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Influence of Recycled Aggregate based Pervious Concrete with Flyash

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Abstract: Aggregate in concrete is a structural filler which accounts for non-porous and impervious behaviour whereas pervious concrete is unique which uses a single size aggregate without fines and it would prove to be effective for growing environmental demands. It also captures rainwater and allows it to seep into the ground. This pavement technology creates more efficient land use by eliminating the need for retention ponds, swell, and other costly storm water management devices. Generally, it has low strength and very good permeability. In this paper, partial replacement of recycled aggregate (RA) for making pervious concrete (PC) was studied. PC was prepared by partial replacement of cement with class F fly ash (FA). The results of various mixes were compared and best mix was proposed based on infiltration and strength. Compressive strength, splitting tensile strength, and water permeability coefficient of the PC were determined.
Keywords: Recycled aggregate, pervious concrete, flyash, strength, permeability.

Introduction

A larger amount of rainwater ends up falling on impervious surfaces such as parking lots, driveways, sidewalks, and streets rather than soaking into the soil. This creates an imbalance in the natural ecosystem and leads to a host of problems including erosion, floods, ground water level depletion. A simple solution to avoid these problems is to stop constructing impervious surfaces and switch to pervious concrete or porous pavement, a material that offers the inherent durability and low life-cycle costs of a typical concrete pavement while retaining storm water runoff and replenishing local water-shed systems [1].

Considerable research has been conducted on environmentally sustainable development. This has lead to the use of no-fines concrete in place of conventional concrete and asphalt surfaces. This material dramatically reduces environmental degradation and the negative effects associated with urban sprawl [2]. No-fines concrete has been used as an effective method for treating and reducing negative environmental impacts [3]. Problems plagued the initial development, with the pores becoming clogged and stopping the water from passing through, causing ponding and reducing the skid resistance of the road surface. The second problem was concerned with the unsightly raveling that occurs on the surface shortly after construction and the unsafe perception that it creates. This paper analyses the effectiveness of no-fines concrete in pavement applications. This was achieved by analyzing the properties and characteristics of no-fines concrete. The performance of no-fines concrete was compared with a concrete sample that is comparable to the material used for the construction of conventional concrete road pavements [4]. Pervious concrete is a special concrete that contains continuous voids and possesses high water permeability compared to normal concrete. It has been developed as an environmentally friendly material for use in water purification, permeable pavement, acoustic absorption, thermal insulation, and other applications in civil engineering and architecture.

Pervious concrete can be defined as an open graded or “no-fines” concrete that allows rain water to percolate through to the underlying sub-base (ACI Committee 522-2006). Pervious concrete is a tailored-property concrete with high water permeability which allow the passage of water to flow through easily through the existing interconnected large pore structure. The principal ingredients are quite similar to conventional concrete like aggregate, Portland cement, admixtures, fine aggregate (optional), and water. A mix proportion providing the optimal combination of strength and porosity was chosen [5]. The main difference is the percentage of void space within pervious concrete. The use of supplementary materials to partially replace Portland cement and alternative cementing materials should be developed in order to reduce the use of Portland cement. The use of recycled aggregate was also studied in this paper [6].

Typical ranges of void space between 15-25 percent, roughly .08 in to .32 in (2 mm to 8 mm) (NRMCA 2004) [7]. Generally, the sizes of connected pore in pervious concrete range from 2 to 8mm in diameter with void content 15% and 35% and compressive strength between 2.8 and 28.0 MPa. For a given set of materials, the strength and infiltration rate of pervious concrete is a function of concrete density. Greater the density, higher is the strength and lower the infiltration rate.

Materials and Methodology

Cement

Cement used for the present work is Portland pozzolana cement with a characteristic compressive strength of 53 MPa. The physical properties of cement were determined as per the IS 4031:1968 and results are given in the table.

Table 1: Properties of OPC

Properties	Values
Initial setting time	30 minutes
Final setting time	10 hours
Standard consistency	28%
Specific gravity	3.10

Flyash

Flyash used for the present work is Class F and obtained from Ennore thermal power plant. The chemical composition of Flyash used is given in the Table 2.

Table 2: Properties of Class F fly ash

Properties	Values
Specific gravity	2.3
Chemical composition	SiO_2 – 51.1% Al_2O_3 – 22.9% Fe_2O_3- 12.2%

Natural Aggregate

Granite aggregates were used and its physical properties are given in Table 3.

