Pervious Concrete Block with Recycled Aggregate

Mubashir.V. P[1], Vyshak Ram.M[2], Athul.K. E[3],Jaritha.P[4], Afsana Meheri.A.C[5], Gokul.A[6]
[6]*Assistant Professor, Department of Civil Engineering, Eranad Knowledge City Technical Campus, Manjeri, Malappuram, Kerala, India.*
[1,2,3,4,5]*B. TechStudents, Department of Civil Engineering, Eranad Knowledge City Technical Campus, Manjeri, Malappuram, Kerala, India.*

Abstract —*Pervious concrete pavement block is a unique and effective means to address important environmental issues and support green, sustainable growth. Major portion of precipitation reaching into earth will drain out in addition to soil infiltration. Pervious concrete block is capable to capture the water and allowing it to seep into the ground. Almost all type of pavement block available in market is not permeable. If the slope is not sufficient or debris filled on pavement block joints, will causes water logging. So the necessity of pervious concrete block is important for sustainable development, also helps to accelerate ground water recharge. Now a day, demolished concrete waste is one of the non-degradable waste in the earth. Recycling has a number of benefits that have made it a more attractive option in this age of greater environmental awareness, more environmental laws, and the desire to keep construction cost down. Pervious concrete is different from conventional concrete which contains cement, coarse aggregate, and water as main constituents. The coarse aggregate is bonded with paste formed from cement and water leaving void spaces which allows water to infiltrate. Unlike conventional concrete pervious concrete has high permeability. The proposed pervious concrete block with recycled aggregate is eco-friendly, which can replace the conventional interlock brick.*

Keywords —*Permeability, Porosity, Zeolite, Percolation, Interlock.*

I. INTRODUCTION

Pervious concrete is a special type of concrete having high porosity. It consists of cement, coarse aggregate, little or no fine aggregate, admixtures, and water. Combination of these ingredients when mixed, placed, compacted and cured properly, produce a hardened material that not only has sufficient strength and durability to bear the specified load and to resist environmental conditions, but also have interconnected pores that provide adequate permeability to the material. Pervious concrete pavement is expected to reduce the impact of development by allowing the rain water to percolate to the soil below, recharging the ground water aquifers, reducing the volume of direct water runoff from pavement and enhancing the quality of storm water. It reduces or eliminates the need for additional control structures, such as retention ponds for storing the run off.

The uniform coarse aggregate gradation in combination with low water-cement ratios ranging from 0.28 to 0.4 makes a concrete mixture with void contents ranging from 18% to 35% which allows for high water and air permeability. The compressive, tensile, and flexural strength of pervious concrete mixtures tend to be lower than that of conventional concrete due to the high void ratio and lack of fine aggregates.

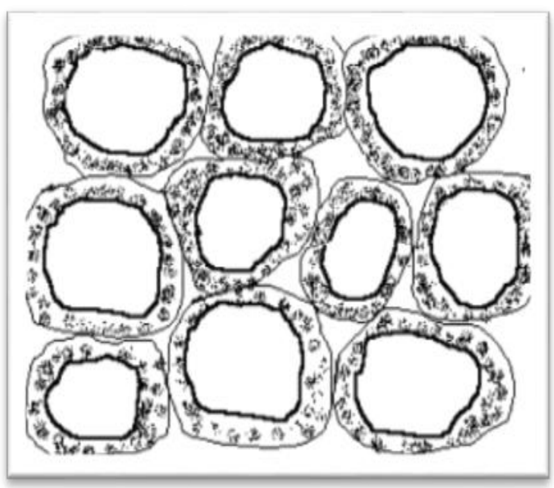

Fig. 1: A schematic model of pervious concrete

A schematic model of pervious concrete is shown in Fig.1. The porous structure allows both water and air to percolate through the matrix into the subsoil beneath. Because of the interconnected pores, pervious concrete not only reduces runoff, but also performs the role of a filter by the entrapment of contaminants such as oils and debris on and within the pervious concrete structure. The size of these pores is affected by the gradation and type of the aggregate in the mix, the quantity of water and cement added, and the level of compaction.

Pervious concrete pavements also have greater acoustic absorption properties than conventional concrete pavements, which results in quieter pavements. This superior acoustic absorption is due to the porous nature of the material. Due to its open structure, it helps absorb noise at the tire–pavement interface.

