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Mechanical Properties and Microstructural Features using Stone Dust as a Partial Replacement of Sand

Bikram Paul, Kushal Ghosh, Partha Ghosh

Abstract*: *Today's world is always leads to development in technology as well as the economic growth though sometime these will affect the environment badly. That's why world environmental commission coined the termed called sustainable development where development takes place without hampering the others' needs. Concrete industry is rapidly growing industry in India which consumes lots of natural resources during the production of concrete. Here Stone dust is used as a sustainable material in place of sand partially. M25 grade of concrete has been chosen for the experiments. Different mechanical properties of concrete like compressive strength, Split tensile, flexural strength etc. and Microstructural features like SEM, EDX have been included in this study. Compressive Strength and flexural strength test results shown the increase in the strength. Sulphate Resistance Properties have been tested by curing the cubes in the $MgSO_4$ solution and increase in weight has been observed. Similarities are found in the SEM pictures.

Keywords: SEM, EDX, Compressive strength, Split tensile Strength and UPV.

I. INTRODUCTION

Today concrete has the great advantages over the other alternative structural materials like lumber and steel due to the advancement of material science by applying this science to the production of concrete, we can improve the durability and sustainability of concrete in near future. From the industrial point of view, we divided the world into two part: one whose industrialization started many years ago and other whose industrialization has just started. These industrial development act as an accelerator to increase the demand of raw material in the production of concrete. Approximately 10 to 15 percent of cement, 8 to 15% of water and 70 to 80 percent of aggregates by mass, we consumed in the production of concrete. From the reports of different organization almost 11.5 billion tonns of concrete has been produced by the concrete industry which is the biggest consumer of the raw material. It has been also found that the demand of concrete will be increased by the year 2050. Design Mix of concrete is an art by which we can prepare a concrete mix using optimum quantity of fine aggregates, coarse aggregates, water and cement. Normally, River sand is primarily used in the concrete as a fine aggregate. Nowadays, sustainability is an issue where we have to make things happened without harming the environment and reduction in the use of Natural Resources as much as possible. We used concrete in huge quantity for the constructional works and for a result we are using huge quantity of natural resources like River sand, Coarse aggregate, limestone, River sand etc. Now, we are facing a challenge of saving natural resources and it is possible when we stop or reduce the production concrete or by searching alternative materials for making concrete. One can reduce the use of natural sand by replacing it partially or fully with stone dust which is a waste material obtained from crusher plant. We can improve the quality of concrete by using stone dust and also save natural sand for future generation. Restrictions are being imposed by states in India in quarrying sand from river beds. By mining sand from river bed, we lower the ground water level in the river in summer when there is no flow in the river. This, in turn, will lower the ground water level in all neighborhood. Generally fine aggregates are used to reduce shrinkage and to give economy to the concrete mixtures. Though aggregates are considered as an inert ingredient in concrete, now this conception is changed as some aggregates are considered as a chemically active aggregate. Those aggregates may show chemical bond with the paste. Generally fine aggregates are used depending on the following properties like grading, shape, size, texture, specific gravity and chemical properties etc. Here stone dust is used as partial replacement of sand and stone dust is a by- product from stone quarry. Different types of stone dusts are found depending upon their parent rock. Chemical compositions of stone dust are silica, iron oxides, magnesium oxides and some percentage of alumina etc. Celik and Marar [1] investigated the properties of hardened concrete and mixing stone dust as a partial replacement of sand. They suggested 10% replacement as an optimum replacement for compressive strength and flexural strength and 15% for water absorption. MD. Nuruzzaman [2] et al. replaced stone dust as a replacement of sand from 0 to 50% and studied the compressive strength and tensile strength of that mix.

