International Journal of Current Advanced Research
ISSN: O: 2319-6475, ISSN: P: 2319 – 6505, Impact Factor: SJIF: 5.995
Available Online at www.journalijcar.org
Volume 6; Issue 8; August 2017; Page No. 5577-5584
DOI: http://dx.doi.org/10.24327/ijcar.2017.5584.0754

Research Article

PERFORMANCE OF STONE WASTE AGGREGATE IN PERVIOUS CONCRETE

Venkata Ramana N*

Civil Engineering Department, University B.D.T. College of Engineering, Davangere, Karnataka (State), India (Country)

A R T I C L E I N F O

Article History:

Received 10th May, 2017
Received in revised form 13th June, 2017 Accepted 6th July, 2017
Published online 28th August, 2017

Key words:

Pervious concrete, Stone waste aggregate, compressive strength, split tensile strength, permeability.

A B S T R A C T

This article presents the behaviour of pervious concrete made with stone waste aggregate as replacement to natural granite aggregate in various proportions of 0%, 25%, 50%, 75% and 100% by volume of cast specimens. The study mainly focused to evaluate compressive strength, split tension strength and permeability. The split tensile strength was compared with ACI318-M-11 and GB50010-2002 codes and it is noticed that, the codes are underestimated the real strength of split tension. Hence a regression model was proposed to estimate the results and the model was checked with reliability based Integral Absolute Error (IAE). Micro structure analysis was performed for various mixes through Scanning Electron Microscopy (SEM) images.

INTRODUCTION

Pervious concrete comprises little or no fine aggregate (sand) and carefully measure amounts of cementations materials and water. The paste binds the aggregate particles together to develop a system of interconnected and highly permeable voids to encourage the quick drainage of water. Pervious concrete is rough surfaced and has honeycombed texture, with reasonable amount of surface revelling which occurs on heavy traffic roadways. When compared to normal concrete, pervious concrete has a lower unit weight and compressive strength and greater permeability. However, pervious concrete has a better advantage in many fields. Nevertheless, it has its own drawbacks which must be given proper attention when planning its use.

The purpose of this experimental study is to make use of stone waste aggregate for porous concrete works and to assess the performance of pervious concrete in terms of strengths and permeability. To attain this, five mixes were prepared with stone waste aggregate as replacement to the conventional concrete. The stone waste aggregate is considered as second grade quality material in the aggregate family. The use of second grade aggregates for the production of new concrete has become common in recent past years. The lack of natural resources (aggregates) encourages the usage of stone waste as aggregate in the concrete mixes and also observed that as, it is an alternative to primary (normal) aggregates in construction. In the present study the stone waste obtained from layered stone (locally it is named as kadapa marble) available at Tadipatri (Town) in Anantapur (Dist), Andhra Pradesh (State), India (Country) and has been used for present experimental work. This (Tadpatri) area is well known for abundance of marble stone, which is extracted as layered stone from quarries and taken to the cutting and polishing industries to convert them into finished products, which are useful for flooring in dwelling houses and for ornamental purposes also. These (layered marble stone) are made into required shape according to the requirement of consumer. During the generation of required shape, a waste is produced and disposing of this waste near by the factories, day to day it leads a big problem for the owners of the factories and municipal authorities (due to lack of dumping areas). In this town around 1000 stone polishing industries are working per day and the author is left to reader for imagination of waste generation per day. The enormous quantities of stone wastes available at various industry/quarry sites can easily be recycled as useful aggregate to use for concrete works. After having a look over this scenario, it is planned to utilize this waste material for construction works. To make use of this waste for concrete works, the waste stone was transported from polishing industry to crusher unit to make a single graded material of 20mm size aggregate. Utilization of this material, safeguards the natural resources and it may solve the disposal problem up to some extent for the municipal authorities. Before going to objectives and detailed experimental work, a brief review in this arena is furnishing below.

Sung-Bum Park *et.al*, (2003) studied on compressive strength properties of porous concrete. The results showed that when

Corresponding author:* **Venkata Ramana N
Civil Engineering Department, University B.D.T. College of Engineering, Davangere, Karnataka (State) India (Country)

