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Research Article

UTILIZATION OF BLACK STONE POWDER AS FINE AGGREGATE IN CONCRETE

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ABSTRACT

Cement, sand and aggregate (coarse) are the primary needs for the construction industry, sand plays major role in the preparation of mortar and concrete. But now there is scarcity of river sand, hence there is need to find the alternative material to river sand. Many alternatives have been suggested by many authors and researchers. Black stone powder is one among them and this black stone powder is produced during the processes like cutting, polishing, grinding etc. of black marble stone (kadapa stone). To overcome the problems like, shortage of river sand and also dumping of stone waste in and around the factories and outskirts of town, it would like to use the black stone powder as alternative material to sand in concrete. In this experimental work the sand is replacing by black stone powder in various proportions (0%, 25%, 50%, 75% and 100%). In order to observe the behaviour of black stone powder concrete it is proposed the conduct tests on cubes and cylinder to find out compressive and split tensile strengths. The test results were then compared with various codes such as IS456-2000, ACI318-M-11 and GB 50010-2002. The results showed that 50% replacement of sand by black stone powder is effective. Regression models are developed to assess the strengths for the experimental results.

INTRODUCTION

Cement, sand and coarse aggregates are the essential materials for construction works. Sand is a noteworthy material in the preparation of the mortar and concrete. It takes a most imperative part in the mix design process. In practice, utilization of sand is high, because of the extensive utilization of cement and mortar. Thus the necessity of natural sand is high in developing nations to fulfil the infrastructure development. The developing nation like India is facing deficiency of natural sand. Quick extraction of sand from stream bed bringing on such a large number of issues like losing water holding soil strata, bank slides, loss of vegetation and also it affects horticulture because of bringing down the water table in the well. To defeat these, different stream sand options, for example, quarry dust, seaward sand and filtered sand have been found. Physical and chemical properties of the aggregate influence the workability and it also affects quality of concrete. The fine aggregate make significant rate of aggregate volume of concrete by coarse total and thus it is vital to identify appropriate and quality aggregate. Now a day's normal sand is turning into an expensive material as a result of its importance in the construction field because of this condition exploration started for economical and by regional standards accessible option material to common sand. Many option materials have as of now been utilized as a replacement of common sand, for example, siliceous stone powder, fly-ash, copper slag and so on.,. Specialists and Engineers have turn out with distinctive thoughts to lessening or completely supplant the utilization of stream sand and utilization late advancements, for example, Manufactured sand, robotic sand, dust obtained from stone crushers, sieved residue expelled from the reservoirs and additionally dams other than sand from other water bodies. In this connection the author would like to use the black marble stone powder as alternative material for sand in concrete. Before going to objectives and detailed experimental work, a brief review in this arena is presenting below.

Targan *et.al*. (2003) made experimental study on the use of natural pozzolana, coal fly ash, colemanite ore waste in the concrete. In this study they mainly concentrated on compressive, and bending strength, volume expansion and also on the setting time. From the experimental results it is observed that, for cement paste the finial setting time was faster when natural pozzolana is used as a replacement for cement. It is recommended that the compressive strength is increased for 5% replacement level of natural pozzolana. Nuno Almeida *et.al* (2007) made study on the effect of substitution of sand by stone slurry in concrete. The effect of 20% replacement of stone slurry as fine aggregate without affecting its mechanical properties is studied. From the results it is suggested that the replacement of 5% of the sand content

