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Effect of Stone Dust on the Mechanical and Microstructural Properties of Opc Based Concrete Subjected To Acid Exposure

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Abstract: ***A separate approach of sustainable development is to make the structures durable. More durable structures need to be replaced less frequently and will reduce the need for cement. Such increase in durability can be achieved by choosing appropriate mix designs and selecting suitable aggregates and admixtures. In this experiment sand (fine aggregate) is partially replaced by stone dust to make the concrete mix sustainable in nature. This study also investigates the durability of different types of concrete in acid exposure. Cube compressive strengths of different mixes have been compared to see how the concrete strength differs from original mixes. In addition different types of non-destructive tests such as ultrasonic pulse velocity test, rebound hammer test and half-cell potential tests have also been performed on the concrete samples for better analysis of their strength and durability characteristics. Specimens were analysed through the Scanning Electron Microscope to understand the microstructural changes of concrete samples. Energy dispersion X-ray analysis was also done to understand the changes in the nature of the hydration products of some specimen.***

Keywords :. EDX, SEM, Acid Exposure, UPV and Half Cell.

I. INTRODUCTION

Sustainable concrete can be made by using currently available resources in such a manner that it will not affect the required needs of our future generations. Concrete produced with recycled material of very low inherent energy, high thermal mass and with little wastage may be classified as sustainable concrete. The waste material is generally formed as by products from different industrial manufacturing processes. Construction Industries can create a noticeable impact on the environment with this sustainable technology. Use of "green" materials in production of sustainable concrete gives us an opportunity to lower the energy costs, maintain the durability, as well as use of high proportion of recycled materials.Concrete always has the long life expectancies unless exposure conditions are severe. Structures like wastewater systems have the tendency for corrosion which is due to the different types of chemicals like sulfuric acid. Acids attack in concrete often has led to a costly repair or in some cases demolition of structure. This type of corrosion is also known by different names, such as hydrogen sulfide (H_2S) corrosion, microbial induced corrosion etc. Different type of case studies have been done to find the solution to reduce repairs and maintenance costs. Here we replaced sand by stone dust to improve the durability properties of the sustainable concrete.

Several other authors gave their significant inputs in this field of research, H. Donza et al. (2002) [1] suggested that high strength concrete sand can be produced using crushed sand as fine aggregate and the concrete produced with crushed sand has better performed better in its' hardened state. Ramsburg (2004) [2] specified that generally two types of corrosions are induced by sulfuric acid in concrete. One is biogenic and the other one is simply chemical. It is interesting that the corrosion of sewer pipes has been falsely called a corrosive gas problem. Reaction between the H_2S and thiobacillus bacteria is the main reason for the corrosion in concrete. Monteny et al. (2000) [4] confirm that Gypsum is the initial product of the reaction between sulfuric acid and hydration composites which is followed by an expansion in volume of the concrete. Skalny et al. (2002) [5] groundwater usually contains many different sulfates and free sulfuric acid may also be one of the products. It should be noted that the rate of the deterioration of concrete structures close to groundwater is dependent on the concentration of the sulfuric acid and the amount of water that can reach the concrete surface. The permeability of the soil that is in contact with concrete also plays an important role.

II. RESEARCH SIGNIFICANCE

The two main objectives of this study is to see whether the target strength of concrete prepared by part replacement of fine aggregate with stone dust can be achieved or not and to compare the durability of sustainable concrete to traditional concrete in acid exposure.

III. EXPERIMENTAL PROGRAM

A. Material Used

Cement: Ordinary Portland Cement (53 Grade) [Conforming to IS 12269:2013] was used during the whole research work.

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Coarse Aggregate: Aggregate most of which is retained on 4.75-mm IS Sieve and containing only so much finer material as is permitted in IS 383 are coarse aggregate. Here 20 mm nominal size crushed stone angular in shape was used as coarse aggregate (C.A.).No replacement was done for C.A. in this experiment.

Fine Aggregate: River sand (yellow) conforming to Zone-III has been used in the experiment work.

Stone Dust: The available stone dust has excess amount of 4.75mm retained and 150micron passing particle as per allowable limits of fine aggregate, specified in IS 383 .So the portion passing of 4.75 mm IS Sieve and retained by 150 micron IS Sieve is taken for concrete mixes.

Water: Potable water having pH value 7.2 was used for concrete mix.