aggregate size is smaller more will be the compressive strength. Karthik H. Obla (2007) has given a complete overview of the pervious concrete regarding application, materials, properties, design and testing. Yukari *et.al*, (2009) studied the properties of pervious concrete by changing cement content with 20% and 50% of fly ash. Studies revealed that strength decreases with increase of fly ash content. C.Lian *et.al*, (2010 and 2011) carried out an experimental investigation for developing a new type of permeable concrete with improved structural strength. A.K.Jain *et.al*, (2011) studied the size of aggregate and W/C ratio effect on permeability of porous concrete. Smaller sized aggregate produced less permeability compared to the one with larger size aggregate.M. Aamer Rafique Bhutta *et.al*, (2012) conducted a study to estimate properties of high performance porous concrete. The results showed that, the larger the coarse aggregate, lower is the strength. S.O Ajamu *et.al*, (2012) study was performed using two different coarse aggregate sizes of 9.375mm and18.75mm. The results showed that pervious concrete with coarse aggregate of 9.375mm has more compressive strength values compared to those made of 18.75mm. Rasiah Sriravindrarajah *et.al*,(2012) showed that compressive strength of pervious concrete decreased with the increase in aggregate size from 13 mm to 20 mm. Muhammad Aamer Rafique Bhutta *et.al*, (2013) studied the properties of porous concrete from waste crushed concrete. The purpose of the study was to develop porous concrete with satisfactory permeability and strength using recycled aggregate from waste crushed concrete. It was observed that the compressive strength of porous concrete using recycled aggregate was lower the one using normal aggregate. Darshan S Shah *et.al*, (2013) studied the necessity of pervious concrete in rural road pavement. M.Uma Maguesvani *et.al*, (2013) studied the important parameter that effects the voids in aggregate that is its angularity, which is characterised by its sharp edges. Partik P.Patel *et.al*, (2014) investigated the properties of pervious concrete by replacing cement with 20% fly ash and 10% of silica fume. Georgia vardaka *et.al*, (2014) conducted the experimental work on porous concrete by taking the three types of aggregates i,e conventional lime stone, construction and demolition wastes and steel slag. Darshan S. Shah *et.al*, (2014) carried out an experimental study on durability and water absorption properties of pervious concrete. The paper represents the experimental methodology and experimental results related to durability and water absorption. Darshan S. Shah *et.al*,(2014) performed a laboratory experiment on the hardened properties of porous concrete. The main objective of the experiment was to focus on the harden properties such as compressive strength and flexural strength. Weichung Yeih,(2015) carried out an experimental study on properties of pervious concrete with replacement of aggregate with EAFS(air-cooling electric arc furnace slag) and the results showed higher compressive strength and higher permeability than gravel. Jerzy Wawrzenezyh (2015) studied the preparation of samples for 1D and 2D image analysis. The result of image analysis in the paper describes more accurately the air voids structure in the concrete. The 1D and 2D analysis showed the aggregates, paste and air voids in the concrete. Djoko Sarwono *et al* (2016), investigated the characteristics of porous concrete filled with soil, natural sand and volcanic sand in voids space of concrete. From the recent past research works, it can be noticed that majority of the experimental works concentrated on obtaining the compressive and split tensile strengths by varying the natural aggregate size or by making use of steel slag, construction and demolition wastes and bricks as a coarse aggregate in pervious concrete specimens. It can also be noticed from the earlier studies that, no experimental investigation has been performed on replacement of the natural aggregate by stone waste aggregate. Hence the present study is concentrated on the replacement of natural aggregate by stone waste aggregate in various proportions to know the pervious concrete properties, in this concern the specific objectives are presenting below.

Objectives and Experimental Programme

The Specific objectives of present study are

1. To evaluate the compressive and split tensile strengths of pervious concrete.
2. To obtain the permeability of pervious concrete.
3. Comparing the results with ACI provisions.
4. Developing of Regression Model to assess the split tensile strength.
5. Micro level analysis with the help of Scanning Electron Microscopy analysis

To achieve the specified objectives, test program was planned using standard cube and cylindrical specimens. The cubes and cylinders are tested in compression testing machine (CTM) to obtain strengths. In addition to these tests, permeability test was carried on cylindrical specimens using constant head permeability test. The detail test programme was presented in

Table 1 In the table the nomenclature can be read as

1. PC 0: Where PC refers to pervious Concrete, '0' refers to % replacement of natural coarse aggregate by stone waste aggregate. This mix can be referred as control mix or normal mix in the further discussion.
2. PC 25: Where PC refers to pervious Concrete and '25' refers to % replacement of natural aggregate by stone waste aggregate.
3. PC 50: Where PC refers to pervious Concrete and '50' refers to % replacement of natural aggregate by stone waste aggregate.
4. PC 75: Where PC refers to pervious Concrete and '75' refers to % replacement of natural aggregate by stone waste aggregate.
5. PC 100: Where PC refers to pervious Concrete and '100' refers to % replacement of natural aggregate by stone waste aggregate.

Table 1 Test programme

Sl.No	Nomenclature	Cube Specimens	Cylindrical Specimens
		28 Days	28 Days
1	PC 0	3	9
2	PC 25	3	9
3	PC 50	3	9
4	PC 75	3	9
5	PC100	3	9

Materials Used

Cement: Ordinary Portland cement of 43 grade confirming to IS 8112-1989 standards was used to cast the specimens. The specific gravity of cement was noticed as 3.12.

Natural Coarse Aggregate: Crushed natural granite aggregate from local crusher has been used and which has maximum size of 20mm. The specific gravity of coarse aggregate was observed as 2.69.

