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Performance of Recycled Aggregate in Pervious Concrete

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Abstract- ***Pervious concrete can be noticed as a gap-graded concrete. This type of concrete treats a new way to control or manage of storm water. The pervious concrete is important to address bionomical issues and confirmable growth. In beside, demand for aggregate to producing concrete is still high while natural resources are reducing. In this connection at attempts has been made for utilization of recycled aggregate in the concrete mix, by replace the natural coarse aggregate in the ratio of 0, 25, 50, 75 and 100%. To obtain the behavior of pervious concrete compressive, split and bearing strength are evaluated. In the addition to those strengths, coefficient of permeability also found. In this experimental work total five mixes are taken to evaluate strengths. A regression model has developed to assess the split tensile strength and ANSYS software has been used to know the stress and strain variation for the cube specimens. From experimental work, it is noticed that, the pervious concrete with recycled aggregate is viable for pavement works.***

Key Words: Recycled aggregate (RA), Pervious concrete, Compressive strength, Split Tensile strength, Bearing strength and ANSYS Software

I.INTRODUCTION

Pervious concrete has been used approximately 150 years ago in construction industry. Firstly it was used in Europe, where it was referred as gap graded concrete. The initial application of this type of concrete was found in load bearing walls, making of pre-fabricated panels. In the year 1852, the construction of two houses using pervious concrete was carried out by Richard Langle in UK. In late 1930's the technology was used for residential construction by Scottish Housing Association and at the end of 1942 over 900 houses were built by this concrete. After World War II, pervious concrete was made use to support the housing needs as there was scarcity of availability of building bricks and also due to its lower production cost its popularity spread in the regions of Europe and Middle East countries. In US it did not gain much popularity, as there was no scarcity of building material. Currently, pervious concrete finds its application only for pavement purpose such as sidewalks and parking lots.

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Pervious concrete can be noticed as permeable, gap-graded, and enhanced porosity or no fines concrete, this concrete is treated as new way to control, manage and it treat storm water runoff. Porous concrete thus allow1the excess of water to infiltrate into the ground by effectively capturing and retaining the storm water and there by recharging ground water. Pervious concrete comprises little or no fine aggregate (sand) and carefully measured amounts of cementations materials and water. The paste binds the aggregate particles together to develop a system of interconnected and highly permeable voids that encourage the quick drainage of water by definition; pervious concrete is mixture of the cement, granite stone and little to no sand (fine aggregate), and water. When the pervious concrete is used for pavements the open cell structures permit storm water to pass through the pavement into the underlying to ground. Pervious concrete is an also the important and effective means to an address ecological issues to sustainable growth. Pervious concrete acts to a drainage system in the regions of heavy rainfall; thereby placing water back where is it belongs. Pervious concrete is rough surface and has in the honeycombed texture, and reasonable amount of the surface raveling which occurs to heavy traffic roadway. During mixing and placing process, to prevent the over flow the paste forms a dense coating around aggregate particles. Due to absence of sand in the porous concrete harsh mix is obtained which adversely affects batching, transporting and placing. It is light in weight due to the presence of high voids. When is it compared the normal concrete and pervious concrete is the lower unit weight & compressive strength and higher permeability. However, then pervious concrete has been the better the many fields. Nevertheless, it has been own draw backs which is the must be given the proper attention when planning its use.

II.PAST RESEARCH WORKS

In this section recent past literature works have been presenting to know the status in the arena of pervious and recycle aggregate concretes. Jigar J. Anghan et.al [4] did the experimental work on concrete to estimate the pervious. For the concrete preparation they have taken the broken stones, silicon ash and mineral powder for conventional concrete. Their work mainly focused to pavement areas and from their work it is noticed that, the proposed permeable concrete is well suited for parking lots. Alalea Kia et.al [1] provided the review on mitigating strategies towards clogging mechanism and also they have specified the unresolved issues. Dang Hanh Nguyen et.al [2] provided the information to arrest the clogging in the concrete and they used the technique of pressure washing and vacuum sweeping to make more effective towards permeable of water thorough the porous concrete.

