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Investigation of Mechanical and Physical Properties of No-Fines Concrete

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***Abstract* – The paper presents investigation on the mechanical and physical properties of no-fines aggregate concrete through laboratory testing. The concrete employ locally available coarser aggregates with no fine aggregates, where aggregate-to-aggregate bond is achieved through water-cement paste resulting in significantly lightweight concrete. Laboratory tests were conducted on twenty four standardcubes (150x150x150) mm, with different mix proportions to estimate the basic mechanical property i.e. compressive strength, and the physical properties including permeability, porosity and void ratio. The effect of water-cement ratio and aggregate-cement ratio is also investigated for essential optimization. It was found that the strength of no-fines concrete is lower than that of normal weight concrete and in the range of (0.8to8.0) MPa, but appears to be sufficiently enough for specialized construction works where compressive stress demand is not very high. A maximum measured value of permeability was 9.4m/hr. (2.6mm/sec). Porosity for the tested specimens was in the range of (10 to 17)%, and void ratio was measured in the range of (12 to 20) %.**

***Keywords* – Porous Concrete (No-Fines Concrete), Compressive Strength, Porosity, Void Ratio, Permeability.**

I. Introduction

No-fines concrete is a form of lightweight aggregate porous concrete, obtained by mixing Portland cement, aggregate and water only, resulting in a cellular rough-texture of concrete.The use of fineaggregate is avoided in making the concrete mix for no-fines concrete for construction. In this type of concrete a covering of thin layer of cement paste surrounds the coarse aggregates. Thus, a small fillet of cement paste brings the coarse aggregates in point-to-point contact with each other that binds coarse aggregates together. No-fines concrete is used in construction widely after the pioneering work of Wimpey in the UK in 1924 (Ghafoori and Dutta, 1995a; Newman and Owens, 2003), however its first use was noticed in the construction of two houses in the UK as early in 1852 (Francis, 1965). The advantages of no-fines concrete are lower density, lower cost due to lower cement content, good thermal conductivity, relatively low drying shrinkage (one half of dense concrete), no segregation even in case of material discharge from high levels, nocapillary movement of water due to low hydrostatic pressure when wet (one-third of denseconcrete), better insulating characteristics than conventional concrete because of the presenceof large voids (Abadjieva and Sephrir, 2000; C&CI, 2009; Neville, 1981; Ghafoori and Dutta1995,b; Sommerville et al., 2011.

II. Experimental Program

An extensive experimental program was conducted to investigate the compressive strength, permeability, porosity and void ratio of no-fines concrete specimens. This program includes the no-fines concrete mix preparation procedure and the required tests to provide a clearindication of the characteristics of no-fines concrete.

In this research,24 mixes within 2 groups, (every group has 12 mixes), and every group hascharacteristics with some variances to find the relationships between the investigated properties.There were a large number of different mixes that are currently being used for a whole range of applications. For this reason four different mixes were trialed. From previous researches, the suggested aggregate-cement-water/cement ratio mixes are given in Table 1.

Table 1: Mix Proportions used for No-fines Concrete Trial Mixes

Aggregate	Cement	Water/Cement ratio
8	1	0.4
6	1	0.4
4.5	1	0.4
4.8	1	0.36

The concrete specimens are cast in steel or cast- iron molds of robust construction generally (150x150x 150mm), which should conform within narrow tolerances to the cubical shape, prescribed dimensions and plane-ness.

The trial mixes were used to determine the most suitable mixture for the analysis. The four different samples were mixed and tested for compressive strength and indirect tensile strength at 14 days. From these results, the most appropriate mix was determined and used for the remainder of the analysis. The 28 day strength was tested later to ensure that the chosen concrete mix possessed the highest ultimate compressive strength of the concrete mixes. Also, many tests were conducted on the aggregate used in this research. The results of these tests indicate the followings:

- The flakiness of the aggregate sample used is 6.7 % which is suitable where

The lower amount of flaky particles meant that a higher compressive strength could be obtained.

- The Bulk Density and Voids Ratio of Loose Aggregates were suitable and good.
- The specific gravity of coarse aggregate was in the range of (2.5- 2.8) and the water absorption is very low.

- The percent wear using Los Angeles testwas in the range of (25- 30) %.
- The Impact value of the coarse aggregate is low.

III. TESTS RESULTS AND ANALYSIS

The prepared specimens were tested to determine the investigate properties, simple equations were used for calculations as follows:

To calculate compressive strength fc (MPa) using the following simple equation was used:

$$f_c = \frac{Applied \quad Load \quad (N)}{Area \quad (mm^2)} \qquad (1)$$

Porosity is a measure of the void spaces in a material, and is measured as fraction, from 0to1, or as a percentfrom 0 to 100%.

$$n\% = (Vv/V_T)\ 100\% \qquad (2)$$

Where:
n% is the porosity percentage
V_V is the volume of void-space (such as fluids)
V_T is the total or bulk volume of material, including the solid and void components.

Void ratio of no fine concrete was determined by calculating the difference in weight between the oven dry sample and the saturated under water sample using equation 3

$$e\% = \frac{V_v}{V_s}\ 100\% \qquad (3)$$

Where:
V_v is the total volume of voids
V_s is the volume of solid material

Permeability is the property of concrete that controls the amount of water passes into the aggregate pores.This property of concrete is extremely important determining the durability of concrete structure.Thepermeability of the samples was determined using the falling head permeabilitytest.

