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Experimental Investigations on Previous Concrete Produced by Blending Recycled Aggregates along with Low Density Aggregates

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Abstract

Pervious concrete is a special type of concrete, which consists of cement, coarse aggregate, water with the minimal or no fine aggregate and admixtures if required. Due to high void ratio Pervious concrete allow storm water to infiltrate into the soil and overcome runoff problems. In this paper, the main aim is to develop a pervious concrete using recycled aggregates along with the low-density aggregates i.e., cinder for sustainable construction. Use of recycled aggregates along with cylinder aggregates helps to produce acceptable service concrete having both drainage and strength properties. The mix ratios of cinder and recycled aggregates in this paper is varied in the proportion of 50-50%, 75-25%, 25-75% and full replacements. The pervious concrete specimens were evaluated by determining the compressive strength, split tensile strength test at 7 & 28 days curing and permeability test after 28 days. But it can be noted that with increase in strength, the permeability of pervious concrete will be reduced. Hence, the improvement of strength should not affect the permeability property because it is the property which serves its purpose.

1. Introduction

Pervious concrete is a special type of concrete, which consists of cement, coarse aggregate, water and if required admixtures are used. Controlled amounts of water and cementitious material are used to create a paste that forms a thick coat around the aggregate particles without flowing off during mixing and placing. As there are no fine aggregates used, the void content is more, which allows the water to flow through its body. Hence, the pervious concrete is also called as permeable concrete and porous concrete. The increasing population in metro political cities brings urban sprawl which leads to impact on environment. The land use changes made into residential areas and industrial areas has increased the surface runoff problems as everywhere impervious pavements are used. Pervious concrete is the best solution for runoff problems and can support ground water recharge. The compressive strength of pervious concrete is less when compared to conventional concrete due to its porosity and voids. Hence, the usage of pervious concrete is limited inspite it has lot of advantages.

Nowadays the world's attention towards the environmental issues continues to increase, especially utilization of construction and demolition waste to avoid increasing off landfill issues. Concrete being most consumable thing in the world after water. The demolition waste producers approximately 20 billion tonnes per year causing environmental problems. By recycling concrete waste as in aggregate is another solution to the environmental problems being faced. Natural aggregates need to be obtained from quarries which obtain from mountains thereby reducing use of natural aggregates indirectly helps environment. Pervious concrete is a unique and effective means to address important environmental issues and sustainable growth. Environmental Protection Agency (EPA) has identified parvas concrete as a Best Management Practice (BMP) for storm water management. When it rains pervious concrete automatically acts as drainage system thereby putting water back into where it belongs.

Pervious concrete is rough textured and has honeycombed surface. The lack of sand in Pervious concrete results in a very harsh mix that negatively affects mixing and placing. In this study along with recycled concrete aggregates cinder aggregates is used. Cinder is in industrial waste which is obtained from iron and steel

manufacturing factories. Utilization of cinder aggregates is also another step towards the sustainable construction. The density of the cinder aggregate and recycled aggregate is lesser than normal aggregates natural aggregates thereby producing a lightweight Pervious concrete. This paper presents a systematic work to address the same.

2. Experimental Work

2.1 Materials

Materials used in the study are discussed below:

2.1.1 Binder: In this study we have used the Ordinary Portland cement of 43 grade is used, the characterization of cement are shown in Table 1.

Table 1: Properties of 43 Grade OPC.

Tests	Values
Specific gravity	3.1
Fineness test	2%
Initial setting time	34min
Final setting time	10hrs
Standard consistency	36%

2.1.2 Coarse aggregate:

Fig 1. Recycled aggregate and Low density aggregate(Cinder)

a) Recycled concrete: Aggregate of size 20mm -10mm are used for the study. Recycled aggregate are obtained from C&D processing unit. The characteristics of Recycled aggregate are shown in Table 2.

Table 2: Properties of Recycled Aggregate

Tests	Values
Specific gravity	2.3
Crushing strength	17.12%
Impact strength	27.74%
Bulk density	1673kg/m³
Water absorption	27%

b) Cinder: Type of Cinder aggregate used was artificial type of size 20mm to 12mm are used for the study. Cinder was obtained from local supplier. The characteristics of Cinder are shown in Table 3.