Suraya Hani et al. [9] studied the mechanical properties of recycle aggregate concrete.

In their work they have replaced the natural aggregates by the recycle aggregate concrete in the range of 0 to 100% with an enhancement of 25%. P. Sravana kumar and G.Dhinakaram et al. [7] conducted the experiments to evaluate strength characteristics of high volume fly ash with recycled aggregate of M50 grade was studies. Finally they analyzed the work in the view of strength and economic way. The result conveys us as there is a reduction in cost about 40%. From the studies it came to know that a little work has focused on pervious concrete by using the recycle aggregate concrete. Hence in this view herein it is planned to know performance of recycle aggregate concrete in the previous concrete.

III.OBJECTIVES OF THE EXPERIMENTAL WORK

The main aim of the present work is to evaluate the strength and permeability characteristics for pervious recycle aggregate concrete. To produce the pervious concrete, the concrete mix prepared with help of coarse aggregate only, this indicates as no fines aggregate. In the concrete mix the natural aggregate is replaced by the recycle aggregate in the proportion of 0,25,50,75 and 100%. For effective mix design, here we have taken the ACI522R-06 code provisions and according to this here the mix arrived as 1:4.3 with water cement ratio of 0 .4. The following objectives are set for the experimental work.

- To study the strength characteristics of compression, split tensile and bearing strengths. In addition to the strength tests, here it is also aimed to find coefficient of permeability for the hardened pervious concrete.
- The obtain results are to compare with ACI code provisions.
- For estimation of split tensile strength a model is to deduce with association of cube compressive strength.
- To know stress and strain distributions within the cube, an analysis is to perform by using ANSYS soft ware.

IV. MATERIAL CHARACTERIZATION AND TEST PROCEDURE

For the present experimental work the following materials were used.

Cement: OPC 43 grade cement was used and it confirms the requirements of IS 8112-1989.The cement has the specific gravity of 3.14 and it is free from lumps.

Natural Coarse Aggregate: 20mm granite aggregate used as coarse aggregate.

Recycled aggregate: 20 mm aggregate was used and which is obtained from the demolished building.

Water: portable water was used.

Casting and Curing

Standard cubes (150x150x150mm) and cylinders (150mm diax300mm height) are taken to evaluate strengths tests. The specimens are cast in the laboratory as per the mix design specified in the above and the specimens are exposed to water curing for period of 28 days. Total 30 cubes and 45 cylinders are casted for the work. Compressive and bearing strengths are conducted on cubes. Split tensile strength and coefficient of permeability tests are conducted on cylinders. Total five mixes are considered for the experimental work. The mix and casted specimens (few) can viewed in the figure.1, rectification is not possible.

Testing of specimens

In the experimental work for five mixes, 15 cubes and 15 cylinders are used for evaluation of compressive strengths; the compressive test has been conducted on compression testing machine (CTM). 15 cylinders are tested for split tensile strengths and this test has been conducted on CTM. The bearing strength test conducted on cubes with a bearing ratio of 10, for this a solid steel plate (47x47x23mm) used and this placed on the top of the cubes. The load was applied by using CTM and bearing strengths are found for each mix. To evaluate coefficient of permeability, permeability test with constant head has been conducted on cylinders. The tests conducted on cast specimens can be viewed in figure 2. To arrive the permeability coefficient Darcy's equation was used and it furnished below

K= QL/AHT

Where

K = Permeability of coefficient Cm/s

Q = Collected water in volume specified time T (sec)