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by stone slurry resulted in increase in the compressive and also split tensile strength. Mustafa Karasahin and SerdalTerzi (2007) conducted an experimental investigation on the use of marble waste dust as a filler in the asphalt mixtures. The study showed that the locally available marble waste dust could be used in asphalt mixtures as a filler material. The asphalt mixtures with marble dust shows higher plastic deformations, this can be used for secondary and local roads. HanifiBinici *et.al.*(2008) conducted research on the concrete durability with marble and granite as a recycle aggregate. In this they used the granite and marble as replacement materials in concrete. They used these materials in various percentages and conducted tests. The study results showed that the effects of use of granite and marble waste as by- product in the production of concrete. KursatEsatAlyamac and RagipInce (2009) conducted experimental study by using the marble powder in self compacting concrete. The marble powder which is a waste material obtained during processes like polishing, cutting and grinding processes. They developed the relationship between the fresh concrete and hardened concrete.V.Corinaldesi, G.Moriconi, T.R.Naik (2009) were concentrated on the portrayal of marble powder for its utilization in concrete. Inferred that the marble powder ended up being extremely successful in guaranteeing great binding capacity of mortar and solid, On the premise of the low thixotropy qualities got, it appears that the utilization of marble powder would not be joined by an obvious propensity to vitality misfortune amid solid putting, as it is regular for other ultrafine, mineral increments, (for example, silica fume) that have the capacity to give high binding capacity to the solid mixture.The results showed that 10% replacement of sand by marble powder is effective after 28 days curing. BaharDemirel (2010) led experimental study on concrete with utilization of marble dust waste as replacement of fine sand. They supplanted the sand by waste marble clean in different proportions. Furthermore, saw the quality of the solid in every extent and brought up the extent in which quality accomplished is more. The outcomes found that the utilization of waste marble dust (WMD) in cement is improves the mechanical properties. Marmol *et.al* (2010) have focused on the utilization of granite sludge wastes in the production of coloured cement-based mortars. From the experiments, it was revealed that the compressive strengths was increased by replacement of $CaCo_3$ filler with Granite sludge. The compressive strength values range from 5.2 to 6.25N mm^{-2}. Nabil M *et.al.*(2010) conducted the experiment on mortar mixes with addition of Jordanian burnt stone slurry (BSS). This study is concentrated on fresh and hardened concrete properties. With the increase in the BSS content the setting time workability was decreased and the strengths were slightly increased. Naghabhushana and H.Sharadabai (2011) explored the characters of mortar and concrete where crushed rock powder(CRP) is utilized as replacement for natural sand. The quality of mortar with 40% CRP is much greater than ordinary mortar. The 40% CRP can be successfully used to supplant normal sand without decrease in quality of cement. Priyanka A.jadhav and Dilip K.Kulkarni(2012) made investigation on the properties of concrete prepared by using manufactured sand. The results showed that strength is more when M-sand is used. Tansia Hoque *et.al*, (2013) were studied the effect of stone dust as partially replacement of cement sand on the mechanical properties of mortar. This investigation mainly focused on the comparison between fresh mortar and modified mortar. The results showed that, the strength of mortar with 25% stone dust is higher than the normal mortar. But the replacement of cement by stone dust results in decreasing of mortar strength. Akshay C.Sankh *et.al*, (2014) carried out experimental work on replacement of natural sand with different alternatives like copper slag, washed bottom ash, quarry dust, building waste, spent fire bricks, sheet glass powder. The result showed that the effective utilization of these materials for concrete mix and building mortar.

From the above review of literature it is noticed that, no work has been carried with utilization of black stone marble powder for concrete works. Hence in this concern, the present study is planned to observe the behaviour of concrete with replacement of sand by black stone marble powder in various proportions of 0,25,50,75 and 100%. The specific objectives and plan of programme of present experimental work has been presented in the next chapter.

Objectives and Experimental Programme

The objectives of experimental study are:

1. To estimate the optimum percentage of stone powder usage to the concrete.
2. To estimate the cube and cylinder compressive strengths of concrete prepared with black stone powder in various proportions (0, 25, 50, 75 and 100%).
3. To estimate the split tensile strength of concrete made with black stone powder for various proportions.
4. To establish the relationship between compressive and split tensile strengths.
5. Comparing the results with ACI, GB and IS code provisions.
6. Regression Model Analysis is to assess on the basis of Integral Absolute Error (IAE %).
7. Comparative studies of different mixes at microscopic level are to be analysed with the help of Scanning Electron Microscopy analysis (SEM).