Stone Waste Aggregate: It is obtained from polishing industries and it is noticed as waste generated material during the process of finished products or goods. The detail discussion of generation of stone waste was furnished in the introduction section. The waste stone is unable to use as in the available form for concrete works, so it is required to brought to 20 mm size, for this the waste is transported to crusher unit and there it was made as 20mm(figure.1).

Fig 1 Stone waste Aggregate

The specific gravity of coarse aggregate was observed as 2.67. The chemical properties of stone waste aggregate are presented in Table 2.

Table 2 Chemical Properties of Stone Waste Aggregate

S.No	Property	Values Obtained
1	Silica (SiO_2)	22.35%
2	Calcium Oxide (CaO)	38.91%
3	Magnesium Oxide (MgO)	2.75%
4	Ferric Oxide (Fe_2O_3)	1.30%
5	Alumina (Al_2O_3)	2.80%
6	Loss on Ignition (LOI)	30.52%

Water: Clean fresh water was used for mixing and curing of the specimens.

Casting and Testing

Casting

The cubes were cast in steel moulds with inner dimensions of 150 × 150 × 150 mm and the cylinders in the moulds of 150mm diameter and 300mm height. The cement and coarse aggregates were mixed thoroughly manually. The mix proportions adopted for all the mixes as 1: 4.3: 0.4 (cement: coarse aggregate: water). Total five mixes were prepared, out of five, four with the use of stone waste aggregate and other one mix was prepared with natural aggregate (reference mix). The cast specimens were kept for one day in the moulds. After 24 hours the moulds are removed and specimens are transferred to curing pond for curing and it was done for 28 days.

Testing

Compression test on cubes is conducted with 2000kN capacity compression testing machine and the machine has a least count of 1kN. The cube was placed in the compressive-testing machine (CTM) (figure.2) and the load is applied on the cube at a constant rate (0.2 to 0.4 MPa/sec) till to failure of the specimen and the corresponding load is taken as ultimate load. Then cube compressive strength of the concrete mix is then calculated by using standard formula. The cylinder also tested in CTM in similar way to obtain cylinder compressive strengths for various mixes (figure.3).

Fig 2 Testing of Cube

Fig 3 Testing of Cylinder

Split Tensile strength Test

To evaluate the tensile strength for all mixes of porous concrete, split tensile test was carried on cylindrical specimens and the testing is carried as per IS: 5816-1970. The load configuration creates a lateral tensile stress in the cylinder across the vertical plane of loading. It can be observed in figure 4.

Fig 4 Testing of cylinder for Split Tensile Strength

Permeability Test

Permeability of porous concrete for various mixes was determined by using constant head Permeability meter (figure.5). The permeability meter consists of 150mm inner diameter PVC pipe with sufficient drainage facilities. Flexible sealing material (M-seal) was applied around perimeter of sample to prevent water leakage between perimeter of sample and inner surface of permeability meter (figure.5). Co-efficient of permeability for each mix was determined using the following equation and the obtained results are presented in the next section.

Fig 5 Permeability test

K= QL/AHT
Where,
K = co-efficient of permeability (cm/sec)
Q = volume of water collected in time t (sec)
H = head causing the flow (mm)
A= cross-sectional area of sample (cm^2)
L = height of sample (mm)
T = time in sec.

RESULTS AND DISCUSSION

Cube Compressive Strength

The cube compressive strength results for the pervious concrete is presented in Table 3.

Table 3 Cube Compressive Strength

SL No	Nomenclature	Failure Load (KN)	Compressive Strength (MPa)
1	PC 0	228	10.14
2	PC 25	141	6.27
3	PC50	120	5.34
4	PC 75	109	4.85
5	PC 100	102	4.54

From the table it is noticed that as the % of stone waste aggregate is increasing the cube compressive strength is decreasing. For 0% of stone waste aggregate or reference porous concrete the compressive strength is found to be 10.14MPa at 28th day. For 28 days, the compressive strength is decreased from 38 to 55% for 25 to 100% replacement of stone waste aggregate with natural aggregate. ACI 522R-10 recommends that the compressive strength of pervious concrete should be in the range of 2.8 to 28MPa. The obtained results are thus found to fall in the stipulated values of ACI code. Some of the researchers have conducted studies on pervious concrete. Few studies are presented here in for comparison purpose. S.O. Ajamu, A.A. Jimoh and J.R.Oluremi (2012) conducted a research work on evaluation of structural performance of pervious concrete in construction. From their study they found that for aggregate-cement ratio of 6:1 with coarse aggregate of size 9.375mm showed highest compressive strength of 10.8 MPa compared to coarse aggregate of size 18.75 mm whose compressive strength is 8.2 MPa. Darshan S Shah and Jayeshkumar Pitroda (2014) performed an experimental study on hardened properties of pervious concrete. From their results they observed that for aggregate-cement ratio 6:1, the compressive strength is found to be 12.71 MPa for coarse aggregate size 9.375mm when compared with the other aggregate size i.e. 18.75 mm whose compressive strength is 5.96 MPa. From both the case studies done by previous researchers and the results obtained from our study shows that the compressive strength is in the range of 10.14 to 4.5MPa and this satisfies ACI recommendations. Further it can be concluded that reduction in the strength due to increase in the stone waste aggregate percentage may be due to the reduction of bonding between aggregate and the cement paste. The stone waste aggregate having fractured smooth surface texture; this may be one of reason for obtained the lesser strength as the % of stone waste aggregate increase.