Table 3: Properties of Cinder Aggregate.

Tests	Values
Specific gravity	1.9
Crushing strength	12.32%
Impact strength	51%
Bulk density	641kg/m³
Water absorption	13%

From Table 2 & Table 3 it can be observed that cinder aggregate and recycled aggregates bulk density are lesser than the natural aggregate thereby the unit weight of concrete is reduced. The water absorption of recycled aggregate is higher because of the mortar coat on the aggregates, hence before using the aggregates for casting of specimens they were soaked in water and surface dried

2.2 Mix Design

In this paper for the mix design, we have used the "Guidelines for Mix Design for Cement Concrete Pavements" i.e., IRC 44-2017 Chapter 6. IRC 44 is a code of practice issued by the Indian Roads Congress (IRC) for the use of pervious concrete in road construction. The code provides guidelines for the design, construction, and maintenance of pervious concrete pavements.

In this study we have designed the pervious concrete for 0% fine aggregate and 10% fine aggregate in the specimens. The quantities of the materials per cubic meter after following the design steps and procedure mentioned in IRC 44 are illustrated in Table 4 & 5.

Table 4: Quantities for '0'% fine aggregate.

Sl. No	Materials	Proportion (kg/m³)
1	Cement	350
2	Recycled Aggregate	1560
3	Cinder Aggregate	1300
4	Water Cement ratio	0.35
5	Fine Aggregate	0

Table 5: Quantities for 10% fine aggregate.

Sl. No	Materials	Proportion (kg/m³)
1	Cement	305
2	Recycled Aggregate	1440
3	Cinder Aggregate	1200
4	Water Cement ratio	0.35
5	Fine Aggregate	189

2.3 Casting of specimens

The specimens were casted after calculating the mix design with appropriate mix proportions. Specimens of cube and cylinders are prepared for compression and split tensile strength test. The aggregate proportions in each batch is varied to check the strength variation. The aggregate proportion in each batch is shown in Table 6. Based on the previous study made we made a conclusion that adding fine aggregate in the preparation on specimens increased the strength with reduction of permeability so in this study only in the first batch we have casted for 0% fine aggregate and all other batches we have casted with 10% of fine aggregate.Cubes of size 150x150x150mm are cast for compression strength test and cylindrical specimens of 100mmϕ and 200mm length were casted for split tensile strength test and permeability test.

Fig 1. Recycled aggregate and Low density aggregate(Cinder)

Table 6: Aggregate proportions in Batches.

Batch Number	Cinder Aggregate	Recycled Aggregate	Fine aggregate
1	50%	50%	0
2	50%	50%	10%
3	75%	25%	10%
4	100%	0%	10%
5	0%	100%	10%
6	25%	75%	10%

2.4 Curing

The test specimens are stored in moist air for 24hours after casting and after this period the specimens are demolded and marked and kept submerged in clear fresh water until taken prior to tests.

3. Testing procedure

The compressive strength test and split tensile test was performed on all seven batches prepared from the three mix designs with varying proportions of cinder and recycled aggregate. Two samples from each batch were tested for compressive strength and split tensile strength was determined. Specimens with two curing times (7-days and 28-days) was used in the compressive strengths test and split tensile strength. The dimensions of each sample were measured at the top, and bottom after which the cross-sectional area is calculated. Each specimen was loaded until the load began to decrease rapidly. The compressive strength was then calculated by dividing the average final maximum load recorded by cube at failure to the average to cross-sectional area of the cube. The split tensile strength was determined by using the formulae

$$\sigma = \frac{2P}{\pi DL}$$

where P is failure load, D is diameter of cylinder, L is length of cylinder.

