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Investigation of Strength and Workability in No-Fines Concrete

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***Abstract*— The present paper reports the results of laboratory experiments carried out to investigate the properties of concrete such as strength, workability, etc. of No-Fines concrete which may offer the alternative to traditional non porous concrete. The mixes were prepared with a variable water cement ratios as well as varying sizes of coarse aggregate. The size of coarse aggregate taken for the study was 10 mm, 20 mm and a size varying from 10 to 20 mm. Cement contents used was 250 kg/m^3, 275 kg/m^3 and 300 kg/m^3. The main aim of this study was to investigate the strength and workability of various mixes of No-Fines concrete and to propose an optimum proportion for desired strength and workability of porous concrete. Also study focuses on the effect of particle size of coarse aggregate on the strength and workability of No-Fines concrete.**

***Index Terms*—No-Fines concrete, workability, coarse aggregate**

I. INTRODUCTION

Concrete is one of the largest consumable materials after water. The use of concrete is increasing tremendously due to infrastructure developments taking place worldwide. Impervious pavement is a major part of the infrastructure of the built environment. Because of the impermeability of the surface, there is an increased risk of flooding as well as a reduction in the groundwater recharge (Kuennen, 2003; Dreelin et al., 2006; Kuang et al., 2011; Moriyoshi et al., 2013, 2014) [5,6,7]. Recently, there is rise inconsideration to promote utilizing of porous concrete towards the environment and sustainable management. This concrete can be a successful means in addressing a number of environmental issues and supporting sustainable development. Despite of having a lower strength, the porous concrete with a higher porosity is useful for many applications, such as permeable pavement [12], storm water quality management [13], rain water harvesting [14], and purification of water [15]. In Australia, permeable pavement has been utilized as a potential tool of Water Sensitive Urban Design (WSUD) to manage natural water. From 1994 the University of New South Wales (UNSW) started to research into permeable concrete paving and more recently the University of South Australia is also involved in such studies [10]. The use of pervious concrete for the construction of secondary roads, parking lots and drive ways is increasing in USA [1]. The construction industry is the largest industry in India and accounts for about 11% of India’s GDP. India consumes 450 million cubic meter of concrete per annum. Compared with research on traditional concrete very limited research had been conducted on the porous concrete.

No-Fines concrete is a mixture of cement, water and a single sized coarse aggregate combined to produce a porous structural material. It has a high volume of voids, which is the factor responsible for the lower strength and its lightweight nature. No-Fines concrete has many different names including zero-fines concrete, pervious concrete and porous concrete [9]. It is a porous concrete which allows the passage of water to flow through easily reducing runoff and recharging ground water level [1]. The range of porosity that was commonly reported for pervious concrete utilized in pavement was about 15%-25% [3]. Typical pervious concrete mix consists of 180-355 kg/m^3 of cement and 1400-1600 kg/m^3 of coarse aggregate and water to cement ratio ranged from 0.25 to 0.43 [2]. In spite of these advantages of porous concrete, its interconnected porous structure makes it less strengthen and less workable. Lian and Zuge concluded that the grading of aggregate also needs to be controlled in order to achieve the best strength of porous concrete [16]. Kervin proposed that workability of the No-Fines concrete can be improved by adding polymer (styrene butadiene rubber) in it [4]. It is imperative to focus on the strength and workability of porous concrete by using different sizes of coarse aggregates. In this work trial is made to work on raw material mix proportion, different voids ratios, mechanical properties such as strength and workability of porous concrete. Also work had been conducted on the optimization of strength and workability of No-Fines concrete and effect of particle sizes of coarse aggregate on them.

II. MATERIALS

A. Cement

In this experimental work OPC 53 grade cement was used. The tests conducted on the cement were fineness test conforming to IS 12269: 1987, standard consistency test, compression test conforming to IS 650: 1991.