Super Plasticizer: Super plasticizing admixture of a particular brand (conforming to IS 9103: 1999) has been used in concrete mixes to make fresh concrete workable. As the mixes are very stiff, 0.8% super plasticizing admixture by weight of cementitious material has been used. But this was not enough to make slump more than 50mm. As the focus was on strength criteria of concrete percentage of admixture was not varied mix to mix but remains 0.8% for all the mixes.

B. Sulphuric Acid

Durability of concrete has been experimented by submerging cube samples into sulphuric acid solution for 28 days under normal room temperature. To achieve accelerated corrosion effect in short time, 4% diluted sulphuric acid solution was chosen for the experiments. Sulphuric acid of 98% was mixed with potable water at a ratio of 41gm of concentrated (98%) H_2SO_4 to 1 liter of H_2O. Each of the containers was filled with 15L of potable water and then 615 gm. concentrated acid added. The surface level was constantly maintained to compensate absorption or evaporation loss so that the samples remain submerged for 28 days. The acidity of prepared solution at day 1 was 0.5pH and before taking out of solution the pH was 0.7.

C. Concrete Mix Proportions

M 45 grade of concrete was designed to study the durability of the sustainable concrete mix in which sand was replaced by stone dust by 20%, 25%, 30% and 35% by volume. Mix Proportions has given in the Table 1.

Table- I: Mix Proportions

Descriptions	M 45
Cement	410 Kg/m3
Sand	639 Kg/m3
Coarse Aggregate 20mm	796.8 Kg/m3
Fine Aggregate 10mm	531.2 Kg/m3
Water	156 L
Admixture	0.8% by Weight of Cement

D. Casting of Specimen

150mm x 150mm x 150 mm Cube samples were casted for compressive test and same can be measured after the acid exposure.

IV. RESULTS AND DISCUSSIONS

A. Compressive Strength

In normal concrete (i.e. when stone dust was not used in mix) subjected to 28 days water curing compressive strength came as 55.11 N/mm2. And when stone dust added for replacement of sand with percentages of 20, 25, 30 and 35%, the compressive strengths appeared as 52.89, 56.44, 60.00 and 57.33 N/mm2respectively, i.e., all the four sustainable mixes i.e. from 20 to 35% replacement of sand reaches target mean strength of M45 grade concrete. These shows that with partial replacement of sand by stone dust and using OPC, higher grade (M45) of sustainable concrete can be produced. At 30% replacement level maximum compressive strength was reported. All results are given in Fig.1. In normal concrete after acid exposure, compressive strength reduces to 48.89 N/mm2 from the 28 days water curing strength of 51.11 N/mm^2. Subsequent compressive strengths after acid exposure with 20%, 25%, 30%, and 35% stone dust replacements are 45.77, 49.78, 52.89 and 51.11 N/mm2 respectively. As the stone dust has limited chemical reaction with acid, sustainable concrete with stone dust does shows reasonable residual strength of concrete when subjected to acid exposure. But more the strength of concrete more residual strength can be obtained by comparing to the traditional concrete. All results are shown in Fig.1 and Fig.2.

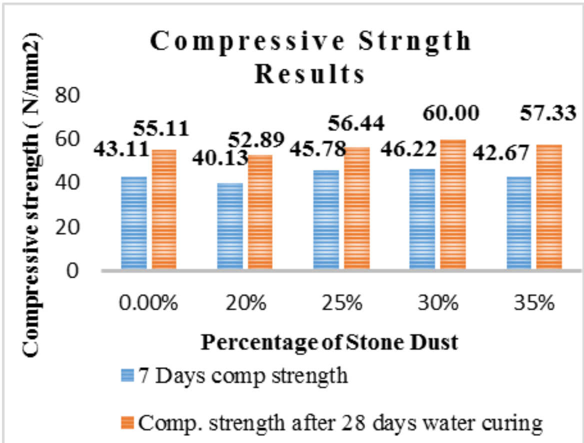


Fig.1

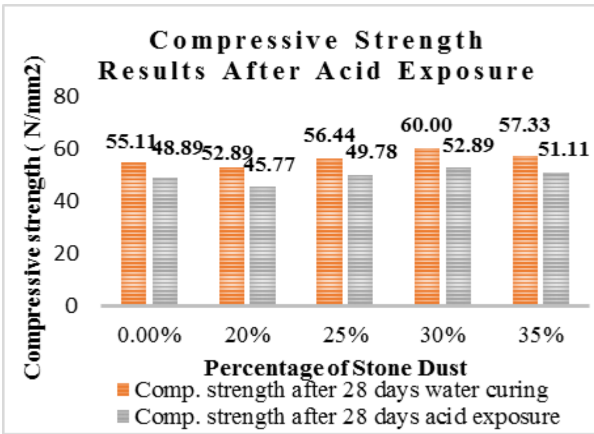


Fig.2

B. Ultrasonic Pulse Velocity Test

All the UPV values are more than 4.5kM/Sec even after 28 days of acid exposure, i.e., quality of concrete of sustainable concrete may be said as excellent as per IS 13311 (Part I). All Ultrasonic Pulse Velocity results are given in Fig.3.