Cylinder Compressive Strength

The cylinder compressive strength results for all mixes are presented in Table 4.

Table 4 Cylinder Compressive Strength

SL No	Nomenclature	Failure Load (KN)	Compressive Strength (MPa)
1	PC 0	152	8.56
2	PC 25	107	6.01
3	PC50	75	4.28
4	PC 75	69	3.89
5	PC 100	65	3.66

From the table it is observed that as the % of stone waste aggregate increasing, the compressive strength is decreasing. For 0% of stone waste aggregate or for normal porous concrete specimen, the compressive strength at 28 days is 8.56MPa. At 28 days, the compressive strength is decreased from 29 to 57% for 25 to 100% replacement when compared with the normal porous concrete specimen. In general pertaining to convention concrete, the cylindrical compressive strength is about 70-75% of cube compressive strength, it may be due to the volume, shape, height to lateral dimension of concrete. From the experimental work the cylinder compressive strength for PC 0 (Reference mix) is 8.56 N/mm^2. The average cube compressive strength at 28 days is 10.14 N/mm^2 (Table 6), if it is considered to obtain the cylindrical compressive strength, as per the general value it should be in the range of 7.10MPa (0.70×10.14) to 7.60MPa (0.75×10.14). The experimental cylinder compressive strength nearly matches at higher end ratio i.e 0.75 and for few replacements slightly more than the 0.75 of cube compressive strength. ACI-318 M-11 code suggests that the compressive strength of cylinder is 0.76 times of cube compressive strength. The obtained cylinder compressive strength results are compared with the ACI code and presented in Table 5. From this table it is observed that ratio of EXP/ACI is about 1.05 to 1.26.

Table 5 Comparison of Experimental Cylinder Compressive Strength with ACI code

SL.No	Nomenclature	Experimental Compressive Strength (MPa)	ACI Value (MPa)	EXP/ACI
1	PC 0	8.56	7.70	1.11
2	PC 25	6.01	4.76	1.26
3	PC 50	4.28	4.05	1.05
4	PC 75	3.89	3.68	1.05
5	PC100	3.66	3.45	1.06

Split Tensile Strength

The split tensile strength results for different replacements levels of stone waste concrete mixes are presented in Table 6.

Table 6 Split Tensile Strength

SL No	Nomenclature	Failure Load (KN)	Split tensile Strength (MPa)
1	PC 0	62	0.87
2	PC 25	60	0.84
3	PC 50	52	0.73
4	PC 75	47	0.66
5	PC 100	45	0.63

At 28 days for 0% of stone waste aggregate replacement the split tensile strength is noticed to be 0.87MPa. From these results it is observed that the split tensile strength is decreasing as the percentage of stone waste aggregates increases. The percentage decrease in strength for the replacements from 25 to 100% replacements with natural aggregates is 3 to 27%. Few studies were available on porous concrete of split tensile strength. Through the studies are not directly impact for the present experimental work but the past studies were mentioned herein for comparison purpose. M Uma Maguesvari and V.L. Narasimha (2013) on their study on properties of porous concrete inferred that as the size of coarse aggregate decreased the split tensile strength increased and they concluded that it is due to increase in the contact area, which increased as the aggregate size reduced. S.Deepika *et.al*, (2015) study showed that, using natural aggregate with partial replacement of recycled concrete aggregate resulted in significant losses in strength as compared to a natural aggregate pervious concrete. In the present study also, the strength is decreasing as the % of stone waste aggregate increases, this may be due to, in the experimental work single graded aggregate was taken, as stated by M.Uma Maguesvari *et.al*, (2013) the size of aggregate is one of the factor to decrease the strength. The aggregate texture is also influence the strength of concrete, as mentioned in compressive strength discussion (surface texture is smooth for stone waste aggregate), same reason is also applicable for split tensile strength.