B. Aggregate

Coarse aggregate occupies the maximum volume in concrete; hence it plays an important role in performance of concrete. It occupies nearly 70 to 85 % by volume of the concrete and hence their properties are vital. Plastic and hardened concrete properties are largely depends upon the type of coarse aggregate. In this work coarse aggregate conforming to IS 383 : 1970 was used in three batches. First batch and second batch consists of single sized coarse aggregates of 10mm and 20mm diameter respectively while the third consists of the particle sizes of coarse aggregate varied from 10 mm to 20 mm.

TABLE I
ENGINEERING PROPERTIES OF AGGREGATES

S.N.	Property	Results
1	Shape	Cubical
2	Specific Gravity	2.65
3	Fineness Modulus	6.88
4	Water Absorption	1.7%

C. Water

Water plays an important role in modifying the plastic and hardened properties of concrete. It reacts with cement and helps in setting and hardening the cement by evolving heat of hydration. The workability of concrete directly depends on the water-cement ratio and hence the quantity of water used for making concrete. The water-cement ratio affects directly the workability and strength of hardened concrete. For making the concrete potable water was used.

D. Super Plasticizer

In present investigation Conplast SP 430 super plasticizing admixture was used, which complies with IS 9103:1999. Conplast SP 430 is based on sulphonated naphthalene polymers and is supplied as a brown liquid instantly dispersible in water. It has been specially formulated to give high water reduction up to 25% without loss of workability. Its specific gravity is 1.145 (at 30 °C) and chloride content is Nil. Air entrainment is approximately 1%.

III. LITERATURE SURVEY

The initial use of No-Fines concrete was in the United Kingdom in 1852 with the construction of two residential houses and a sea groyne. The strength of concrete depends on many parameters such as amount, quality and type of cement, aggregate, water and admixtures. Lian and Zuge pointed out the effect of size of aggregate on the strength of porous concrete and concluded that grading of aggregate also need to be controlled in order to achieve the best strength of porous concrete. He stated that smaller size aggregate gives more strength as compared to the larger one [16],[17]. Yang Zhifeng , Ma Wei, Shen Weiguo and Zhou Mingkai (2008) investigated the effect of proportion of aggregate, the maximum size of the aggregate on the porous concrete[18]. The results found correspondence with the results of previous researcher. Crouch et al. (2007) stated that not only the size of aggregate, but also the gradation and amount of aggregate could affect the compressive strength of porous concrete [19]. Compared with related results on strength of porous concrete very limited research had been conducted on the effect of aggregate sizes on its strength. No work had been done on the workability of the pervious concrete neither on optimization of the strength and workability of it. The objective of this paper is to investigate the effect of aggregate sizes on the compressive strength and workability of No-Fines concrete and to provide the optimal strength for workable porous concrete. Also study investigates the effect of particle size of coarse aggregate on the strength and workability of No-Fines concrete.

IV. CONCRETE MIX DESIGN AND METHODOLOGY

A. Concrete Mix Design

For the mix proportion of the No-Fines concrete, it is imperative to consider the aggregate/cement ratio and is generally taken from 6:1 to 10:1. Aggregate used are normally of single sized or may be of varying sizes passing through 20 mm and retain on 10 mm. In traditional concrete strength is primarily controlled by the water/cement ratio. In No-Fines concrete, it depends on water/cement ratio, aggregate/cement ratio and unit weight of concrete. Based on the results of trial batches, adjustments and improvement were made for the further mix. Trial mix was prepared for target mean strength of 26 MPa. The mixes were made with a variable water cement ratios as well as varying coarse aggregate sizes as 10 mm, 20 mm and 10 to 20 mm. Cement contents used are 250 kg/m^3, 275 kg/m^3, 300 kg/m^3. As there is no special IS code for the mix design of No-Fines concrete, concrete mix was designed in accordance with IS 456 : 2000 and IS 10262 : 1982. Table I depicts mix proportion for the No-Fines concrete used in this research work.

