus disrupting water flow through no fines concrete. It is found that the up to 10% addition of fine aggregate, water permeability is reduced to 1.45 from 9.53 mm/s.

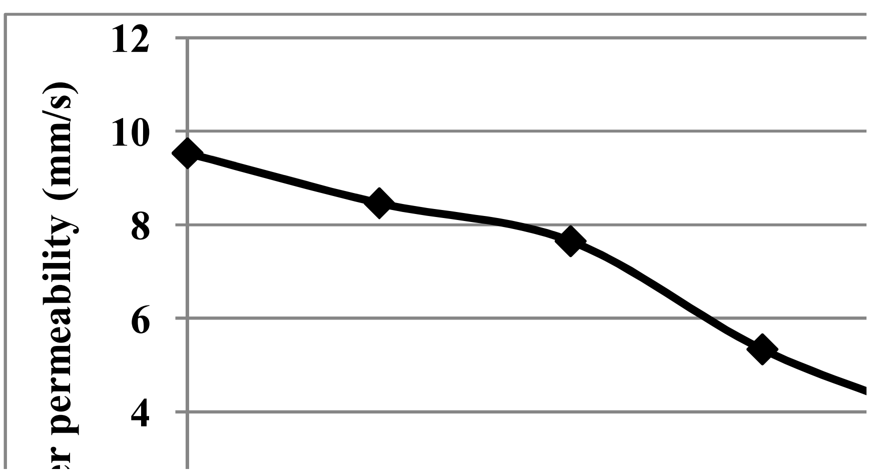

Figure 7: Effect of adding fine aggregate on water permeability

4.4 Effect of Adding Fine Aggregate on Porosity

Figure 8 shows that porosity decreases with the addition of fine aggregate significantly. This was occurred because fine aggregate fill up the void spaces between the aggregates and made an impact on pore structure of the no fines concrete. From the figure, when no fine aggregate was added porosity was 21.65% and decreased to 5.26% after addition of 10% fine aggregate.

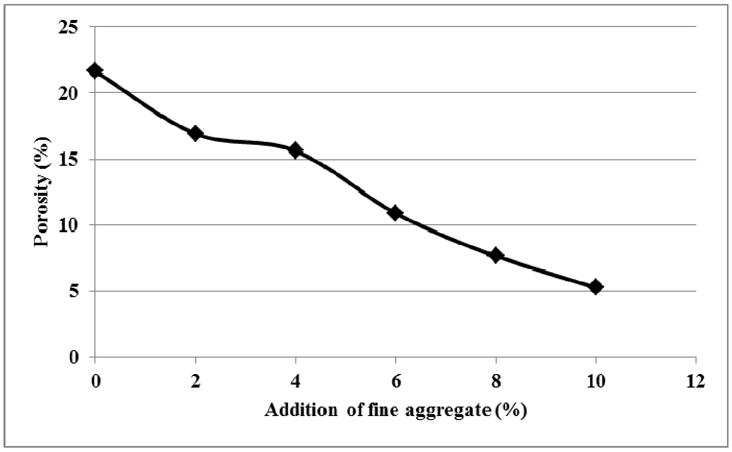

Figure 8: Effect of adding fine aggregate on porosity

4.5 Effect of Porosity on Compressive Strength and Water Permeability

Figure 9 represents effect of porosity on compressive strength and water permeability. From the figure it can be state that the relationship between porosity and permeability is directly proportional but the relationship between porosity and compressive strength is inversely proportional. But the rate of change is not the same. About 16% increase in porosity increases about 84% water permeability and decreases about 36% compressive strength. So permeability is likely to be more sensitive to porosity than compressive strength.