The test was performed using several water heights which represented values that apavement may experience in practice. The average coefficient of permeability (K) was determined using the following equation:

$$K = 2.3\ \frac{a\,L}{A\,t}\ Log\frac{H_2}{H_1} \qquad (4)$$

Where:
K: coefficient of permeability(mm/sec)
a:cross-sectional area of stand pipe (mm^2)
A: cross-sectional area of specimen (mm^2)
t: time for water to drop from H_1 to H_2
H_1:initial water height
H_2: finalwater height
L: length of concrete specimen

Mix Proportions and Test Results for Group (1) Specimens

Mix proportions and test results for group(1) of test specimens are shown in Tables 2, 3 and 4.

Table 2: Mix Proportions for Group (1)

Specimen No		Mix			W1 kg	W2 kg	W3 liter	additions
		Cement	Agg.	W/C				
G1-1	A	1	4	0.4	4	16	1,6	0%
	B							
	C							
G1-2	A	1	6	0.4	2.67	16	1.067	15% pass no.12 retained no.9
	B							
	C							
G1-3	A	1	8	0.4	2	16	0.8	10% pass no.12 retained no.9
	B							
	C							
G1-4	A	1	12	0.4	1.33	16	0.533	0%
	B							
	C							

Table 3: Test results for group (1) specimens

Specimen No.	Permeability mm/h	Compressive Strength (MPa)	Void ratio e%	Porosity n %
A	7848	3.33	16,3	14
B	7740	3.24	16,6	14,2
C	7560	3.24	16,4	14
A	1290	8	13	12
B	1224	8.22	12	11
C	1209	8.17	12	11
A	1656	5.3	14,2	12,4
B	1512	5.4	14,5	12,6

C	1728	5.3	13,9	12,2
A	9432	.84	20,9	17,3
B	9144	.77	20,7	17,2
C	9180	.84	20,8	17,2

Table 4: Summary of Test Results for Group (1) specimens

Specimen No.	**Average Compressive strength (MPa)**	**n %**	**e %**	**Permeability (mm/h)**
G1-1	3.24	14.1	16.4	7716
G1-2	8.13	11.3	12.3	1241.2
G1-3	5.33	12.4	14.2	1632
G1-4	0.82	17.2	20.8	9252

Mix Proportions and Test Results for Group (2) Specimens

Mix proportions and test results for **Group (2)** of test specimens are shown in Tables 5, 6 and 7

Table 5: Mix Proportions for Group (2)

Specimen No			**Mix**		**W1 kg**	**W2 kg**	**W3 liter**	**Additions**
		Cement	**Agg.**	**W/C**				
G2-1	A	1	4	0.5	4	16	2	0%
	B							
	C							
G2-2	A	1	6	0.5	2.67	16	1.33	20% pass no.12 retained no.9
	B							
	C							
G2-3	A	1	8	0.5	2	16	1	0%
	B							
	C							
G2-4	A	1	12	0.5	1.33	16	0.667	0%
	B							
	C							

Table 6: Test results for group (2) specimens

Specimen No.	**Permeability mm/h**	**Compressive Strength (MPa)**	**Void ratio e%**	**Porosity n %**
A	6883	3.77	15.6	13.5
B	6764	3.77	14.6	12.8
C	6793	3.64	17.1	14.6
A	922	9.02	10.5	9.5
B	956	9.02	10.7	9.6
C	934	8.88	11.5	10.4
A	7704	1.77	19.4	16.3
B	7718	1.86	18.6	15.7
C	7743	1.73	17.7	15
A	9360	1.46	20.1	16.7
B	9216	1.42	19.4	16.2
C	9288	1.46	20	16.7

Table 7: Summary of Test Results for Group (2) specimens

Specimen No.	**Average Compressive strength (MPa)**	**n %**	**e %**	**Permeability (mm/h)**
G2-1	3.73	13.6	15.8	6813
G2-2	8.97	9.8	10.9	937
G2-3	1.77	15.7	18.9	7722
G2-4	1.42	19.8	19.8	9288

IV. Discussion, Conclusions and Recommendations

Discussion and Conclusions

The objective of this research was to determine the applicability of no-fines concrete as a road pavement material. The performance of the no-fines concrete was determined by comparing its properties with those obtained from conventional concrete. The followings provide an overview of the objectives achieved that were set at the commencement of the project:

1. Research background information relating to the use of no-fines concrete in pavement and non-pavement applications.
2. Conduct some initial mix design test to evaluate some possible alternatives. This will include using different water/aggregate/cementratios.
3. Conduct tests and analyze the results to form a conclusion as to the effectiveness of no-fines concrete as a road pavement.

There was a considerable difference in the compressive strength between the concrete samples but this does not affect the outcome as it was the relationships between the characteristics that were assessed. The relationships showed that no-fines concrete acts in a manner similar to what was found in the conventional concrete sample. Also, all the investigated properties of no-fines concrete were affected as the concrete mix proportions changed and by the way affect the outcomes results.

In general, no-fines concrete has a low compressive strength but at the same time it is permeable that could be used as a layer in the pavement construction.

Recommendations for Further Research

There are an unlimited number of possible topics for further studies but there are a small number that would be particularly useful. Investigation of these may affect the future design and specifications of no-fines concrete pavements.

The elements that should be investigated relates to the size, shape, flakiness and type of the aggregate particles used. It was found during this research that a small change in these elements can have a dramatic effect on compressive strength of the no-fines concrete.

This could be taken further by investigating different aggregates or to investigate the use of recycled aggregates. Alternative materials that can be readily used in no-fines concrete applications could reduce costs and make it more environmentally friendly.

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