To achieve the specified objectives test program was planned using cube and cylindrical specimens. The cubes and cylinders are tested in compression testing machine (CTM) to obtain the cube and cylindrical compressive strength. In addition to these tests, split tensile test is also carried on cylindrical specimens using CTM. The detail test programme was presented in Table 1. In the table the nomenclature for various mixes can be read as,

Table 1 Test programme

Sl.No	Nomenclature	Number of Cube specimens			Number of Cylinder specimens		
		3days	7days	28days	3days	7days	28days
1	NC 0	3	3	3	6	6	6
2	SPC 25	3	3	3	6	6	6
3	SPC 50	3	3	3	6	6	6
4	SPC 75	3	3	3	6	6	6
5	SPC 100	3	3	3	6	6	6

NC 0 – Normal concrete without Blackstone powder, it can be consider as reference mix or controlled mix.
SPC 25 – SPC indicates stone powder concrete and 25% indicates replacement of sand with stone powder in the mix.
SPC 50 – SPC indicates stone powder concrete and 50% indicates replacement of sand with stone powder in the mix.
SPC 75 – SPC indicates stone powder concrete and 75% indicates replacement of sand with stone powder in the mix.

SPC 100 – SPC indicates stone powder concrete and 100% indicates complete replacement of sand with stone powder in the mix.

Materials Used

Cement: Ordinary Portland cement of 53 grade confirming to IS 8112-1989 standards was used to cast the specimens. The specific gravity of cement was noticed as 3.05.

***Fine aggregate*:** River sand from local sources was used as fine aggregate and specific gravity of sand was observed as 2.70.

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 2.75.

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

***Black Stone Powder*:** Black stone marble powder which is obtained from the cutting and polishing industries (fig.1). Waste stone powder was collected from stone industries in and around the Tadpatri (Town), Anantapur (Dist), A.P (State), and India (Country). From the sieve analysis (Table 2), it is confirming to Zone II with specific gravity of 2.56. The tests were conducted as per IS 2386-1963provisions. The physical and chemical properties of the stone powder can be observed in Table 3 and 4.

Table 2 Sieve analysis of black stone powder

IS Sieve Size	Weight Retained (gm)	Cumulative weight Retained	Cumulative% weight Retained	Cumulative % passing	Grading Zone
10mm	0	0	0	100	
4.75mm	15	15	1.5	97	
2.36mm	45	60	6.0	92.5	
1.18mm	152	212	21.2	78.8	Zone-II
600µ	390	602	60.2	39.8	
300µ	326	928	92.8	7.2	
150µ	70	998	99.8	0.2	

Table 3 Physical properties of stone waste powder

Physical properties	Fine aggregates	Test Method
Specific gravity	2.56	IS 2386(part III) 1963
Fineness modulus	2.84	IS 2386(part III) 1963
Bulk density (kg/m^3)	1725	IS 2386(part III) 1963
Absorption (%)	1.25	IS 2386(part III) 1963
Sieve analysis	Zone II	IS 383-1970

Table 4 Chemical properties of stone waste powder (IS: 4032-1968)

Constituents	Stone Powder (%)	Natural sand (%)
SiO_2	62.52	80.82
Al_2O_3	18.72	10.52
Fe_2O_3	6.54	1.75
CaO	4.83	3.21
MgO	2.56	0.77
Na_2O	NIL	1.37
K_2O	3.18	1.23
TiO_2	1.21	NIL
Loss of ignition	0.48	0.37

Casting and Testing

Casting

The cubes were cast in steel moulds with inner dimensions of 150 x 150 x 150mm.The cement, sand, coarse aggregate were mixed thoroughly manually. The mix proportion was adopted for all mixes as 1:1.44:2.56 with water cement ratio of 0.45. During mixing of concrete the required water quantity was added to the mix in two stages. At first stage 25% of water quantity added to the mix and mixed thoroughly. Later the remaining quantity of water is added to the mix and mixed till to uniformity occurs. For this entire process it has taken about 2 minutes. All the test specimens of moulds were kept on level ground and the concrete was poured into the moulds, in three layers and compaction was provided with a tamping rod in addition to this table vibrator was also provided (fig.2). The moulds were removed after twenty four hours and the specimens were moved to curing pond. After curing for a period of 28 days the specimens were taken out and allowed for drying under shade. Three cubes were tested for each mix as specified in test program to achieve required strengths. The cast cubes can be viewed in figure.3. In similar way the cylinders were cast with standard dimensions of diameter 150mm and height 300mm.