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They suggested the optimum percentage of stone dust as 30% for compressive strength whereas minimum tensile strength for the mix would be 50%. Quarry stone dust can be utilized with the help of silica fume for replacing higher quantity of sand. R. N. Uma et al. [8] replacing sand up to 50% and showed a higher compressive and flexural strength than that of natural concrete. Whereas inclusion of stone dust with silica fume showed lesser flexural and tensile strength by Lohani T.K et al. [5] In mortar manufactured sand can be used up to 50% with sand and a good compressive strength was found. Mix ratio were selected as 1:2, 1:3, 1:6 and w/c ratio as .50 and 0.55 by Priyanka A. Jadhav et al. [7] Other researchers also made an attempt on this subject introducing different materials like waste foundry sand, brick kiln dust, slag, fly ash etc. Gurpreet Singh et al. [9] carried out an examination on partial replacement of sand by Waste foundry sand and put forward for a consideration of WFS. They used waste foundry sand with concrete as a replacement of sand by 0%,10%,15%,20% and 25% and testing the mechanical properties (compressive Strength, Split Tensile) and durability (RCPT) were done at the ages 7 days,28 days and 91 days. Malkit Singh et al. [10] were studied the effects of partial replacement of sand using bottom ash as a replacement. They concluded that the mixing of bottom ash in concrete increased the probability of bleeding of concrete and this bleeding water gets trapped by aggregate and formed pores in the concrete. This lead to porous and low-density concrete and followed by lower compressive strength though it can be ignored by using high dose of admixture with 50% replacement of sand.

II. RESEARCH SIGNIFICANCE

To find the optimum percentage for the concrete and make the mix sustainable by reducing the use of River Sand.

III. EXPERIMENTAL PROGRAM

A. Material Used:

Cement:

Portland Pozzolana cement (Ultra-Tech) has been used conforming to IS 1489: part 1. Test result has given below:

Table- I: Physical Properties of Cement

Physical Properties	*Test Result*
Initial Setting Time (minute)	122
Final Setting Time (minute)	252
Compressive Strength (MPa)	-
3 Days	21.22
7 Days	31.30
28 Days	42.12
Standard Consistency (%)	32.5

Coarse Aggregate:

Coarse aggregates were used of nominal maximum size 20 mm and requirements met as per IS 383:1970. Different test results are given in below table Sieve Analysis was done to meet the requirements of grading of Coarse Aggregate as per IS 383:1970. Fig.1 shows the grading curve of Coarse Aggregate.

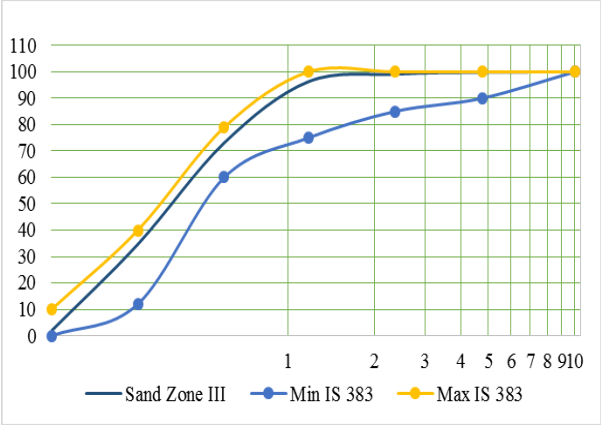


Fig. 1

Fine Aggregate:

Locally available sands are used for this research work and sands are tested as per IS -383:1970. Several physical properties of sand were tested such as moisture content, water absorption, sieve analysis, specific gravity etc. Above graph represents the sieve analysis of fine aggregate in Fig .1

Stone Dust:

Stone Dust was collected from Nalhati, West Bengal. It is a by-product of rock quarry. We were using it as partial replacement of sand and it was replaced by volume 10%, 15%, 20%, 25%, 30%, 35%. Fig.2 represents the sieve analysis of raw stone dust and sieve analysis also done after sieved the stone dust 2.36 mm sieve to make it within the limits of IS 383. [14]

Water:

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

Admixture:

Sikament 2004 Ns was mixed with concrete to improve the workability of the mix. Here 0.8% weight of cement dose of the admixture was used.