Relation between Split Tensile Strength and Cube Compressive Strength

Many codes (for conventional concrete) provided the relation between tensile strength to compressive strength and this relation is using for design purpose. From the recent past review of literature it came to know that, there no correlation between the compressive and split tensile strengths. However the present experimental results, would like to compare with help of equations, which were established for conventional concrete. The relationship between split and compressive strength conventional concrete expressed as,

$f_{sp} = 0.49\sqrt{f_{ck}}$------------------------- As per ACI code
$f_{sp} = 0.19\ (f_{ck})^{0.75}$------------------------- As per GB code

By using the above equations the results are presented in Table 7. From this table it is observed that, The ACI (code) provided relation is under estimating the results for porous concrete. But the GB code is good at predicting the result compared to ACI. The ratio of EXP to GB is varying about 20%. However the GB code variation is less, the author is very much interested to reduce the variation, for that a regression model was deduced and presented below. The obtained regression equation had the correlation coefficient (R^2)0.86176 and Standard Deviation (SD) is 0.06512.
$f_{sp}=0.30\sqrt{f_{ck}}$

Table 7 Comparison of Experimental Split Tensile Strength with different Codes

S.No	Nomenclature	Experimental Split Tensile Strength (MPa)	ACI (MPa)	GB (MPa)	EXP/ACI	EXP/GB
1	PC 0	0.87	1.56	1.08	0.56	0.81
2	PC 25	0.84	1.23	0.75	0.68	1.12
3	PC 50	0.735	1.13	0.67	0.65	1.13
4	PC 75	0.66	1.08	0.62	0.61	1.06
5	PC 100	0.63	1.04	0.59	0.61	1.07

Comparison between the test results and that predicted by proposed equation is presented in Table.8. The ratio between EXP/RM is about 0.9 to 1.1. From this it noticed that the proposed equation has good agreement with the experimental results. Still to accept the regression model an Integral Absolute Error (IAE) index has been used and it is presented below.

Table 8 Regression Model performance for Split Tensile strength

S.No	Nomenclature	Experimental Compressive strength (MPa)	Experimental Tensile Strength (MPa)	Regression Model (MPa)	Experimental Split Tensile strength / Regression model
1	PC 0	10.14	0.87	0.95	0.92
2	PC 25	6.27	0.84	0.75	1.12
3	PC 50	5.34	0.735	0.69	1.06
4	PC 75	4.85	0.66	0.66	1.00
5	PC 100	4.54	0.63	0.64	0.98

Integral Absolute Error (IAE (%))

In the above discussion the regression model was deduced to predict the split tensile strength with respect to compressive strength of cube. The performance of regression model is checked with reliability based Integral Absolute Error (IAE %). The IAE equation is given below and this Index used by Gardner (1990), Oluokun (1991) and Anoglu(1995).

$$IAE = \sum \{[(O_i-P_i)^2]^{1/2}\} \times 100 / \sum O_i$$

Where O_i is the experimental value and P_i is the predicted value obtained from the regression equation. The IAE measures the relative deviations of results from the regression model equation. When the IAE is zero, the predicted values are equivalent to the experimental values; this circumstance rarely occurs. When comparing different equations, the regression equation having least value of the IAE can be judged as the most reliable. A range of the IAE from 0 to 10% may be considered as the limits for an acceptable regression equation. The value of IAE computed for the developed regression equation and is found as 6.02% (Table 9). This value reveals that, it is in good agreement with the suggested range value of 0 to 10%.

Table 9 IAE value for proposed Regression Equation

S.No	Nomenclature	Experimental Tensile Strength (O_i)	RM (P_i)	$[(O_i-P_i)^2]^{1/2}$
1	NC 0	0.87	0.95	0.08
2	PC 25	0.84	0.75	0.09
3	PC 50	0.735	0.69	0.045
4	PC 75	0.66	0.66	0
5	PC100	0.63	0.64	0.01
		$\sum O_i$= 3.735		$\sum [(O_i-P_i)^2]^{1/2}$=0.225

The Table 9, shows IAE value for proposed Regression Equation/modal

IAE = $\sum \{[(O_i-P_i)^2]^{1/2}\} \times 100 / \sum O_i$

= 0.225/3.735 = **6.02 %**

Permeability Test

The permeability values obtained for the various mixes can be viewed in Table 10.

Table 10 Permeability

SL No	Nomenclature	Co-efficient of Permeability (cm/s)
1	PC 0	1.33
2	PC 25	1.80
3	PC 50	2.12
4	PC 75	2.45
5	PC 100	3.89

From the table, it can be noticed that as the percentage of stone waste aggregate is increasing the permeability goes on increasing. For the comparison purpose few studies have been quoted here in. Muhammad Aamer Rafique Bhutta *et.al*, (2013) and Kardon J B (1997) noticed that, the of porous concrete prepared using recycled aggregate exhibited larger permeability values, the obtained range was in between 2.4-3.7 cm/s, which is high enough to be used for drainage purpose in pavement or precast product application. Neetu B. Yadav *et.al*, (2013) stated that flow rate through pervious concrete depends on type of aggregate used and the typical flow rate through pervious concrete was in the range of 0.54cm/s to1.2 cm/s. In the present experimental work the permeability of reference conctete showed 1.33cm/sec. As the % of stone waste aggregate increases the permeability values are also increasing and it ranges from 1.8 to 3.9 cm/sec. The higher value is noticed at higher dosage of stone waste aggregate. As per guidelines of Kardon J B (1997) the present porous concrete is also good enough for pavements. The permeability for various mixes is increasing due to the allocation of aggregate in the concrete mix and the corresponding mix having its own void ratio. In general as the percentage of void ratio increase the permeability is increases but in the other senses the compressive and tensile strengths were decreases. This was proven in the present experimental work. As the % of stone waste aggregate increases in the concrete mix, the permeability increased and the strengths were decreased. The designer has to take the decision for choosing the % of replacement of stone waste concrete with the consideration of both strengths and permeability criteria.