Fig 1 Black marble stone powder

Fig 2 Mixing and compacting the specimens on table vibrator

Testing

The compressive strength test set up is depicted in Figure 4. Compression test on cubes is conducted with 2000kN capacity Compression Tesing Machine (CTM) and the machine has a least count of 1kN. The cube was placed in the compressive-testing machine and the load is applied on the cube at a constant rate (0.2 to 0.4 MPa/sec) till the failure of the specimen and the corresponding load is taken as ultimate load.

Fig 3 Cast specimens

Fig 4 Testing of Specimens

Then cube compressive strength of the concrete mix is then calculated by using standard formula. Along with cubes, the cylinders were also tested in CTM to evaluate the cylinder compressive strength. The similar test procedure is adopted for cylinder. The split tensile strength was conducted as per IS:5816-1999. This test is conducted to measure the tensile strength of concrete by placing the cylinders longitudinally in the compression testing machine and it can be viewed in figure 4.

RESULTS AND DISCUSSION

Cube Compressive Strength

The cube compressive strength results are presented in Table 5. From this it is observed that, up to 50% of black stone powder content, the compressive strength increases gradually and for later replacements the strength is decreased. The compressive strength (average of three cubes) for control or reference specimen at 3, 7 and 28 days is 21.66, 23.62 and 29.55MPa respectively. The control specimen shows the 28 day compressive strength more than the targets mean compressive strength (26.6MPa). At 3 days, for 25 to 50% replacement of stoned powder the compressive strength was increased by 5 to 11% with respect of control specimen. For 75 to 100% replacement there is decrease in strength about 38 to 46% with respect to reference specimen strength. At 7 days, for 25 to 50% replacement of stoned powder the compressive strength was increased by 7 to 14% with respect of control specimen. For 75 to 100% replacement there is decrease in strength about 39 to 48 with respect to reference concrete specimen strength. The similar trend is continuing for 28 days strength also. The increase in strength is about 2% to 9% for 25 to 50% replacement of stone powder. The decrease in compressive strength is about 38% to 43% for 75 to 100% replacement of sand with stone powder. From above all it is observed that, the strength is effective at 50% replacement of sand with stone powder. The tesing of cube can be viewed in figure 4.

Cylinder Compression Strength

The cylinder compressive strength results are presented in Table 6. From this it is observed that, the strengths are differing for various mixes. At 25% and 50% replacements the strengths were shown higher than the reference concrete. But after 50% replacement the strengths are less than the reference mix. The compressive strength for control or reference specimen at 3, 7 and 28 days is 16.38, 17.36 and 20.78MPa respectively. At 3 days, for 25 to 50% replacement of stoned powder the compressive strength was increased by 2% with respect of control specimen. For 75 to 100% replacement there is decrease in strength about 19 to 34% with respect to reference specimen strength. At 7 days, for 25 to 50% replacement of stoned powder the compressive strength was increased by 2 to 13% with respect of control specimen. For 75 to 100% replacement there is decrease in strength about 22 to 35% with respect to reference specimen strength. The same trend is continuing for 28 days strength also. The increase in strength (at 28th day) is about 1% to 2% for 25 to 50% replacement of stone powder. The decrease in compressive strength is about 28% to 45% for 75 to 100% replacement of sand with stone powder. From above all it is observed that, the strength is effective at 50% replacement of sand with stone powder.