Fig. 2: Permeability of porous concrete

Pervious concrete's key characteristic is its open pore structure that allows high rates of water transmission as shown in Fig.2. More recently, pervious concrete has been certified for construction projects by the US Green Building Council's Leadership in Energy and Environmental Design (LEED) Green Building Rating System, because of its environmental benefits along with the potential capability of lowering the heat island effect. (The heat island effect is a situation where the average temperature of an urban area is higher than nearby rural areas. It is caused by the absorption of sunlight by materials like concrete and asphalt.) Urban areas tend to enclose large areas of impervious pavements, which add to the level of heat. The concentrated heat wave can be reduced by the open structure of pervious concrete that allows air to flow through it. Additionally, the roots of plants and trees adjacent to these pavements not only experience watering but also aeration.

II. PROPERTIES OF CONSTITUENT MATERIALS

Determine all material properties such as specific gravity, standard consistency, compressive strength and setting time of cement. Similarly, the material properties such as specific gravity, porosity, void ratio and bulk density of aggregate were also determined. After determining the material properties mixes were prepared by varying the quantities of recycled aggregate keeping water cement ratio constant.

A.Cement

Bharathi 53 grade Ordinary Portland cement confirming to IS 12269-1987 was used throughout the experimental program. Different laboratory tests were conducted on cement to determine standard consistency, initial and final setting time and compressive strength as per IS 4031-1988. The results of the tests conducted on cement is tabulated in the Table 1.

Table 1: Properties of Cement (BHARATHI OPC 53 GRADE)

Properties	**Values**	**Recommended values (IS 12269-1987)**
Specific Gravity	3.15	
Standard Consistency	33%	
Initial Setting time	90 minutes	>30 minutes
Final Setting time	310 minutes	<600 minutes
Compressive Strength 3^{rd} day 7^{th} day	 27 N/mm^2 42 N/mm^2	 >27 N/mm^2 >43 N/mm^2

B. Coarse Aggregate

Crushed rock was used as coarse aggregate in this study. The different tests as per IS 2386-1963 (Reaffirmed 1990) were concluded on coarse aggregate. The properties of coarse aggregate are tabulated in Table 2.

Table 2: Properties of Aggregate

Property	**Values**
Bulk density (kg/m^3)	1.465x10^3
Void ratio	0.749
Porosity (%)	42.85
Specific Gravity	2.86

C. Recycled Aggregate

The demolished waste of a bridge is used as the recycled aggregate. Some properties of recycled aggregate are tabulated in Table 3

Table 3: Properties of Recycled and Normal Aggregate.

Properties	Recycled Aggregate	Normal Aggregate
Water absorption (%)	4.6	1.2
Specific gravity	2.62	2.86

III. MIX SESIGN

As per the ACI design (522. 1-13) procedure followed and given below. Water cement ratio is taken as 0.31.

A. Determination of Coarse Aggregate (Wa)

Stone with no fine aggregate ACI table 6.1 recommends b\bo of 0.99, with dry-robbed

density given as 1465 Kg \m3

Wa = Dry rotted density\ (b/bo)

Wa = 1465 Kg/m3 x 0.99

= 1450Kg (Dry weight)

B. Adjust to ssd Weight (wssd)

Wssd = Wa X water absorption on Aggregate.

Wssd = 1450 Kg X 1

= 1450 Kg (ssd)

C. Determination Paste Volume (Vp)

ACI table 6.3 and read along the required percentage voids (40%for this example) to the well compacted curve. Then read down to find the paste percentage at 30% of a cubical yard is $8.10ft^3$.

Thus,

$Vp = 8.10ft^3$

D. Determination of Cement Content (C)

C = {Vp/(0.315 + water cement ratio)}x1000

C = {(8.10/35.314)/ (0.31 +0.38)} X1000

=330 Kg

E. Determination of Water Content (W)

W = Cement x water cement ratio.

W = 330Kg x 0.31

= 102 Kg

F. Iterative Trail Batching and Testing

The trail batch weight per cubic meter as follows;

Cement	=330 Kg
Water	=102 kg
Coarse Aggregate	=1450 kg
Total weight	=1882 Kg.

IV. DETAILS OF CASTING

The casting conducted by three stages. In the first stage, casting conducted for determining the compressive strength, split tensile strength and flexural strength on the standard moulds. For this 30 Beams, 30 Cubes and 30 Cylinder specimens were casted. In the second stage of casting 30 interlock blocks having size 18cm x 21cm x 6cm is casted, which is the normal interlock block size available in the market. After the mixes are prepared, they are filled in the respective moulds and immersed in water after 24 houres. After 7 days and 14 days of water curing, hardened properties such as compressive strength, flexural strength and split tensile strength are determined for beams, cubes and cylinders. Only compressive strength test is conducted for block specimen. In the 3rd stage, casting conducted for determining the constant head permeability. For this 15 cylindrical specimen of standard size were casted. In all casting water cement ratio kept as 0.31 and recycled aggregate are replaced by normal aggregate by 20%, 30%, 40% and 50%.