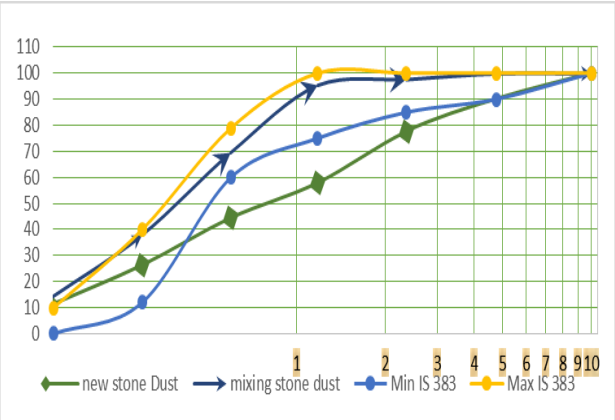


Fig. 2

Concrete Mix Proportions:

A M25 grade of concrete was designed as per IS 10262:2009 which has mean target strength of 31.67 MPa. Sand of this mix has been replaced by volume of 10%, 15%, 20%, 25%, 30%, and 35% to make this sustainable and to study and compare its mechanical properties with each other.

Table- II: Design Mix Proportions

Descriptions	*M 25*
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

B. Casting of Specimen:

150mm x 150mm x 150 mm Cube samples were casted for compressive test and flexural Tests were conducted on 150mm x 150mm x 700mm Beam samples. Split Tensile Tests also carried out on cylinder of 150 mm diameter samples.

IV. RESULT AND DISCUSSION

A. Compressive Strength:

Concrete Mix was designed for M25 grade which had a target mean strength of 31.67 MPa. Normal concrete, i.e., 0% replacement of stone dust in Table 4 showed 22.82 MPa and 31.68 MPa compressive strength for 7days and 28 days respectively. When sand was replaced by 10%, compressive strength was reduced to 22.00 MPa for 7 days after that Strength increased for 15% substitution both for 7 days and 28 days. Each replacement beyond 10% gets increased and at 25% maximum strength achieved after that strength gets reduced for 7 days and 28 days respectively. Basically, the quantity of fine particles in the matrix was less for 10% and it was increasing from 15% to 30% and compressive strength also increased for that reason. In case of 35% mix, it was not a homogeneous mix and slump was almost zero for the mix as water gets absorbed by the fine particles so there was not enough water in the mix to complete gel formation and strength gets reduced. Though the optimum condition found at 25%, it is possible to replace up to 30%. It was confirmed by the MD. NURUZZAMAN et al. [2] and Sanjay Mundra et al. [3] in their Literature. Compressive Strength Testing results are given in Table 5 and Table 6. Fig1 and Fig2 are the graphical representation of the results shown above.

B. Flexural Strength:

Flexural Strength of concrete get decreased for 10% replacement of sand by stone dust than that of normal concrete. After that flexural strength was started increasing from 20% replacement and increased up to 35%. It was noticed for both 7 days and 28 days. It may possible to replace

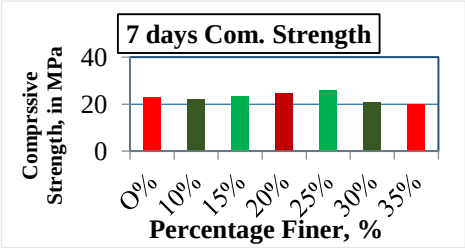


Fig. 3

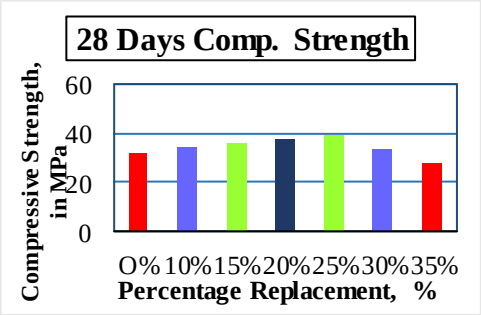


Fig. 4

further from 35% because surface texture is quite rough for stone dust and it develops the bond between the paste and stone particles.Same reason can be stated for flexural strength as that it was discussed for compressive strength. Not only the fine particles were responsible but also rough texture of the stone dust was responsible. Results of flexural strength are tabulated in Table 7 & Table 8 for 7 days and 28 days respectively. Fig 6 & Fig 7 show the graph of the same. Stone dust increased the flexural strength as the percentage increased in SD content which is also reflected by R. Ilangovana et al. [4] in his literature.