Table 5 Cube compressive strength

SL No	Nomenclature	Average compressive strength of cube (N/mm^2)		
		3 days	7 days	28 days
1	NC 0	21.66	23.62	29.55
2	SPC 25	22.81	25.40	30.16
3	SPC 50	24.20	27.16	32.35
4	SPC 75	13.31	14.38	18.22
5	SPC 100	11.55	12.11	16.57

Table 6 Cylinder compression strength

SL No	Nomenclature	Average compressive strength of cylinder (N/mm^2)		
		3 days	7 days	28 days
1	NC 0	16.38	17.36	20.78
2	SPC 25	16.82	17.61	20.90
3	SPC 50	16.82	19.69	21.12
4	SPC 75	13.19	13.54	15.08
5	SPC 100	10.67	11.16	11.50

Split Tensile Strength

The cylinder split tensile strength results are presented in Table 7. From this table, it is observed that, up to 50% of black stone powder content, the split tensile strength increases gradually and for later replacements the strength is decreased. The split tensile strength for control or reference specimen at 3, 7 and 28 days is 1.95, 2.21 and 2.48MPa respectively. At 3 days, for 25 to 50% replacement of stoned powder the compressive strength was increased by 4 to 11% with respect of control specimen. For 75 to 100% replacement there is decrease in strength about 2 to 22% with respect to reference specimen strength. At 7 days, for 25 to 50% replacement of stoned powder the compressive strength was increased by 3 to 12% with respect of control specimen. For 75 to 100% replacement there is decrease in strength about 7 to 29% with respect to reference specimen strength. The trend is continuing for 28 days strength also. The increase in strength is about 3% to 9% for 25 to 50% replacement of stone powder. The decrease in compressive strength is about 14% to 25% for 75 to 100% replacement of sand with stone powder. From above all it is observed that, the strength is effective at 50% replacement of sand with stone powder.

Table 7 Split tensile strength

SL No.	Nomenclature	Split tensile strength N/mm^2		
		3 days	7 days	28 days
1	NC 0	1.95	2.21	2.48
2	SPC 25	2.04	2.28	2.57
3	SPC 50	2.18	2.49	2.71
4	SPC 75	1.91	2.04	2.12
5	SPC 100	1.51	1.56	1.85

Relation between Split Tensile Strength and Cube Compressive Strength

Split tensile test is one of the best method to find the tensile strength of concrete, and in practical, the tensile strength is calculated from the compressive strength. For normal concrete the relationship between compressive strength and split tensile strength is given as,

$f_t = 0.49\sqrt{f_{ck}}$ -- Asper ACI318 Code
$f_t = 0.19\ (f_{ck})^{0.75}$---------------------- Asper GB50010 Code
By using the above equations the split tensile strength values determined and are presented in Table 8. The ratios of experimental split tensile strength with different codes and researchers are also presented in Table 8.

Table 8 Comparison of experimental split tensile strength with different codes

Nomenclature	Exp Split tensile strength (Mpa)	ACI (Mpa)	GB (Mpa)	EXP/ACI	EXP/GB
NC 0	2.48	2.66	2.40	0.93	1.03
SPC 25	2.57	2.69	2.44	0.95	1.05
SPC 50	2.71	2.78	2.57	0.97	1.05
SPC 75	2.12	2.08	1.67	1.01	1.26
SPC100	1.85	1.99	1.55	0.92	1.19

From this it is observed that the split tensile values obtained by ACI code are having good correlation with the experimental split tensile values. But the GB code underestimated the results for stone powder concrete. In order to improve this, the Regression model analysis was performed and the following regression equation is obtained (for the obtained equation the correlation coefficient (R) is 0.97545 and the Standard Deviation (SD) is 0.0786).

$f_t = 0.47\sqrt{f_{ck}}$

From the regression model (RM) analysis the split tensile values for NC0, SPC25, 50, 75 and 100 is 2.58, 2.66, 2.00 and 1.91 respectively. The split tensile values obtained by RM analysis were compared with the experimental values. Comparison between the experimental test results and the values predicted by proposed equation is presented in Table 9. The ratio between experimental (EXP) values and RM analysis values is about 0.96 to 1.06. From this it is noticed that, the proposed equation has good agreement with the experimental results.