Fig. 3: Prepared Block Specimen

Fig. 4: Prepared Specimen

V. TEST DETAILS

A. Workability

Fresh concrete or plastic concrete is freshly mixed material which can be moulded into any shape. The relative quantities of cement, coarse aggregate and water mixed together control the concrete properties in the fresh state. Workability is defined as the ease with which concrete can be compacted. It is the property of concrete which determines the amount of useful internal work necessary to produce full compaction. Workability of conventional and pervious concrete is found out using Slump test. Workability of various mixes are assessed by determining compacting factor as per IS: 1199-1959 specification.

The concrete slump test measures the consistency of fresh concrete before it sets. It is performed to check the workability of freshly made concrete, and therefore the ease with which concrete flows. It can also be used as an indicator of an improperly mixed batch. The test is popular due to the simplicity of apparatus used and simple procedure. The slump test is used to ensure uniformity for different loads of concrete under field conditions. The test is carried out using a metal mould in the shape of a conical frustum known as a slump cone or Abramscone, that is open at both ends and has attached handles. The tool typically has an internal diameter of 100 millimeters at the top and of 200 millimeters at the bottom with a height of 305 millimeters. The cone is placed on a hard non-absorbent surface. This cone is filled with fresh concrete in three stages. Each time, each layer is tamped 25 times with a 2 ft. (600 mm)-long bullet-nosed metal rod measuring in 16 mm in diameter. At the end of the third stage, the concrete is struck off flush with the top of the mould. The mould is carefully lifted vertically upwards, so as not to disturb the concrete cone.

B. Compressive Strength

Compressive strength at 7days,14 days are tested on 150 x 150 x 150 mm cubes. The test specimens were immersed in water in curing tanks after 24 hours of casting for 7days, 14days.The test was conducted according to the Indian Standard IS. Three specimens were tested each time and the average of the value is taken [1,5,11]

C. Flexural Strength

The flexural test measures the force required to bend a beam under mid-point loading conditions. Flexural strength at 7days,14 days are tested on beam of size 500 x 100 x 100 mm. The test specimens were immersed in water in curing tanks after 24 hours of casting for 7days, 14days.The test was conducted according to the Indian Standard IS. Three specimens were tested each time and the average of the value is taken [1,5,11]

D. Split Tensile Strength

Split Tensile strength at 7days,14 days are tested on cylinder of 300mm length and 150mm diameter. The test specimens were immersed in water in curing tanks after 24 hours of casting for 7days, 14days.The test was conducted according to the Indian Standard IS. Three specimens were tested each time and the average of the value is taken [1,5,11]

E. Constant head permeability test

The ability to allow water pass through its pore structure enables the pervious concrete to stand out among other concrete types. Thus water permeability is a major property for evaluating the performances of pervious concrete.

Constant head permeability test measures the amount of water that goes through a sample in a determined time. in order to perform test, the procedure shown in fig.5 was followed. First of all, specimen is casted in a standard size pipe and which is placed between two PVC pipes with a diameter of 10.16 cm. The water used to keep constant level came from a hose placed on the top of the PVC pipe [2]

Fig. 5: Constant Head Permeability Test

VI. RESULTS AND DISCUSSION

The strength and durability studies were conducted on pervious concrete mixes based on the experimental investigations mentioned in the previous chapter. The test results obtained were tabulated and a detailed analysis and discussion on the results are presented in this chapter. Each test result plotted in the figures or in the tables is the mean value of results obtained by testing three specimens.

A. Slump Test

Table 4: Slump at Different Recycled Aggregate Proportions

Recycled aggregate (%)	Height after subsidence (cm)	Slump (cm)
0	25	5
20	25	5
30	25	5
40	25	5
50	25	5

It was observed from slump test that the pervious concrete is a zero slump concrete.