Scanning Electron Microscopy Analysis (SEM)

A scanning electron microscope (SEM) is used to generate surface images of a specimen on a microscopic level. It does this, by scanning a specimen with a beam of high energy electrons in an optical column. The electrons emitted by the beam then interact with the atomic structure of the specimen and generate microscopic images. In our study samples of specimens were exposed to SEM after 28 days of curing. The micro structure of 0, 25, 50, 75 and 100% PC specimens were studied using scanning electron microscopy (SEM) images. After obtaining the SEM images correlation is done between microstructure images and compressive strength. The microscopic image of PC 0 mix can be vied in figure.6. It clearly shows that the control mix possesses lower porosity and voids packing structure. It illustrates the development of proper and clear cement paste in various phases.

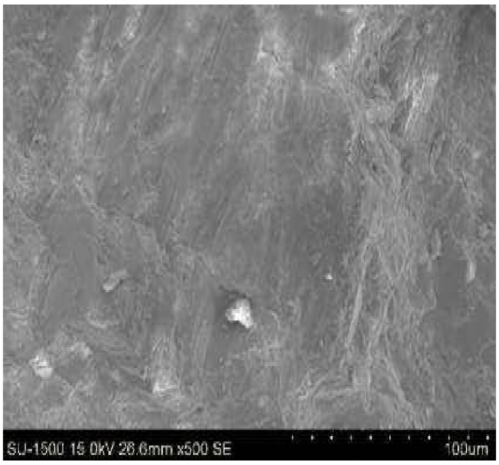

Fig 6 Microstructure of PC 0

The important point to be noted in the microscopic image is that the Cement pastes i.e. the bright mass is spread over the coarse aggregates thus acting as binding paste. Figure.7 is microscopic image of PC 25 mix.

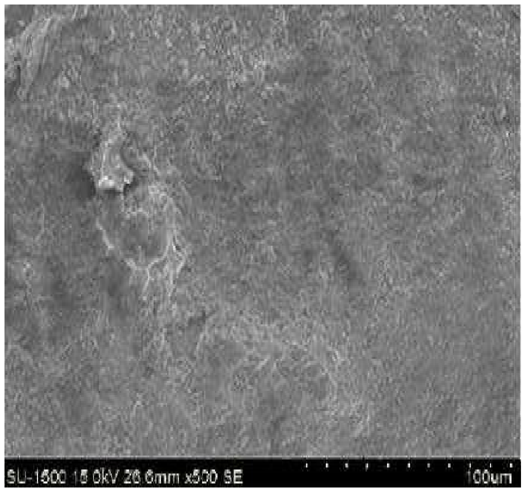

Fig 7 Microstructure of PC 25

It shows that the cement paste is not as widely spread as it was in the reference mix, showing little dislike to the aggregate this may be due to the presence of properties of replaced stone waste aggregate. The decrease in strength of PC 25 specimen is 38% compared to reference mix.

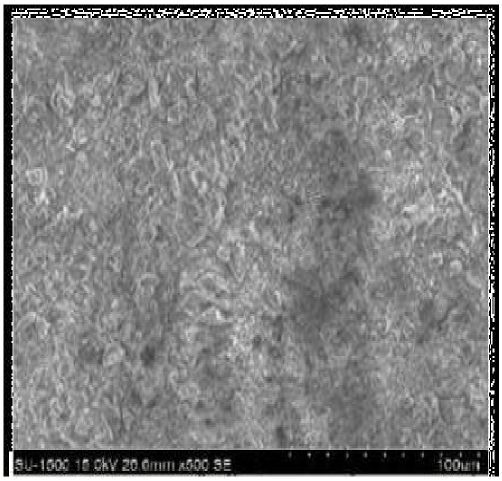

Fig 8 Microstructure of PC 75

The decrease in strength could be credited to the non-formation of proper cement paste as compared to reference mix, although, at few places the creation of cement paste could be noticed. The densification of the mixes of PC 25 is less compared to reference mix. The SEM images for PC 50 and PC 75 depicted in Figure 8 and 9. These micro images show presence of some voids at various places.