Table 9 Performance of regression model

S no	Nomenclature	Experimental values		RM (Mpa)	EXP/RM
		f_{ck} (Mpa)	f_t (Mpa)		
1	NC 0	29.55	2.48	2.55	0.97
2	SPC 25	30.16	2.57	2.58	0.99
3	SPC 50	32.35	2.71	2.66	1.01
4	SPC 75	18.22	2.12	2.00	1.06
5	SPC100	16.57	1.85	1.91	0.96

Integral Absolute Error (IAE(%))

In the present study, the reliability of the relationship obtained between f_{ck} and f_t from the regression analysis was assessed on the basis of the Integral Absolute error. This index has been used by other researchers [Gardner (1988), Oluokun (1991) and Anoglu (1995)]. Nihal Anoglu *et.al*, (2006) reported the work on "Evaluation of Ratio between splitting tensile strength and compressive strength for concretes up to 120Mpa and its application in strength criterion". In their study they used the Integral Absolute Error to know the reliability of the relationship, obtained from the regression analysis. The used IAE equation is furnishing below

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

Where,
O_i – Observed value
P_i – predicted value from the Regression equation

The relative deviations of the data from regression equation can be measured by IAE. The IAE value equal to zero indicates that the observed values and the predicted values from regression equation are equal. The limits for an acceptable regression equation are that, IAE should be in the range of 0 to 10%. The IAE for present experimental work was calculated and it is presented in Table 10. From this it is noticed as 2.64 % and from this, it is concluded that the developed regression equation acceptable to access the experimental results. (Integral Absolute Error (IAE) = 0.31*100 / 11.73=2.642%)

Table 10 Integral absolute error value for proposed regression equation

S.No	Nomenclature	EXP Oi	RM Pi	$[(O_i-P_i)^2]^{1/2}$
1	NC 0	2.48	2.55	0.07
2	SPC 25	2.57	2.58	0.01
3	SPC 50	2.71	2.66	0.05
4	SPC 75	2.12	2.00	0.12
5	SPC100	1.85	1.91	0.06
		$\sum O_i =$ 11.73		$\sum[(O_i-P_i)^2]^{1/2} = .31$

Relation between Split Tensile Strength and Cylinder Compressive Strength

For conventional concrete the ACI and FIB codes are provided the relation between split tensile and cylindrical compressive strengths. Few researchers are also provided relation between above said strengths. In the present experimental work, the author would like to find the suitability of equation for test results. In this regard the provided equations are furnishing below.

$f_t=0.56f_c^{0.5}$ ……………… . As per ACI 318
$f_t= 0.3\ f_c^{\ 2/3}$ ………….. As per CEB-FIB
$f_t=0.131\ f_c^{\ 0.667}$ ………...As per Raphael (1984)
$f_t=0.47\ f_c^{0.59}$ …………….As per Gardner (1988)
$f_t=0.34\ f_c^{0.66}$ …………...As per Gardner (1990)
Where,
ft = Split tensile strength (Mpa)
fc = Cylindrical compressive strength (Mpa)

By using the above equations the split tensile strength values determined and are presented in Table 11. The ratios of experimental split tensile strength with different codes and researchers are also presented in Table 12. Thus it is observed that the split tensile values obtained by ACI code are having good correlation with the experimental split tensile values. The other equations are also good enough to estimate the split tensile strengths for various mixes.

Table 11 Relation between split tensile strength and cylinder compressive Strength

Sl. no	Nomenclature	EXP	ACI 318-99 $f_t=0.56f_c^{0.5}$	CEB-FIB $f_t= 0.3\ f_c^{\ 2/3}$	Raphael $f_t=0.131\ f_c^{\ 0.667}$	Gardner $f_t=0.47\ f_c^{0.59}$	Gardner $f_t=0.34\ f_c^{0.66}$
1	NC 0	2.48	2.54	2.26	2.36	2.81	2.51
2	SPC 25	2.57	2.55	2.27	2.37	2.82	2.52
3	SPC 50	2.71	2.57	2.29	2.39	2.84	2.54
4	SPC 75	2.12	2.17	1.83	1.90	2.32	2.03
5	SPC100	1.85	1.89	1.52	1.59	1.98	1.70