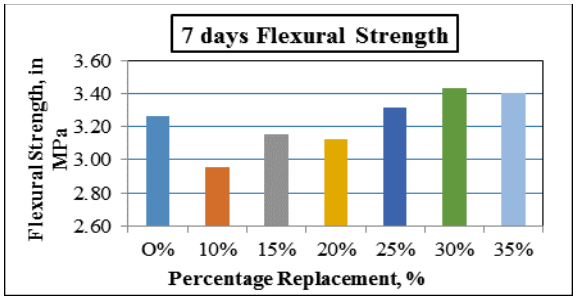


Fig. 5

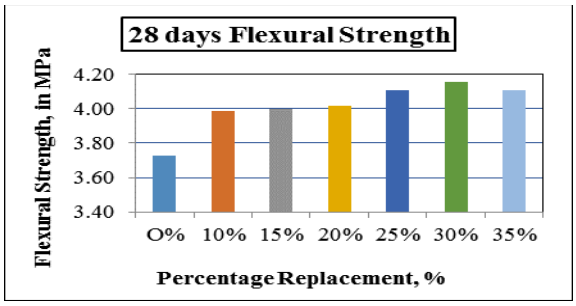


Fig. 6

C. Split Tensile Strength:

Reduction in split tensile was noticed from 10% to 20% substitution after that it was increased for 25% replacement for 28 days results which was supported by the document of Lohani T.K et al. [5].

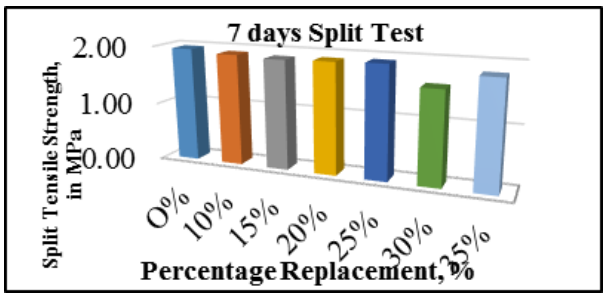


Fig. 7

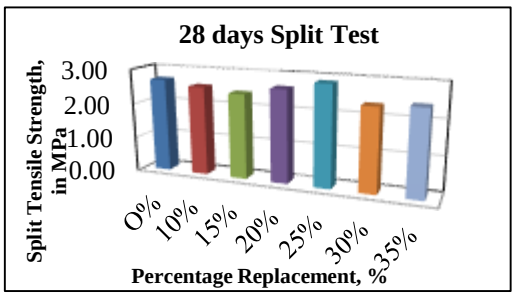


Fig. 8

D. Ultrasonic pulse velocity:

UPV results are within 4.5 to 4.87KM/sec that's mean the quality of concrete is very good. A relationship among compressive strength, UPV value and percentage replacement of sand was shown in Fig. 10. Here UPV value was increased after the sand replaced by 10% up to 15%, then UPV started decreasing. It may be happened because of the porosity of concrete slightly increase that influence the UPV value. Negative effects are almost nil in case of stone dust and there is no significance between compressive strength and UPV value and it is confirmed by Md. Safiuddin et al. [6].

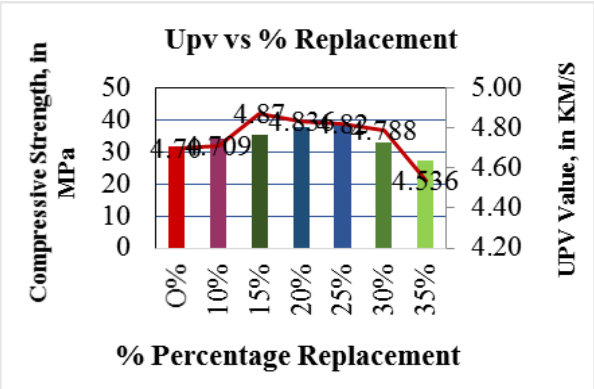
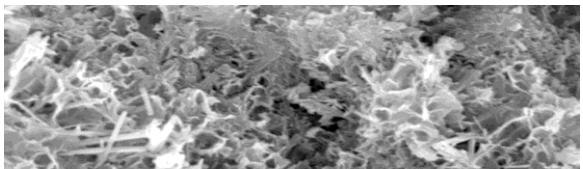


Fig. 9



E. Microstructural Study:

Here we have studied the morphological difference between the stone dust mixed concrete and the normal concrete. Mix1 -15%, Mix1-35% and Mix1-N these mixes are chosen for the microstructural study.