C. Half Cell Potentiometer

Half-cell potential drops become more negative after acid exposure for all the mixes, i.e., corrosion have started in acid exposure. From Fig.5 it can be said that addition of stone dust does not influence the corrosion potential of rebar i.e. percentage potential drop of sustainable concretes are similar to traditional concrete. So sustainable concrete made by partial usage of stone dust will have same rebar corrosion potential when subjected to acid exposure as in case of traditional concrete. Fig.5 showed the percentage decrease in the potential as the percentage replacement increase.

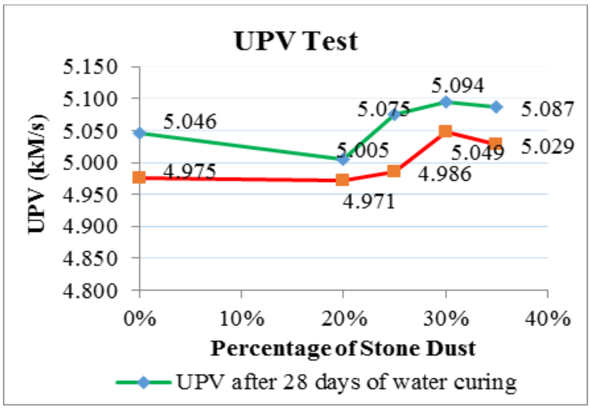


Fig.3

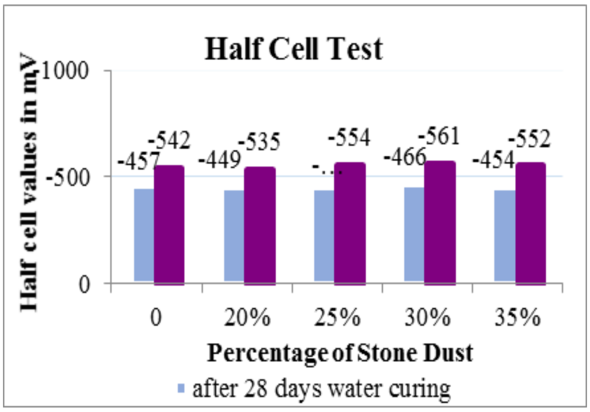


Fig.4

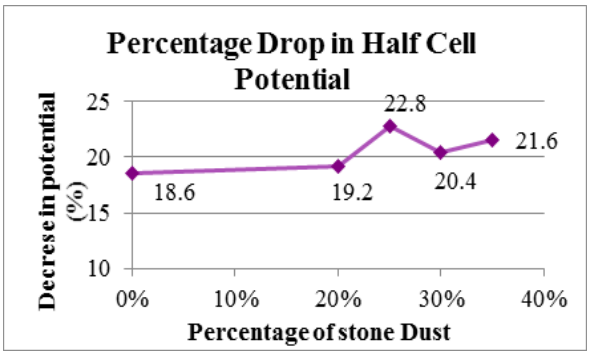


Fig.5

D. Microstructural Study

From SEM analysis formation of ettringite can be seen at 25% stone dust replacement. This reflects ettringite and calcium hydroxide formation was not prevented by stone dust replacements. By comparing Fig. 6.2.9 and Fig. 6.2.11 it can be said that sustainable concrete with 25% stone dust shows denser matrix than traditional concrete matrix.

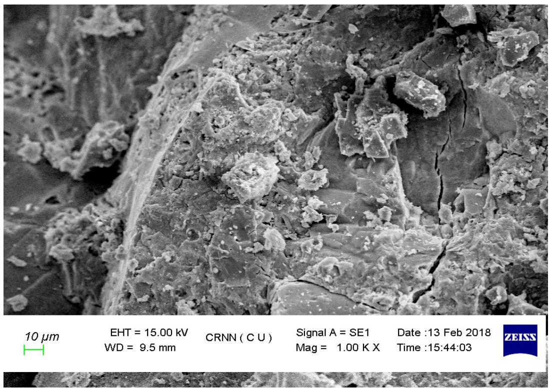


Fig.6 SEM image of concrete specimen after 28 days water curing at 1000 X (OPC is used and sand is not replaced with stone dust)