Table 12 Split tensile strength comparison with different codes and earlier works

S no	Nomenclature	EXP	EXP/ ACI	EXP/CEB-FIB	EXP/Raphael	EXP/Gardner	EXP/Gardner
1	NC 0	2.48	0.98	1.09	1.05	0.88	0.98
2	SPC 25	2.57	1.00	1.13	1.08	1.08	1.01
3	SPC 50	2.71	1.05	1.18	1.13	0.95	1.06
4	SPC 75	2.12	0.98	1.15	1.11	0.91	1.04
5	SPC100	1.85	0.98	1.21	1.16	0.93	1.08

However the ACI provided equations is showing excellent performance. Hence the author is suggesting considering the ACI provided equation to predict the experimental results. From this also it is once again concluded that, ACI proposed equation is best among other equations.

Scanning Electron Microscopy Analysis (SEM)

The scanning electron microscope is a type of electron microscope that produces images of a sample by scanning it with a focused beam of electrons.

The micro structures of the specimens (after 28 days curing) were studied using scanning electron microscopy (SEM) images. Figures 5 to 9 shows the SEM images for concrete with replacement of 0%, 25%, 50%, 75% and 100% black stone powder. The SEM images show clearly that, the specimen with 50% replacement shows less porosity and more packing structure in comparison with other specimens.

The figure 5 belongs to micrograph of control mix form this it is noticed that, control mix possesses lower porosity, voids and more packing structure. It also shows the development of proper and clear C-S-H paste in various stages.

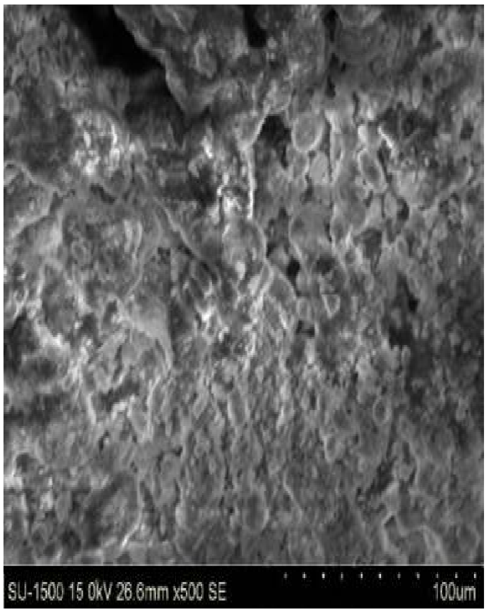

Fig 5 SEM image for normal concrete at 28 days

The important point to be noted in the micrograph is that the C-S-H gel/ pastes i.e. the bright mass with chalky gel parts are spread over the entire aggregates (both coarse and fine) thus acting as binders for the paste. Figure 6 is the micrographs of SPC 25. It shows the C-S-H gel paste is widely spread than it was in the control mix. There is increase in strength of about 2.06% compared to the control mix. The increase in strength could be because of formation of proper C-S-H gel when compared to the control mix microstructure. Figure 7 shows the micrograph of SPC 50. Here the C-S-H gel was more widely spread than the control mix. This behaviour is due to the effect of black stone powder that reduced the porosity of specimen and produced more packing structure compared to the control and SPC 25 mix. There is increase in strength of about 9.47% than the control mix. This has achieved because of C-S-H gel formation at higher level. Figure 8 and 9 shows the micrographs of SPC 75 and SPC 100. Here it is seen that the strength is decreased from 38.34% to 43.92%. in SPC75 and SPC 100 the formation of C-S-H gel is not good, it is not widely spread compared to the control mix. The voids are more in case of SPC 75 and SPC 100. In SPC 100 C-S-H gel is not formed at many places in the micrograph.