B. Compressive strength

Table 5: Compressive Strength Test Results of Cube

Percentage of Recycled Aggregate Added (%)	7 Day		14 Day	
	Load (kN)	Compressive Strength (N/mm^2)	Load (kN)	Compressive Strength (N/mm^2)
0	210	9.33	300	13.33
20	180	8.00	260	11.56
30	160	7.11	220	9.77
40	150	6.66	190	8.44
50	130	5.77	180	8.00

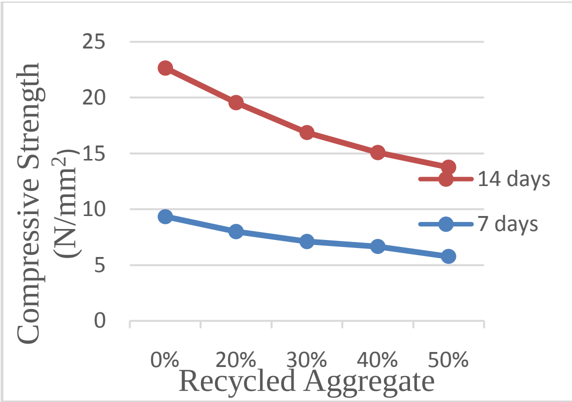

Fig. 6: Compressive Strength of Cube at 7 Days and 14 Days

Table 6: Compressive Strength Test Results of Blocks

Percentage of Recycled Aggregate Added (%)	7 Day		14 Day	
	Load (kN)	Compressive Strength (N/mm²)	Load (kN)	Compressive Strength (N/mm²)
0	150	3.96	280	7.40
20	140	3.70	250	6.61
30	130	3.44	210	5.56
40	130	3.44	200	5.29
50	100	2.65	190	5.02

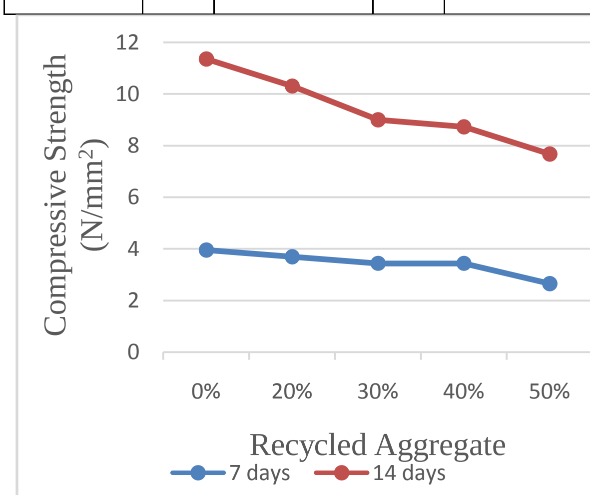

Fig. 7: Compressive Strength of Block at 7 days and 14 days

From the compression test it was observed that, the highest compressive strength is reported in 0% recycled aggregate (Normal aggregate) mix. Meanwhile for 20%replacement of normal aggregate by recycled aggregate showed very close compressive strength to normal aggregate mix. Compressive strength reduced with increasing recycled aggregate content. [11]

C. Split Tensile Strength

Table 7: Tensile Strength Test Results

Percentage of Recycled Aggregate Added (%)	7 D ay		14 Day	
	Load (kN)	Tensile Strength (N/mm²)	Load (kN)	Tensile Strength (N/mm²)
0	110	1.56	136	1.92
20	96	1.36	118	1.67
30	87	1.23	106	1.49
40	77	1.10	96	1.36
50	68	0.96	85	1.20

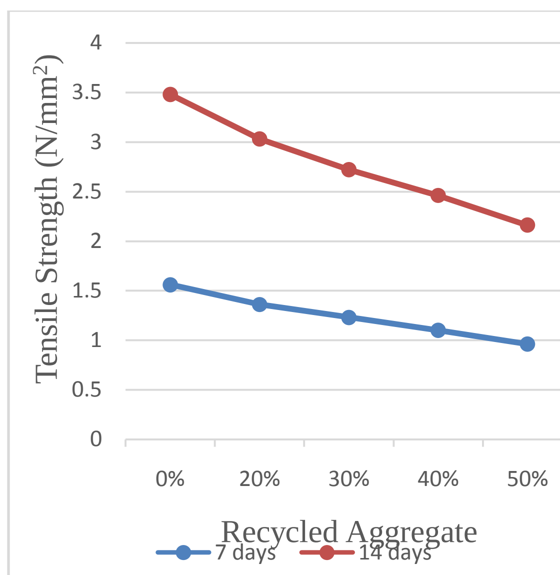

Fig. 8: Tensile Strength at 7 days and 14 days.