Table 3: Properties of Natural aggregate

Properties	Values
Specific gravity	2.72
Los Angeles abrasion value	30.2%

Recycled Aggregate

Recycled aggregates are taken from the demolished building in the surrounding area. The properties of used aggregate are given in Table 4.

Table 4: Properties of Recycled aggregates

Properties	Values
Specific gravity	2.53
Los Angeles abrasion loss	42.4%

Experimental Investigations

The numbers of mixes were obtained by changing three parameters - Cement content, amount of coarse aggregate, aggregate-cement ratio. The cement content was varied from 300 kg/m^3 to 400 kg/m^3 with an increment of 50 kg/m^3. Percentage replacement of recycled aggregates was varied from 0%, 50% and 100%. The aggregate cement ratio was varied as 4 to 6. The pervious concrete for the nine mixes were prepared in nine separate batches. The coarse aggregate was sieved through 20 mm sieve. Cement and fly ash for each mix was batched on the day of casting. Water-cement ratio was obtained based on workability criteria. The mixture was reviewed for consistency by taking a handful of pervious concrete mix and creating a ball. If the aggregate gets separated and was not able to maintain the ball shape, the mixture was considered as too dry. If the ball had a lot of paste, the aggregate was running off and sticking to the glove, and then the mixture was considered as too wet. The range was found to be from 0.32 to 0.45. Although this was subjective, it has been considered a common practice in the industry. Once the observations were noted, the mixtures were then placed in three 150 mm cubes, two 150 x 100 mm cylinders and one 150 x 300 mm cylinder. Each specimen was compacted in 3 layers. After 24 hours, the specimens were demolded and subjected to curing by immersion. Then the cubes and cylinders were tested for compressive strength, split tensile strength and infiltration test at the age of 28 days.

Mix Proportions

Table 5: Mix proportions

MIX NO	CEMENT (kg/m^3)	RCA % of Replacement	A/C	Cement (kg)	NA (kg)	RCA (kg)	Flyash (kg)	W/C
PC1	300	0	6	3.7	27.6	0	0.9	0.32
PC2	300	100	6	3.7	0	27.6	0.9	0.45
PC3	300	50	4	3.7	9.2	9.2	0.9	0.4
PC4	350	0	4	4.3	21.6	0	1.1	0.35
PC5	350	100	4	4.3	0	21.6	1.1	0.42
PC6	350	50	6	4.3	16.2	16.2	1.1	0.4
PC7	400	0	6	4.9	36.6	0	1.2	0.37
PC8	400	100	6	4.9	0	36.6	1.2	0.38
PC9	400	50	4	4.9	12.2	12.2	1.2	0.38

Results and Discussion

Compressive Strength and Tensile Strength

Fig 1(a) Cube under compression test

Fig 1(b) Cylinder under split tensile test

All the 150 mm cubes were tested at the age of 28 days for assessing its compressive strength. This test was performed using compression testing machine. The peak load and stress carried by the cubes were noted. Since tensile strength for concrete cannot be done directly, the split tensile strength test was done by placing the cylinder horizontally in the compression testing machine such that the load was applied perpendicular to the axis. The results are given below.

Table 6: 28 day Compressive and tensile strength values

MIX	Tensile Stress (MPa)	Compressive Stress (MPa)
PC1	5.77	11.13
PC2	3.24	13.79
PC3	9.03	12.77
PC4	7.17	11.75
PC5	4.44	13.18
PC6	2.79	12.77
PC7	6.12	12.16
PC8	3.52	12.36
PC9	4.58	12.16

Effect of W/C Ratio on Compressive Strength

The plot between w/c ratio and compressive strength were shown below. The results indicate that the compressive strength increases with increases in w/c ratio. The compressive stress varies linearly with w/c ratio.