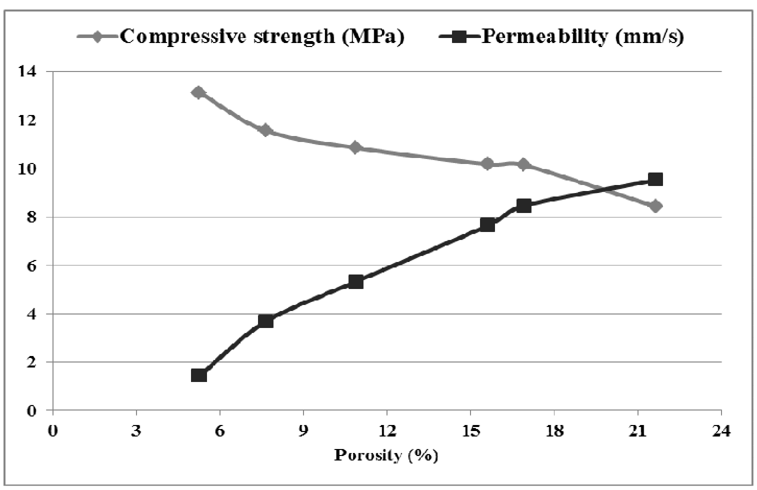

Figure 3.5: Effect of porosity on compressive strength and water permeability

4.6 Correlation for Compressive Strength, Porosity and Water Permeability

From the observed data, linear correlations are developed for compressive strength, porosity and water permeability of no fines concrete and are shown in Figure 3.6 and given by Equations (3), (4) and (5), respectively.

$$y = 8.682 + 0.406x; \quad (r^2 = 0.93) \tag{3}$$

$$y = 21.167 - 1.635x; \quad (r^2 = 0.98) \tag{4}$$

$$y = 10.092 - 0.815x; \quad (r^2 = 0.98) \tag{5}$$

The value of r^2 was found very close to 1.0 for each of the equation indicating these correlations can be used to obtain optimum amount of fine aggregate for a particular task by improving the performance of no fines concrete.

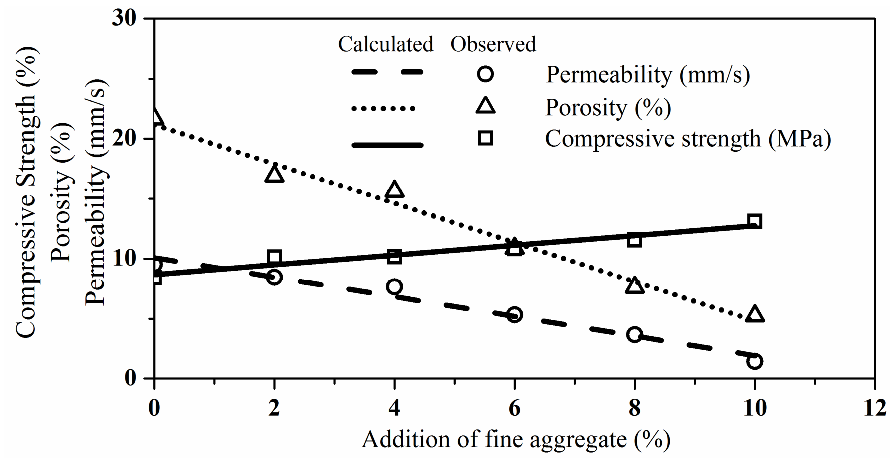

Figure 3.6: Correlation for compressive strength, porosity and water permeability

5. CONCLUSIONS

Although limited in its applications, no fines concrete has the potential to help mitigate many of the urban storm water quality issues. Lack of extensive research on no fines concrete has led to some misunderstanding and narrow focus on the use of this type of concrete. One of the objectives of this research was to develop performance of no fines concrete. Several attempts have been made in this research to fulfill the objectives. Improved performance would lead to a wider application of no fines concrete. Major conclusions obtained from this study are as follows:

- Among the three types of aggregate gradation, the compressive strength is found higher in well graded sample, whereas porosity and permeability is observed higher in uniform graded and gap graded sample, respectively.
- In well graded sample, porosity and permeability are observed 80.5% and 90.1% of highest value, respectively. So it can be concluded that well graded sample is more suitable than other two types of aggregate gradation.
- Addition of fine aggregate (sand) upto 10% increases compressive strength about 56% but decreases porosity and permeability about 85% and 76%, respectively.
- The proposed correlation can be used to obtain suitable amount of fine aggregate for different type of tasks related to compressive strength, porosity and water permeability.

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