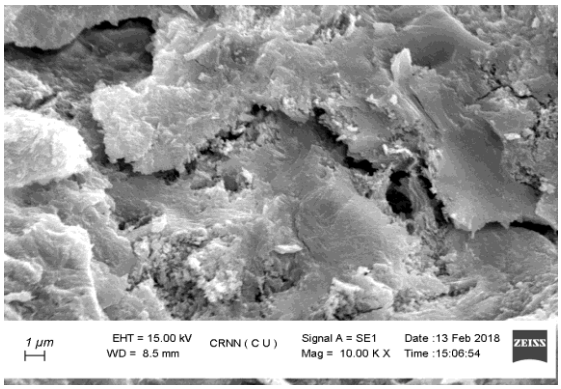


Fig. 10 Mix1-N

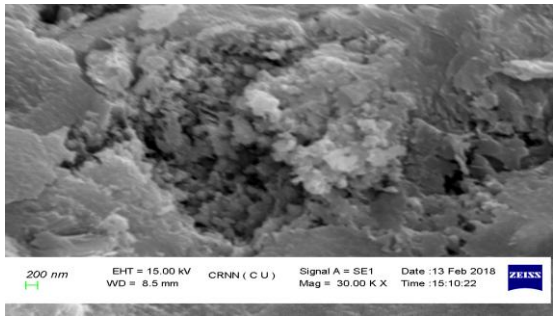


Fig. 11 Mix1-N

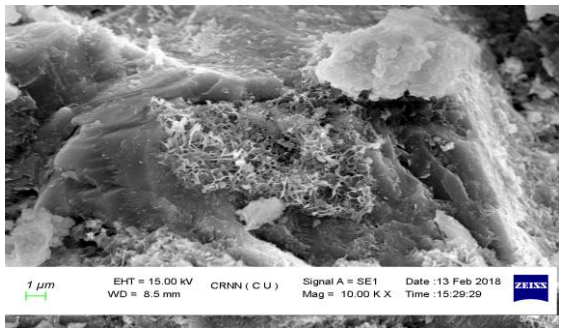


Fig. 12 Mix1-15%

F. EDX analysis:

There is a lot of similarity in the above scanning electron microscopic images in micrometer range but in nanometer range some voids filled with ettringite found in Mix1-15%(b) and Mix1-15% (c) and other pictures almost similar to each other. We can conclude from the above discussion that stone dust can be used in mix as a partial replacement. Energy Dispersive Spectrometry (EDS) analysis of the same concrete mixtures shown in figures including stone dust and sand. Higher silica (SiO2) and low CaO content indicates the higher compressive strength of that mix.

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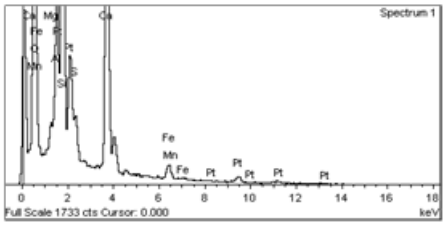

Fig.15 Mix1-15%

Fig. 13 Mix1-15%

Table- III: Chemical Analysis of Mix1-N By EDX

Chemical Compound	*Percentage*
MgO	2.09
Al2O3	10.91
SiO2	29.90
SO3	6.28
CaO	31.69
MnO	0.47
FeO	4.45

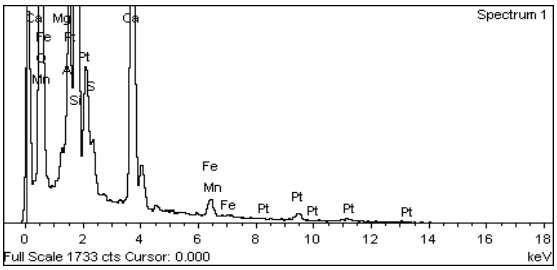

Fig.14 Mix1-N

Table- IV: Chemical Analysis of Mix 1- 15% By EDX

Chemical Compound	*Percentage*
MgO	3.18
Al2O3	10.65
SiO2	42.06
CaO	15.94
FeO	10.24
ZnO	3.81
In2O3	3.33