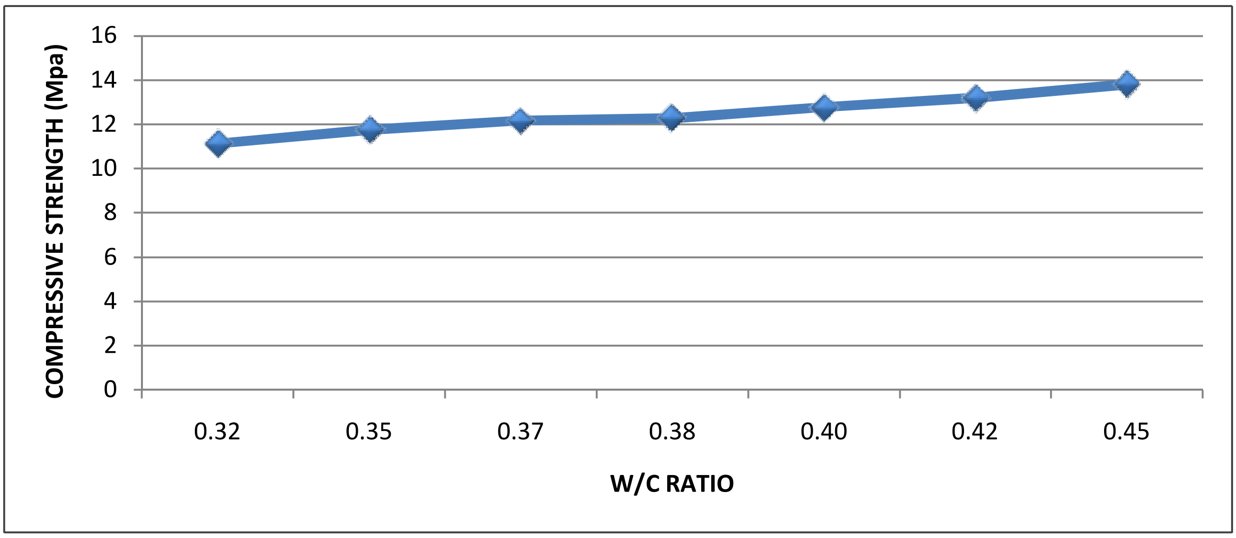

Figure 1: Effect of w/c ratio vs. Compressive strength

Effect of Cement Content and Agg/Cement Ratio on Infiltration

Table 7: Infiltration Test Results

Mix	Cement Content (kg/m^3)	Time (s)	Infiltration (in/h)
PC1	300	30	544.44
PC2	300	32	510.41
PC3	300	40	480.76
PC4	350	45	363.71
PC5	350	50	327.09
PC6	350	37	442.21
PC7	400	47	348.76
PC8	400	51	320.92
PC9	400	38	432.56

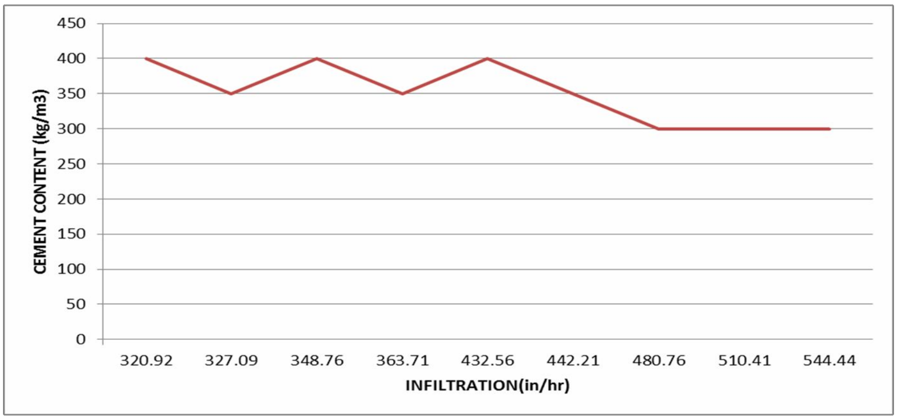

Figure 2: Plot between infiltration and cement content

From the above graph it can be seen that infiltration rate is in the range of 480 - 540 in/hr for the cement content value of 300 kg/m^3. The cement content values are between 350 kg/m^3 and 400 kg/m^3 it is in the range of 320 - 440 in/hr. Hence infiltration rate is high for a cement content value of 300 kg/m^3.

Fig 2 Infiltration test using single ring infilterometer

Conclusions

1) The overall results indicate that use of recycled concrete aggregate as coarse aggregates with fly ash binder for making pervious concrete was found to be feasible with acceptable properties.
2) The optimum cement content should be from 300 to 400 kg/m^3. The replacement of fly ash can be upto 20%. The aggregate-cement ratio can be in the range 4-6 of which 6 gave good infiltration and strength results.
3) Using natural aggregate with partial replacement of recycled concrete aggregate resulted in significant losses in strength as compared to a natural aggregate pervious concrete.

4) Use of fully recycled aggregates gave desirable results in both strength and infiltration when compared to partially replaced RA.

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