H = Causing of head flow in mm

A= Cross-sectional area of sample in Cm^2

L = Sample of the height in mm

T =Time elapsed in sec

V. EXPERIMENTAL RESULTS AND DISCUSSIONS

A.Cube Compressive Strength

The cube compressive strength results are presented in Table1. From this it is observed that, as the dosage of RA content is increases in the mixes the cube compressive strengths are decreasing. For 0% of recycled aggregate the compressive strength is 11.12MPa and this may consider as the mix with natural aggregate. This mix is also considered as reference mix for comparison of other mixes. For RA mixes the compression strengths are decreasing from the 38.84 to 56.83% (for RA content of 25 to 100%) when compared reference mix. As per ACI guidelines the compressive strength of the pervious concrete should be in range is the of 2.8 to 28MPa. From present experimental work it noticed that, the results falls in the stipulated range. Mamery Serifou, Z.M.Sabrtai, S.yotte,M.O.Boffoue [5] studied the performances of the recycle aggregate in the construction of the concrete works. The aggregate of the size should be the 5 to 10 mm and the highest strength for the compression was 11.8 MPa, as compared the single size of the course aggregate is 9.5mm show the highest compressive strength was the 11.2Mpa.Parachi Sohoni and vaishali sahu [8] noticed the harden properties of the recycled aggregate and the result has been the discussed and they observed the compressive strength as 13.4MPa for the coarse aggregate size 10.2mm and for RA with 17.5mm the strength it is noticed as 6.12MPa So in this study for the both concretes the strength results falls in the range of 11.12 to 4.8MPa. From the results it is also noticed that,

strength results are decreasing due to the increasing of the recycled aggregate percentage, perhaps it may be the reduces the bond between cement paste and aggregate.
The recycled aggregate should not have the rough of the surface structure this is main drawback for the decreasing the strength for the recycled aggregate.

B. Cylinder Compressive Strength

The cylinder compress strengths for the all mixes are show in the Table 1. From this table it is noticed that as, percentage of recycled aggregate increasing, the compressive strengths are decreasing. For the 0% of normal concrete specimen the compressive strength is 9.45MPa for 28 days. For RA mixes the compressive strengths are decreasing from the 24 to 52% for the 25.to100% of replacement, this is happen when compare with the normal pervious concrete specimens. In generally for normal concrete, the cylinder compressive strength in compression may lies in between 70-75% of cube compressive strength. It may be the effect of the volume, shape, height of the dimension of the specimen. In this experiment the compressive strength for cylinder (PC 0) is 9.45MPa. For the mix PC0 the cube compressive strength is 11.12MPa, if it is considered for evaluation of the cylindrical compressive strength, the it may lie in the range 7.78MPa (0.70×10.14) to 8.34MPa (0.75×11.12). The experimental cylinder compressive strength is more than the relation provided in the above. Hence it may conclude that, the cylinder compressive strength is little bit higher to the expected values. It may suggest that the use of recycle aggregate is acceptable for pervious concrete. As per the ACI-318 M-11 the compression of the cylinder is 0.76 times of the cube compression strength and to know the result for compression the ACI code provision has been taken and obtained results are provided in Table 2. The ratio between EXP/ACI also presented in Table 5.3 and it indicate that, the ACI code is under estimate the results.

C. Split Tensile Strength of Cylinder

The split tensile strengths are presented in Table 2. From results it is noticed that, as the RA content increases split tensile strengths are be decreasing. The decrement is in the range of 5 to 35% for RA content of 25 to 100%. The maximum decrease the compressive strength is noticed for 100% RA mix, this may due to bond effect between the RA and cement paste. The cement paste may not provide good bond as good as in the mix of NA or PC0 or reference1mix

D. Bearing Strength of Cube

The bearing strength is important parameter in design of pavement. In general the loaded vehicle is rest on the pavement with the contact area of rubber tire wheels. The loaded area many subjected to bearing stresses. In order to asses the bearing strength of pervious concrete the test was conducted on cubes with bearing area ratio of 10. The obtained results are presented in the below Table1. From that table observed as the RA content increases the bearing stress is decreasing, this indicates the material is unable to sustain the for more stresses. This indicates the strength carrying capacity of the RA material is not up to mark. The RA may have weak bonds with the cement mortar. The strength decrement is lies between 42 to 61% when compared with PC0 mix or reference mix.