TABLE II
MIX PROPORTION OF NO-FINES CONCRETE

S.N.	Materials	Cement	Water	Coarse Aggregates
1	Quantity for 0.8 m^3	300	106.785	1585.23
2	Quantity for 1 cube	1.27	0.45	6.687
3	Proportion	1:0.35:5.26		

B. Methodology

The aim of this research work is to study the Strength and workability of No-Fines concrete and the effect of the varying particle sizes on them. Also research had been conducted for optimizing among these parameters. In this work study has been done on the trial mixes made for M20 grade of concrete. For designing the M20 grade of concrete W/C ratio of 0.35 is taken which is further modified up to 0.40 for meeting the value of required workability. In some mixes admixtures were added for improving workability of concrete. Mixes were

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made using natural coarse aggregate and cement only; fine aggregates were deliberately omitted in the mixes to create large textured porous concrete. Trial mixes were made by hand mixing with a variable water cement ratios and varying coarse aggregate sizes as 10 mm, 20 mm and 10 to 20 mm. Cement contents used are 250 kg/m^3, 275 kg/m^3, 300 kg/m^3. For each mix 3 numbers of cubes (with dimensions 150x150x150 mm) were casted in three layers and moulds were gently tapped. As specified in IS code 12727 vibration is avoided to avoid extra segregation. For each concrete mix slump values were found for the computation of workability. Cubes were remolded after 24 hrs and placed for curing for the period of 28 days. For some mixes cylinders with 150mm diameter and 300mm height were casted. These cubes and cylinders were tested on 28th day of curing for their compressive strength. Fundamental properties of porous concrete including its strength and workability were studied. Their relation with voids ratio and cement content on the basis of particle sizes of course aggregate was tried to find out.

V. RESULTS AND DISCUSSIONS

Compressive strength and workability results of porous concrete specimens of aggregate size 20 mm are illustrated in the Table III. As shown in Table III concrete made with aggregate size 20 mm gave compressive strength of 3.88 MPa at 20% voids ratio and cement content of 250 kg/m^3, which is very less when compared with the conventional concrete. The workability results also are not satisfactory. No standard method is recommended, like slump test or compacting factor test for measuring the consistency of No-Fines concrete. Perhaps slump test is used along with the visual observation. When reducing the aggregate size from 20 mm to 10 mm as depicted in the Table IV, compressive strength increased up to 4.23 MPa giving fair workability.

As illustrated in the Table V, in the third trial, instead of single sized coarse aggregate, varying sizes of coarse aggregate ranging from 10 mm to 20 mm was selected. The results showed that the compressive strength of porous concrete was increased with the slight increase in its workability. Still not the single mix gave the satisfactory workability results. For that super plasticizer was added in the mix to enhance the workability. Aggregate to cement ratio was decreased to 4:1 to increase the compressive strength up to desired value at the cost of porosity. Table VI depicts the increased strength and results.

TABLE III
28 DAYS COMPRESSIVE STRENGTH OF AGGREGATE SIZE 20 MM

S.N.	Void Ratio	Cement Content (kg/m^3)	Workability	Compressive strength (N/mm^2)	Mean
1	20%	300-B1	Worst	3.111	2.46
		B2	Worst	2.493	
		B3	Worst	1.782	
2	20%	275-B1	Worst	3.600	3.31
		B2	Worst	3.853	
		B3	Worst	2.471	
3	20%	250-B1	Worst	5.181	4.12
		B2	Fair	3.822	
		B3	Fair	3.360	
4	15%	300-B1	Worst	2.973	3.43
		B2	Fair	3.187	
		B3	Fair	4.116	
5	15%	275-B1	Worst	2.076	2.42
		B2	Worst	1.756	
		B3	Worst	3.427	
6	15%	250-B1	Worst	1.791	2.78
		B2	Worst	3.253	
		B3	Worst	3.302	
7	25%	300-B1	Worst	1.831	3.05
		B2	Fair	4.040	
		B3	Worst	3.284	
8	25%	275-B1	Worst	2.987	3.36
		B2	Fair	3.800	
		B3	Worst	3.293	
9	25%	250-B1	Worst	2.782	2.83
		B2	Worst	2.316	
		B3	Worst	3.382	