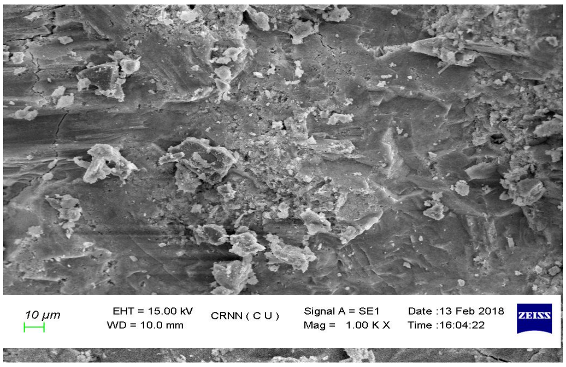


Fig.7 SEM image of concrete specimen after water curing at 1000X (When OPC is used and 25% sand is replaced with stone dust)

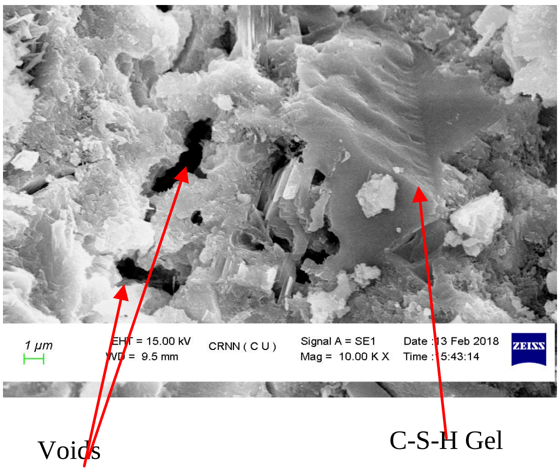
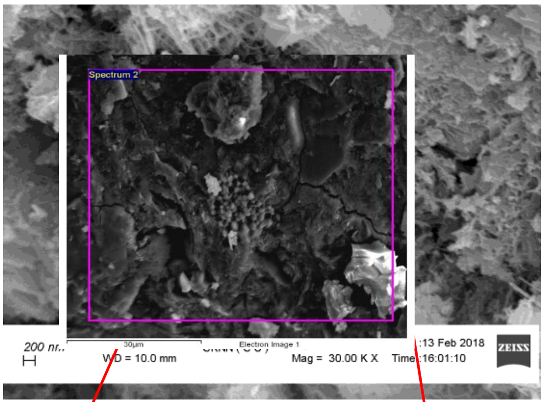


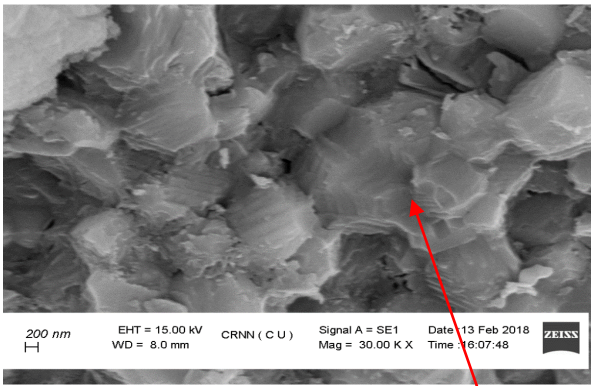
Fig.8 SEM image of concrete specimen after water curing at 10,000X



Needles of ettringite

C-S-H Gel

Fig.9 SEM image of concrete specimen after water curing (OPC is used and 25% sand is replaced with stone dust) at 30000X



Acid Attack

Fig.10 SEM image of concrete specimen after acid exposure (OPC is used and 25% sand is replaced with stone dust) at 30000X

E. EDX analysis:

By EDX analysis it was seen that both in sand and stone dust chemical compositions are almost similar. Percentages of Al_2O_3, SiO_2 and FeO are nearly identical for both materials. But from sieve analysis it was observed that stone dust has less uniformity in particle size distribution. From SEM image it was observed shape of stone dust particles are more angular than sand particles. So when stone was mixed with sand the overall interlocking arrangement changes and thus influence in the strength of concrete. From test results it is seen that at 30% stone dust strength reaches at highest value within the scope of this experiment. From combined sieve analysis graphs it was also observed that at 30% stone dust combined with 70% sand the graph signifies more uniform particle distribution than other combinations. Analysing EDX chart viz. table 2 and 3 it is seen than percentage of CaO present was 56.32% before acid exposure. But after acid exposure CaO reduced to 49.2%