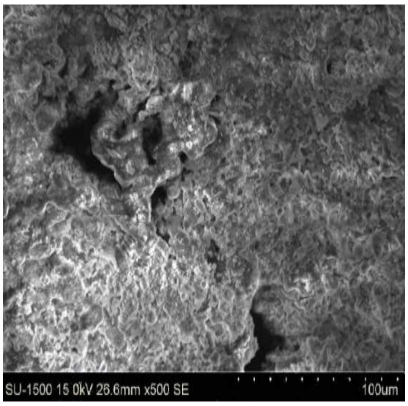

Fig 6 SEM image for SPC 25 at 28 days

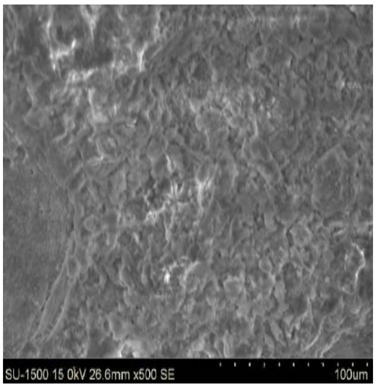

Fig 7 SEM image for SPC 50 at 28 days

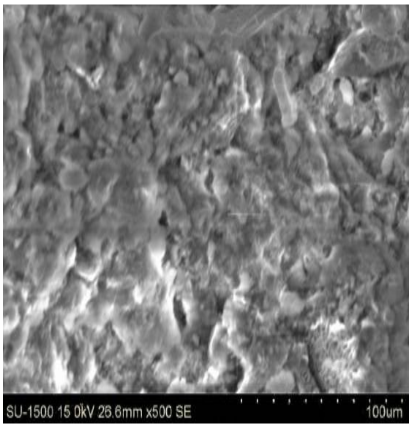

Fig 8 SEM image for SPC 75 at 28 days

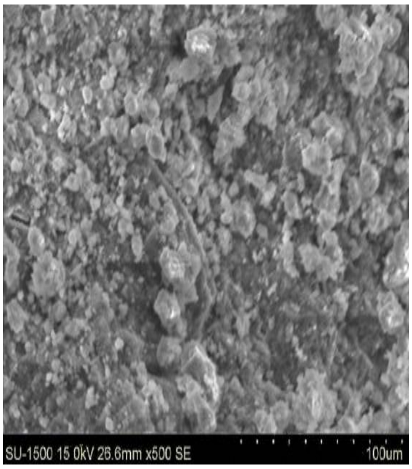

Fig 9 SEM image for SPC 100 at 28 days

CONCLUSIONS

From the present experimental work the following conclusions are drawn.

1. This study showed the utilization of black stone powder is effective as a replacement of sand for construction works up to 50%.
2. As the % of black stone powder increased there is increase in compressive and tensile strength up to 50% replacement. The strengths are highly remarkable at 50% replacement.
3. As the % of black stone powder increased beyond 50% the compressive strength and tensile strength are decreased.
4. The cube compressive strength results showed that, there is increase in strength of about 2 to 9% up to 50% replacement. But when the replacement exceeds 50% replacement i.e, at 75 and 100% there is decrease in strength of about 38 to 43%.
5. The cylinder compressive strength results showed that, there is increase in strength of about 8 to 16% up to 50% replacement. But when the replacement exceeds 50% replacement i.e, at 75 and 100% there is decrease in strength of about 16 to 36%.
6. The split tensile strength results showed that, there is increase in strength of about 3 to 9% up to 50% replacement. But when the replacement exceeds 50% replacement i.e, at 75 and 100% there is decrease in strength of about 14 to 25%.
7. Regression model is developed between the split and compressive strength ($f_t= 0.47f_{ck}$). This relation is verified with IAE index.
8. Split tensile and cylindrical compressive strength results were compared with building codes and earlier research works. From them it is observed that, ACI proposed equation shown good compatibility with experimental results.
9. SEM analysis is carried out to study the micro level behaviour of concrete and the experimental results are supported the behaviour of the concrete.

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