E. Permeability Test

Permeability is important property to drain of the water for pavements. During design of pavement this aspect is important. So by keeping this in view a test is conducted to estimate the permeability coefficient. To estimate this, Darcy's equation was adopted and constant head permeability test was performed on cylinder specimen and the detailed experimentation was discussed in the previous chapter. The output values of the test have been presented in Table 1 for various mixes. As the RA content should be increases in the1mixes the permeability or discharge of water increases. In other way it may convey that the coefficient of permeability is increasing with respect increase of RA content. The maximum value (4.27cm/sec) is shown by the PC100 mix.Neetu B Yadav et.al [6] provided a coefficient of permeability for concrete 0.54 to 1.2 cm/s. So in the present study the K value is in the range of 1.98 to 4.27 cm/sec for various mixes. So with this observation, it is concluding that, the provided mixes exhibiting good permeability.

F. Relation between Split Tensile Strength and Cube Compressive Strength:

In the many codes for the conventional concrete a relation between for the split tensile to compressive strength is provided and the same used for the purpose for the design. From the past literature review, it came to know that, there is no relation between the split and compressive strength for pervious concrete. However here it is decided to check the validity of relation between the split and compressive strengths which were provided by the ACI and GB code. The relation between the split and compressive strength for normal concrete is

$f_{sp} = 0.49\sqrt{f_{ck}}$------------------------------ As per ACI code

$f_{sp} = 0.19\,(f_{ck})^{0.75}$-------------------------- As per GB code

The above equation/s results are presented in the Table 2. From this table it is observed that, the ratio between Exp to ACI code is 0.59 to 0.74. This means the code is under estimating the results for RA pervious concrete. While coming to GB code the ratio is lies in between 0.86 to 1.17. From the ratio it is known that, the GB code showing more deviation of results for the present experimental values. Hence for present work the author is decided to develop a model to suit results for pervious concrete produced with RA. The following regression model was deduced with (R^2) 0.9526 and the standard Deviation (SD) 0.06512 and this model was tested and the results are1presented in the Table 2. From the table it is the noticed that, ratio between the experimental and the regression model lies between 0.86 to 1.06; this indicates the variation is about 4 to 6%.Hence the provided equation is providing better results compared with ACI and GB codes.

$f_{sp}=0.34\sqrt{f_{ck}}$ ----------------------------Regression Model

G. ANSYS Analysis

The stress and strain analysis for each mix was carried with help of ANSYS soft ware. For this the following properties were used (Table 3). The young's modulus was found with the help of IS456-2000 code provision. After performing the analysis the compressive strength results are obtained and the same as the values are compared with the experimental results.

From the Table 3 it is observed that, the ratio is lies in between 0.92 to 0.93, it indicates the deviation is about 8%. The various stress and strain in X, Y and Z directions are presented in the Table 4. From this it can noticed the variations among the mixes.

VI.CONCLUSION

1. The experimental work provided the results in such a way that, the use of recycle aggregate for pervious concrete is viable.
2. As the percentage of recycled aggregate increase in concrete mix, the compression, split and bearing strengths were decreased.
3. The cube compressive strength decreased about the 38 to 56 %for the 25 to 100% of recycled aggregate as coarse aggregate when compared as the normal concrete
4.The cylinder compressive strength is decreased about the 24 to 54 % for the 25 to 100% of the recycled aggregate as a coarse aggregate when compared to reference concrete.
5.The bearing strength of concrete decreased about 42 to 71% for recycled aggregate mixes.
6. The permeability of concrete increasing of 1.46 to 4.27cm/s as the percentage of recycled aggregate increasing for various mixes.
7. The proposed modal of $f_{sp}=0.34\sqrt{f_{ck}}$ is providing good compatibility with experimental results.

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Fig1: Mixing and casted specimens

				
Cube compression test	Cylinder compression test	Split tensile test	Bearing test	Permeability test

Fig 2: Test on specimens

Table 1: Test Results

Sl.No	Cube Compressive strength (MPa)	Cylindrical Compressive Strength (MPa)			Split Tensile strength (MPa)	Bearing strength (MPa)	Coefficient of permeability (Cm/sec)
		Experimental	As per ACI	EXP/ACI			
1	9.45	11.12	9.45	1.17	0.99	26.14	1.46
2	7.13	6.80	5.16	1.31	0.94	15.12	1.98
3	4.97	5.77	4.38	1.31	0.82	12.40	2.33
4	4.30	5.20	3.83	1.35	0.70	10.19	2.69
5	3.90	4.80	3.60	1.33	0.64	7.53	4.27