Table:II Elemental analysis chart from EDX after water curing

Element	Weight %	Atomic %	Compd %	Formula
Mg K	1.36	1.60	2.26	MgO
Al K	2.28	2.42	4.31	Al_2O_3
Si K	7.74	7.88	16.56	SiO_2
Cl K	0.62	0.50	0.00	-
Ca K	40.25	28.73	56.32	CaO
Fe K	2.96	1.52	3.81	FeO

Table III: Elemental Analysis Chart from EDX after acid Curi ng

Element	Weight%	Atomic%	Compd%	Formula
Si K	19.06	16.67	40.77	SiO2
Ca K	35.16	21.56	49.20	CaO
Fe K	7.80	3.43	10.03	FeO

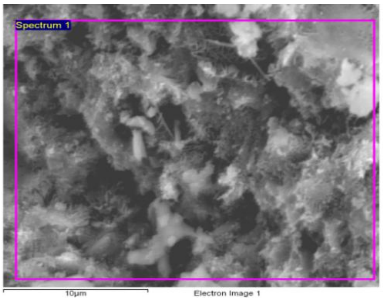


Fig.11 Micrograph after water curing (OPC is used and 25% sand is replaced with stone dust)

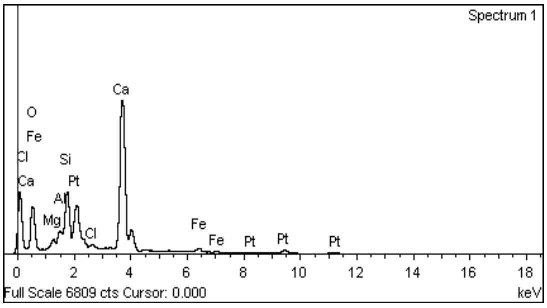


Fig.12 EDX spectrum after water curing (OPC is used and 25% sand is replaced with stone dust)

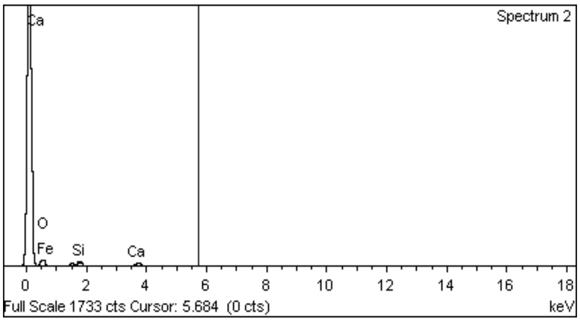


Fig.13 Micrograph after acid exposure (OPC is used and 25% sand is replaced with stone dust)

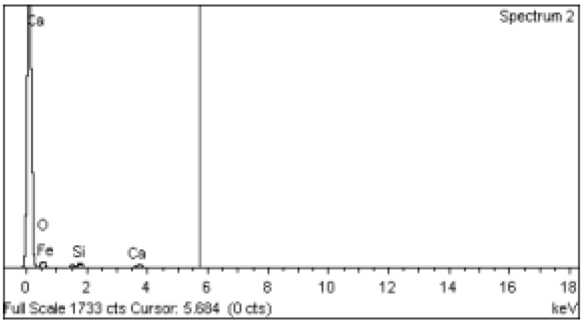


Fig.14 EDX spectrum after acid

V. CONCLUSION

- Replacement of sand with stone dust did not have a negative influence on the acid resistivity of concrete and was comparable to the normal concrete mix.
- Ultrasonic pulse velocity test shows that even after acid exposure for 28 days, all the values were below 4.5 Km/s (Excellent grading quality limit). Vis-a-vis Rebound hammer values also reduced .
- This signifies that in 28 days acid exposure inner core of cube is not much affected but surface material degrades more than inner core.
- In Half-cell potential test non-corroded steels have displayed widespread range of potential values. But potential drops before and after acid exposure of the same sample reveals that corrosion in steel started in acid exposure. In sustainable concretes half-cell potential drops was similar to traditional concrete. So corrosion susceptibility of sustainable concrete is comparable to traditional concrete.
- Scanning Electron Microscope images of different concrete mixes show changes in surface topography at different exposure conditions. C-S-H gel, Calcium hydroxide plates, needles of ettringite, are clearly visible at micro level.
- From the Energy-Dispersive X-ray spectroscopy (EDX) percentage of elemental compound variations before and after acid exposure can be seen.

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