The permeability test was performed in accordance with IRC 44 under Annexure A (Testing Method for Measuring Permeability of Pervious Concrete). The permeability test setup is illustrated in Fig 6. As per Annexure A, after 28days of water curing, cylindrical specimen with 100mmϕ and 200mm length were to be tightly wrapped with 5layers of stretch film to prevent percolation through the sides. Then prewetting of specimens need to be done. In study due to unavailability of hot air blower, we have coated a thin layer of cement paste all around the cylindrical specimen except top and bottom. And falling head method is used to calculate the coefficient of permeability, by using the equation below,

$$K=2.303\frac{al}{At}\log_{10}\frac{h1}{h2}$$

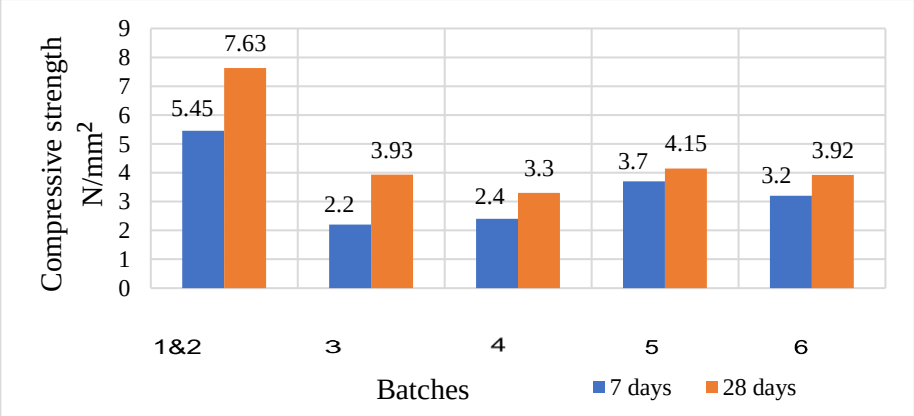
In this equation, a is area of stand pipe, L is the length of specimen, A is the cross-sectional area of specimen, t is time elapsed between h1 & h2, h1 is initial head and h2 is final head.

4. Results and Discussions

The strength properties like compressive strength and split tensile strength of casted specimens were calculated as per ASTM 39 and ASTM C 496 respectively. The permeability is also determined for the different mix ratio. The results of the tests are discussed below.

4.1 Compressive strength

Fig 7 & 8 shows that the compressive strength is increased by inclusion of sand in the specimens have high compressive strength. Among all the specimens prepared highest compressive strength obtained was 7.63MPa



for 50% cinder and 50% recycled aggregate along with 10% of fine aggregate. The results of the compressive strength are shown in Table7

Table7 Results of compressive strength test.

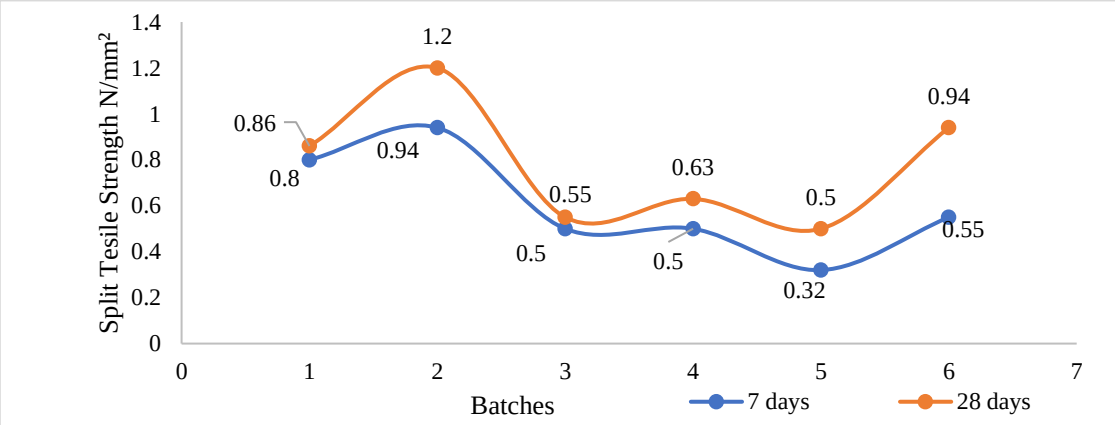
Batch No	Compressive strength			
	7 days		28 days	
	0% Fine aggregate	10% Fine aggregate	0% Fine aggregate	10% Fine aggregate
1 & 2	2.8	5.45	3.71	7.63
3	1.98	2.2	3.1	3.93
4	1.8	2.4	2.9	3.3
5	2.2	3.7	3.3	4.15
6	2.8	3.2	3.5	3.92

4.2 Split Tensile Strength

The result of split tensile strength test of specimens made with 10% of fine aggregate (except for Batch 1) are shown in Table 8. The maximum split tensile strength obtained was 1.2MPa with is within range of 0.5MPa to 1.5 MPa.