From the split tensile test, it was seen that, the tensile strength showed a similar trend, that is the highest Tensile strength is reported in 0% recycled aggregate (Normal aggregate) mix. Meanwhile for 20%replacement of normal aggregate by recycled aggregate showed very close tensile strength to normal aggregate mix. Tensile strength reduced with increasing recycled aggregate content. [11]

D. Flexural Strength

Table 8: Flexural Strength Test Results

Percentage of Recycled Aggregate Added (%)	7 Day		14 Day	
	Load (kN)	Flexural Strength (N/mm^2)	Load (kN)	Flexural Strength (N/mm^2)
0	2.55	1.53	4.30	2.58
20	2.54	1.52	3.65	2.19
30	2.30	1.38	3.30	1.98
40	1.90	1.14	2.75	1.65
50	1.84	1.10	2.30	1.38

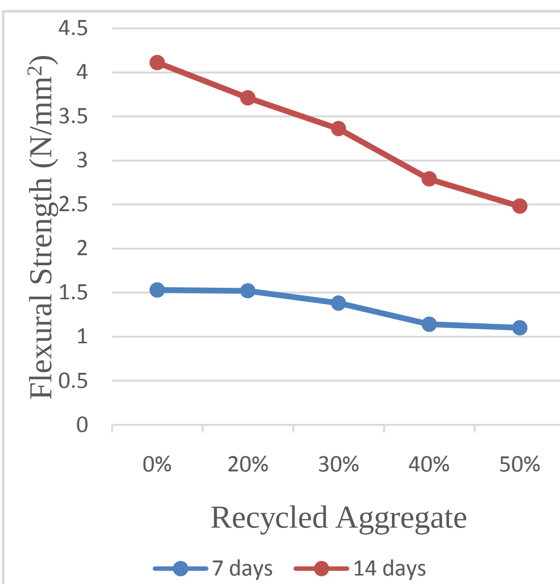

Fig. 9: Flexural Strength at 7 days and 14 days.

In the mid-point test, highest Flexural Strength is reported in 0% recycled aggregate (Normal aggregate) mix. Meanwhile for 20%replacement of normal aggregate by recycled aggregate showed very close Flexural Strength to normal aggregate mix. Flexural Strength reduced with increasing recycled aggregate content. [11]

E. Permeability of Hardened Concrete

Table 9: Constant head permeability Test Results

Percentage of Recycled Aggregate Added (%)	Quantity of water collected (Q) cm^3	$q=\frac{Q}{t}$	Coefficient of permeability (k) cm/s
0	7100	118.3	0.17
20	6000	100.0	0.14
30	4600	76.6	0.11
40	3350	55.8	0.08
50	3050	50.8	0.07

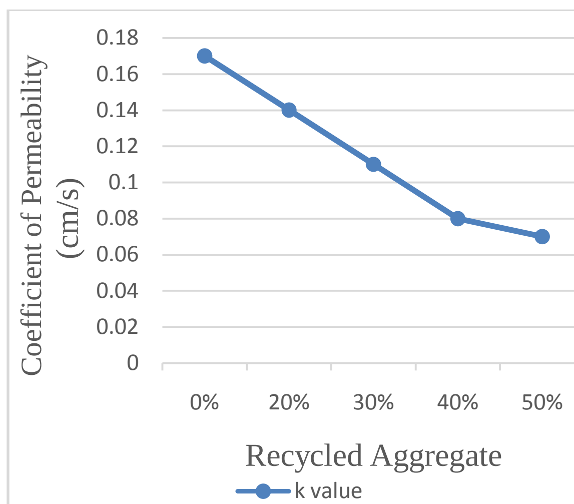

Fig. 10: Coefficient of permeability.

In the constant head permeability test, highest Coefficient of permeability is reported in 0% recycled aggregate (Normal aggregate) mix. Meanwhile for 20%replacement of normal aggregate by recycled aggregate showed very close Coefficient of permeability to normal aggregate mix. Coefficient of permeability reduced with increasing recycled aggregate content. [2,11]

VII. CONCLUSION

Decrease in the amount of percolation of rainwater and thereby the untimely effect on ground water table is one of the cautionary impacts of large scale concrete floors. Now with the proper study and implementation of porous concrete at these open spaces can simultaneously cater to the need of aesthetics and preservation.

A mix with 20% recycled aggregate can be chosen as the optimum design for almost all locations.

From the above study it can be inferred that a well-designed pervious concrete blocks can have sufficient strength to carry loads at the site. The feasibility of its use is limited to places with good supportive drainage, if it receives a moderate to heavy rainfall. Also by the use of recycled aggregate, demolished concrete waste don't become a burden to the environment. Hence the pervious concrete block with recycled aggregate is a sustainable construction material.

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