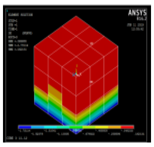
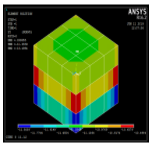
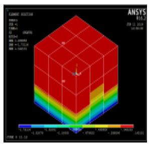
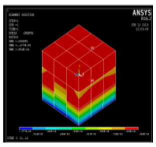
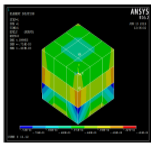
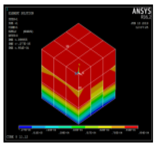
Table 2: Comparison of Experimental results with Different Codes and Regression modal

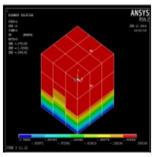
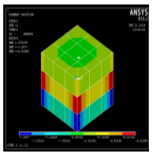
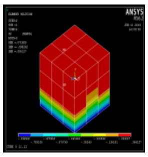
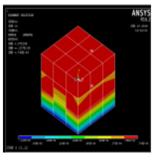
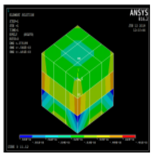
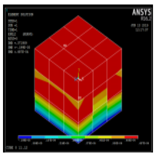
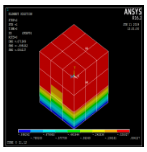
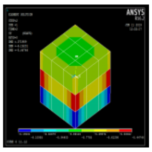
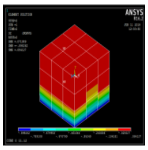
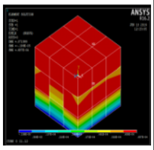
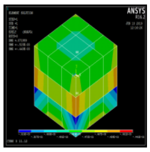
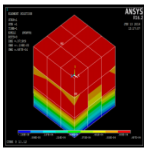
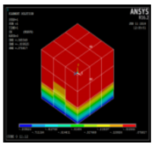
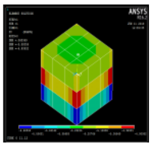
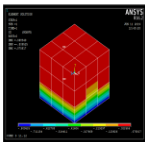
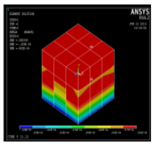
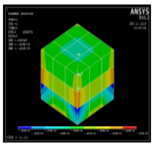
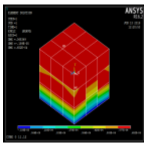
Sl. No	Nomen Cloture	Experimental Split Tensile Strength (MPa)	ACI (MPa)	GB (MPa)	EXP/ACI	EXP/GB	Regression Model (MPa)	Exp/ RM
1	PC 0	0.99	1.63	1.15	0.60	0.86	1.13	0.87
2	PC 25	0.94	1.27	0.80	0.74	1.17	1.06	1.06
3	PC 50	0.82	1.17	0.70	0.70	1.17	0.81	1.01
4	PC 75	0.70	1.11	0.65	0.63	1.07	0.77	0.90
5	PC 100	0.64	1.07	0.61	0.59	1.04	0.74	0.86

Table 3: Comparison of cube compression and Experimental of ANSYS results

Sl. No	Nomenclature	EXP f_{ck} (Mpa)	E_C(Mpa)	(Poissions ratio) μ	ANSYS F_{ck}(MPa)	EXP/ANSYS
1	PC 0	11.12	$16.67X10^3$	0.13	11.96	0.92
2	PC 25	6.80	$13.03X10^3$	0.13	7.31	0.93
3	PC 50	5.77	$12.01X10^3$	0.13	6.20	0.93
4	PC 75	5.20	$11.40X10^3$	0.13	5.59	0.93
5	PC 100	4.80	$10.95X10^3$	0.13	5.16	0.93

Table 4: ANSYS Results

Mix	Stress			Strain		
	x-direction	y-direction	z-direction	x-direction	y-direction	z-direction
PC0						

PC 25						
PC50						
PC75						
PC 100