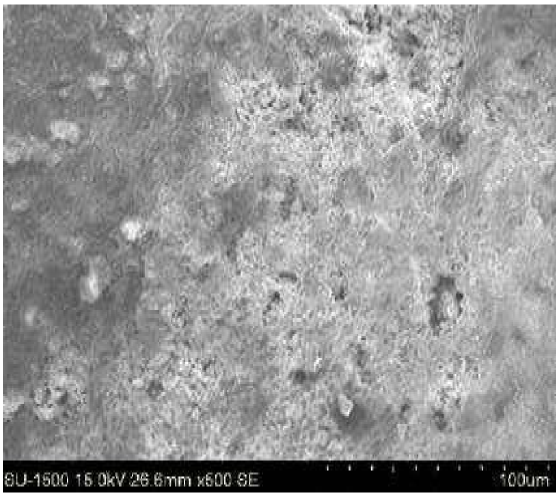

Fig 9 Microstructure of PC 75

The development of cement paste is not good, there by indicating less densification of mixes as related to reference mix and PC 25 mix. The strength of PC 50 and PC 75 mixes is decreasing compared to reference and PC 25 mix.The SEM image of PC 100 mix (figure.10) shows that, the cement paste has crushed with coming out of stone waste aggregate from the mix. This is due to the rough texture and uneven formation of cement paste over the aggregate. The most important implication from the image is that the improper bonding of cement paste with coarse aggregates and this may leads to the decrease in the strength.

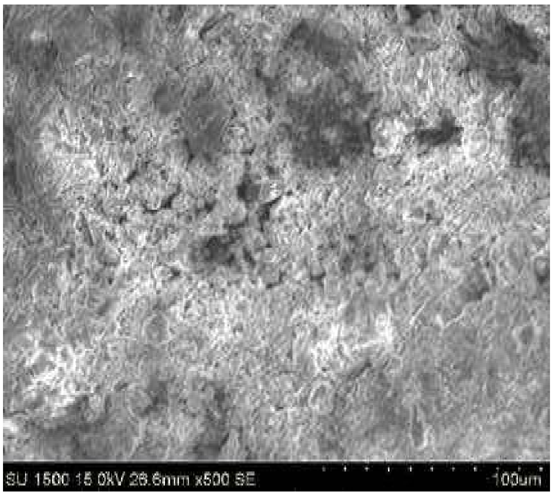

Fig 10 Microstructure of PC 100

CONCLUSIONS

From the present experimental work the following conclusions are drawn.

1. The studies indicate the viability of using stone waste aggregate from the polishing industries as coarse aggregates in the preparation of porous concrete for construction works.
2. As the % of stone waste aggregate increases in the concrete mix the compressive and split tensile strengths are decreased.
3. As the % of stone waste aggregate increases, the permeability is increased.
4. The compressive strength decreased about 38 to 55% for 25 to 100% stone waste aggregate as coarse aggregates when compared with reference concrete.
5. The split tensile strength results shows that, as the % of stone waste aggregate increases in the concrete mix the strength decreases. The % of decrease is 3 to 27% for 25 to 100% replacement when compared with reference concrete.
6. The relation between split tensile and compressive strengths given by ACI-318-M11 and GB code are under estimating the experimental results.
7. A regression modal is developed between split tensile and compressive strength and it is formulated as $f_{sp}= 0.30\sqrt{f_{ck.}}$
8. Microscope analysis for various mixes is discussed using SEM images.

References

1. A.K.Jain, S.S. Goliya, Dr. J.S.houhan, 2011,Effect of shape and size of Aggegate on permeability of pervious concrete, *Journal of Engineering Research and Studies*,Vol.2,Issue 4, pp 48-51
2. American Concrete Institute 318 M-11, Building Code Requirements for Structural Concrete.
3. Anoglu, E., 1995, Discussion of Effects of Size and Curing on Cylinder Compressive strength of Normal and High Strength Concret by P.C. Aitcin, *ACI Materials Journal* V. 92, No. 3, May- June, pp 332-334.
4. C. Lian, Y. Zhuge, 2010, Optimum mix design of Enhanced Permeable Concrete. An Experimental Investigation, Construction and Building Materials Vol 24, pp 2664-2671.
5. C. Lian, Y. Zhuge, S. Beecham,2011, The Relationship between Porosity and strength for Porous Concrete, *Construction and Building Materials* Vol 25, pp 4294-4298.
6. Darshan S. Shah, Jayeshkumar Pitroda, 2014, An experimental study on durability and Water absorption properties of pervious Concrete. International Journal of Research in Engineering and Technology eISSN: 2319-1163, pISSN: 2312-7308, pp 439-444.
7. Darshan S. Shah, Jayeshkumar Pitroda, 2014, An experimental study on Hardened properties of pervious Concrete, *Journal of International Academic Research for multidisciplinary*, Volume 2, Issue 3,pp 332-338.
8. Darshan S. Shah, Prof. Jayeshkumar Pitroda, Prof.J.J.Bhavsar, 2013, Pervious Concrete: New Era for Rural Road Pavement. *International Journal of Engineering Trends and Technology* (IJETT), Volume 4 Issue 8, pp 3495-3499.
9. Djoko Sarwono,2016,The application of porous concrete filled with soil and sands for low volume traffic road, Sustainable Civil Engineering Structures and construction materials, Procedia Engineering, Vol107, pp1429-1434.
10. Gardner, N.J., 1990, Effect of Temperature on the Early-Age properties of Type 1, Type III, and Type

I/Fly Ash Concretes, ACI Materials Journal, V.87, No.1, pp. 68-78.