Table- V: Chemical Analysis of Mix 1- 35% By EDX

Chemical Compound	*Percentage*
Na2O	1.31
Al2O3	14.75
SiO2	53.02
K2O	2.17
CaO	11.09
FeO	8.66

G. Sulphate Resistance:

We have studied the Sulphate resistance property of sustainable concrete and we have used 6% MgSO4 solution. Cube samples are prepared for the experiment. These cubes immerged in the Sulphate solution for 28 days after the 28 days of curing in water. Here we noticed loss of weight for Mix 1 of sample increased after immersion in Sulphate solution. As we go on increasing the replacement from 0% to 30% loss of weight increased for Mix 1. Though M. Shahul Hameed et al. [11] showed that by replacing sand with 50% stone dust and 50% marble sludge decreased the percentage loss of weight than that of the normal mix. Increment in the strength is higher than that of Normal concrete in Sulphate exposure for 28 days but similar strength was observed for 28 days water cured and 28 days MgSO4 cured by the Lohani T.K et al. [5]. All results are shown in Tables and in Figures.

Table- VI: Percentage change in Compressive Strength after sulphate exposure

Name of Mix	*Weight Before MgSO4, in Kg*	*Weight After MgSO4, in Kg*	*%Loss in Weight*	*Strength Before MgSO4*	*Strength after MgSO4*	*% change in Strength*
0%	8.272	8.268	0.048	31.68	32.15	1.484
10%	8.282	8.270	0.145	34.34	35.23	2.592
20%	8.320	8.310	0.120	37.78	38.02	0.635
30%	8.328	8.309	0.228	33.19	32.79	-1.205

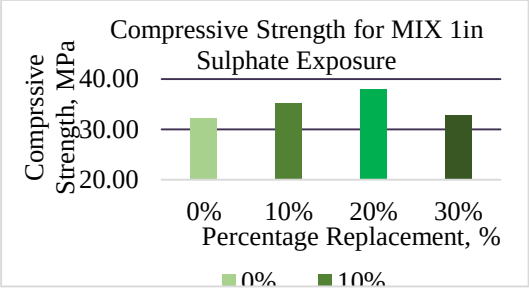

Fig.16

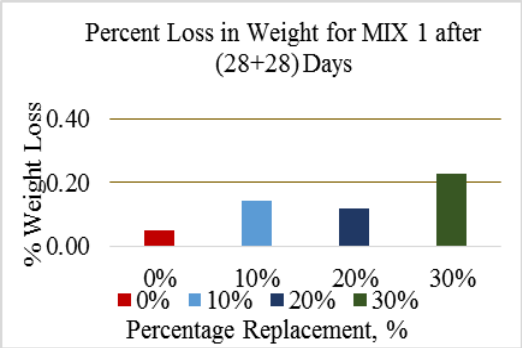

Fig.17

V. CONCLUSIONS:

- Different types of stone dust found and can be used for different purpose. In case compressive strength up to 30% substitution it can be replaced but optimum strength was found at 30%. Strength at 30% substitution is almost equal to Normal concrete.
- Maximum flexural strength was recorded at 35% due to the rough texture and quality bond between the aggregate and cement paste though the optimum percentage of stone dust was 30%.
- There was no such strength improvement noticed for split tensile strength but after mixing of stone dust strength increment was observed up to 30%.
- UPV results are above 4.5 KM/S which indicates the good quality concrete. Results showed the up to 15% replacement the value of UPV was increased after that it was started decreasing slightly.

Stone dust can be utilized as a fine aggregate in concrete in place of sand partially. It can be replaced up to 30% by volume of sand which improve the mechanical properties of concrete like Compressive Strength, Split Tensile Strength, and Flexural Strength etc. Sulphate resistance property is also improved when 20% stone dust is mixed in place of sand with concrete.

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