Table 8 Results of split tensile strength test.

Split Tensile strength (N/mm²)		
Batch	7 Days	28 Days
1	0.8	0.86
2	0.94	1.2
3	0.5	0.55
4	0.5	0.63
5	0.32	0.5
6	0.55	0.94



4.3 Permeability

The permeability being the main test for pervious concrete, the infiltration rate mainly depends on the void content of the concrete, in this study while designing, void content of 20% is kept for all the mix ratios. The coefficient of permeability is determined by using falling head method and the setup procedure is followed mentioned in IRC 44. At 28-days curing the highest infiltration achieved is 0.3cm/sec i.e., for 0% fine aggregate and for 10% the values changed and illustrated in Table 9.

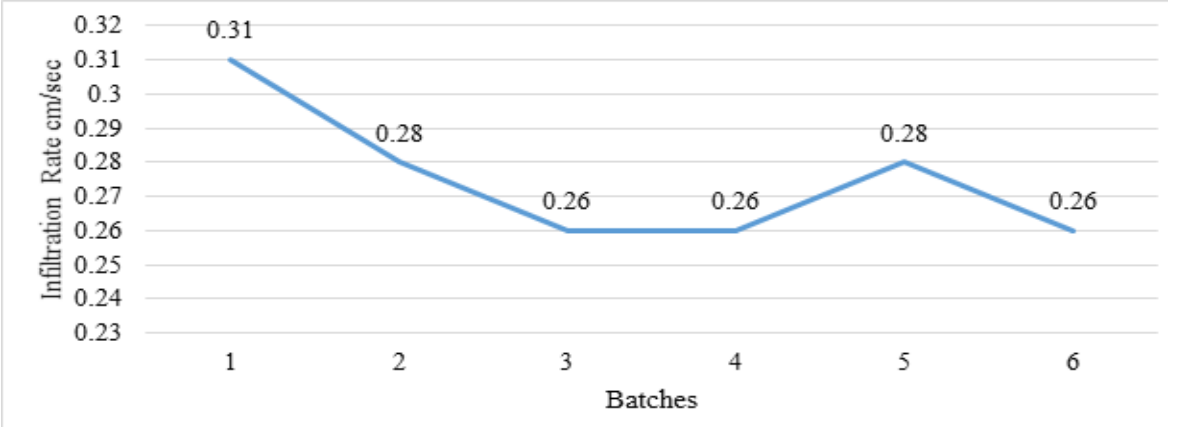


Table 9. Results of Permeability test.

Batch no	Initial head (cm)	Final head (cm)	Time Elapsed (sec)	Infiltration rate cm/sec	
1	99	1	12	0.31	
2	99	1	13	0.28	
3	99	1	14	0.26	
4	99	1	14	0.26	
5	99	1	13	0.28	
6	99	1	14	0.26	

5. Conclusions

The ideal pervious concrete mix is expected to provide the maximum compressive strength, and the optimal infiltration rate. Especially for pervious concrete used on roadways, there is the need for it to be able to withstand various traffic loadings while providing adequate infiltration to reduce surface runoffs. From the results of the analysis made, the Control Mix is recommended which showed a maximum compressive strength of 7.63MPa with a coefficient of permeability of 0.28cm/sec.

1. The utilization of recycled coarse aggregate along with cinder aggregate in the ratio of 50% - 50% to replace natural coarse aggregate has increased compressive strength and splitting tensile strength of pervious concrete.
2. The unit weight of RA concrete is less than NA concrete. This could be attributed to light adherence and the porous nature of old cement mortar to the recycled aggregate.
3. The size of coarse aggregates, water to cement ratio and aggregate to cement ratio play a crucial role in strength of pervious concrete.
4. The infiltration rate of the pervious concrete specimens is reduced by 10% when 10% of fine aggregate is added.

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