11. Georgia Vardaka, Kiriakos Thomaidis, Christos Leptokaridis, Stamatis Tsimas.,2014, Use of steel slag as Coarse Aggregate for the production of pervious concrete, *Journal of Sustainable Development of energy, Water and Environment Systems*, Volume 2, Issue 1, pp 30-40.
12. GB 500010, 2010, Code for design of concrete structures, Ministry of Housing and Urban-rural Development, Beijing, China.
13. IS: 2386-1963 Methods of Test procedure for aggregate for concrete. Bureau of Indian Standards, New Delhi.
14. IS: 5816-1999, "Splitting Tensile Strength of Concrete-Method of Test". Bureau of Indian Standards, New Delhi.
15. IS: 8112-1989, "43 Grade Ordinary Portland Cement-Specifications". Bureau of Indian Standards, New Delhi.
16. Jerzy Wawrzenczyk, Wioletta Kozak, 2015, A method of analysing the porous microstructure in air entrained concrete on the basis on 2D image analysis", 7th Scientific Technical Conference Material Problems in Civil Engineering, pp102-107.
17. Karthik H. Obla, 2007, Pervious Concrete for Sustainable Development. Recent Advances in Concrete technology, Washington DC.
18. Kardon, J.B., 1997, Polymer-modified concrete: review, ASCE *Journal of Materials in Civil Engineering*, 9(2), pp. 85-91.
19. M. Aamer Rafique Bhutta, K. Tsuruta, J. Mirza, 2012, Evaluation of higher- Performance porous concrete properties, Construction and Building Materials, Vol 31, pp 67-73.
20. M. Uma Maguesvaria and V.L. Narasimha, 2013, Studies on Characterization of pervious Concrete for Pavement Applications. Procedia - Social and Behavioral Sciences, pp198-207.
21. Muhammad Aamer Rafique Bhutta, Nor Hasanah, Nur Farhayu, Mohd Warid Hussin, Mahmood bin Md Tahir, J. Mirza,2013, Properties of porous Concrete from Waste Crushed Concrete recycled aggregate). Construction and Building Materials, 47, pp 1243-1248.
22. Neetu B. Yadav, Jayesh A.Shah, Rushabh A. Ahah, 2013, Pervious Concrete: solution for Low Cost Construction. *International Journal of Innovative Science and Modern Engineering*, Vol.1, Issue-10, pp38-41.
23. Oluokun, F. A., 1991,Prediction of Concrete Tensile Strength from its Compressive Strength Evaluation Relations for Normal Weight Concrete, *ACI Materials Journal*, V-88, no.3, pp.302-309.
24. Pratik P. Patel, 2014, Evaluation of Strengths and Permeability of Pervious Concrete, Department of civil Engineering Nirma University, M.E.Thesis (submitted).
25. Rasiah Sriravindrarajah, Neo Derek Huai Wang, and Lai Jian Wen Ervin, 2012, Mix Design for Pervious Recycled Aggregate Concrete Structures and Materials, Vol.6, No.4, pp.239-246.
26. S. Deepika, K. Lalithanjali, M. R. Ponmalar, B. Vinushitha and T. Manju, 2015, Influence of Recycled Aggregate based Pervious Concrete with Flyash, *International Journal of ChemTech Research*, Vol.7, N0.6, pp2648-2653.
27. S.O. Ajamu, A.A. Jimoh, J. R., 2012, Oluremi Evaluation of Structural Performance of Pervious Concrete in construction, *International Journal of Engineering and Technology*, Vol. 2 No. 5,pp 829-836.
28. Sung Bum Park, Mang Tia, 2004, An experimental study on the water purification properties of porous concrete. Cement and Concrete Research, Vol 34, pp 177-184.
29. Weichung Yeih, Tun Chi Fu,Jiang Jhy Chang, Ran Huang, 2015, Properties of pervious concrete made with air cooling electric arc furnace slag as aggregates, Construction an Building Materials, Vol.93,pp737-745.
30. Yukari Aoki, 2009, Development of Pervious Concrete, Faculty of Engineering and Information Technology, University of Technology, Sydney, Master of Engineering (submitted) thesis.

How to cite this article:

Venkata Ramana N (2017) 'Performance of Stone Waste Aggregate in Pervious Concrete', *International Journal of Current Advanced Research,* 06(08), pp. 5577-5584. DOI: http://dx.doi.org/10.24327/ijcar.2017.5584.0754

****