TABLE IV
28 DAYS COMPRESSIVE STRENGTH OF AGGREGATE SIZE 10 MM

S.N.	Void Ratio	Cement Content (kg/m^3)	Workability	Compressive Strength (N/mm^2)	Mean
1	20%	300-B1	Worst	4.190	4.23
		B2	Fair	4.906	
		B3	Worst	3.584	
2	20%	275-B1	Worst	3.751	4.02
		B2	Fair	4.902	
		B3	Worst	3.395	
3	20%	250-B1	Worst	3.847	3.85
		B2	Worst	4.164	
		B3	Worst	3.534	
4	15%	300-B1	Worst	3.110	3.93
		B2	Fair	4.931	
		B3	Fair	3.759	
5	15%	275-B1	Worst	3.582	4.09
		B2	Fair	3.328	
		B3	Worst	5.362	
6	15%	250-B1	Worst	3.989	3.81
		B2	Fair	4.170	
		B3	Worst	3.275	
7	25%	300-B1	Worst	4.028	3.82
		B2	Worst	3.404	
		B3	Fair	4.030	
8	25%	275-B1	Worst	3.109	4.01
		B2	Worst	4.928	
		B3	Worst	3.980	
9	25%	250-B1	Worst	2.692	3.40
		B2	Worst	4.016	
		B3	Worst	3.495	

TABLE V
28 DAYS COMPRESSIVE STRENGTH OF AGGREGATE SIZE 20 MM PASS TO 10 MM RETAINED

S.N.	Void Ratio	Cement Content (kg/m^3)	Workability	Compresive strength (N/mm^2)	Mean
1	20%	300-B1	Fair	6.010	6.16
		B2	Moderate	5.970	
		B3	Fair	6.509	
2	20%	275-B1	Fair	6.330	5.53
		B2	Fair	5.357	
		B3	Moderate	4.912	
3	20%	250-B1	Fair	6.687	6.06
		B2	Fair	5.979	
		B3	Fair	5.521	
4	15%	300-B1	Moderate	7.042	6.57
		B2	Fair	6.157	
		B3	Moderate	6.522	

5	15%	275-B1	Fair	6.473	5.95
		B2	Fair	6.020	
		B3	Moderate	5.357	
6	15%	250-B1	Fair	5.491	5.89
		B2	Fair	6.024	
		B3	Fair	6.148	
7	25%	300-B1	Fair	5.446	5.05
		B2	Moderate	5.339	
		B3	Fair	4.379	
8	25%	275-B1	Fair	4.906	5.10
		B2	Fair	4.653	
		B3	Fair	5.742	
9	25%	250-B1	Fair	5.884	5.08
		B2	Fair	5.321	
		B3	Fair	4.033	

TABLE VI
28 DAYS COMPRESSIVE STRENGTH OF AGGREGATE SIZE 20 MM PASS TO 10 MM RETAINED AFTER THE ADDITION OF SUPER PLASTICIZER AND AGGREGATE CEMENT RATIO AS 4:1

S.N.	Void Ratio	Workability	Compressive strength (N/mm^2)	Mean Compressive Strength (N/mm^2)
1	20%	Moderate	15.502	15.88
		Moderate	17.563	
		Moderate	14.567	
2	15%	Moderate	15.754	16.00
		Moderate	13.674	
		Moderate	18.564	
3	10%	Moderate	18.384	20.11
		Moderate	21.489	
		Moderate	20.459	

VI. CONCLUSIONS

Based on the investigation made on the No-Fines concrete with different sizes of coarse aggregate and different cement content and voids ratios, following conclusions could be made.

[1] Compressive strength and the workability of the porous concrete primarily depends upon the particle sizes of coarse aggregate, voids ratio and the cement content.

[2] Grading of the coarse aggregate in the No-Fines concrete largely influences its workability and strength. Uniformly graded coarse aggregate gives better results than Single graded aggregates.

[3] Decreased in the size of coarse aggregate decreases the voids ratio while increases the workability and its compressive strength.

[4] No-Fines concrete with uniformly graded coarse aggregate sizes from 10 mm to 20 mm gave the maximum strength and moderate workability at 10% voids ratio.

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