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Experimental Investigation on Partially Replacements of Cement and Fine Aggregate with Stone Dust and Crushed Fine Aggregate and Its Effects on Mechanical Properties of Normal Strength Concrete (M20)

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ABSTRACT : Concrete is most widely used construction material all around the world. The main constituents of concrete are binding material, fine aggregate, coarse aggregate and water. Increase in construction activities have led to an increase in demand for the various raw materials in concrete.

Natural sand is most commonly used fine aggregate in concrete. Increasing construction activities requires production of more and more quantity of concrete, which needs more and more natural sand and coarse aggregate. Owing to acute shortage in many areas, cost and environmental factors, an alternative for the same is pondered. During the process of production of coarse aggregate in crushing plants, a huge quantity of stone dust is produced which is considered worth less for any substantial use. The use of Crushed fine aggregate in concrete as partial replacement of fine aggregate will be an alternative material instead of conventional fine aggregate. This will results in conservation of natural resources upto some extent, besides helping in environment protection and disposal of stone dust in abundance. Use of crushed fine aggregate in concrete not only improves the quality of concrete but also conserve the natural river sand for future generations.

Cement is the most active component of concrete usually has the greatest unit cost, its selection and proper use are important in obtaining economical concrete and also concrete of desired properties. The use of large quantity of cement results in increasing C emissions and as a consequence of the green house effect. One of the methods to reduce the cement content in concrete mixes is the use of pozzolanic materials. Stone Dust (stone dust passing through 90micron sieve which contains 93% SiO2) is a supplementary cementitious material with pozzolanic characteristics. It makes concrete more durable and eco-friendly. Stone Dust is added in the hydration process, it reacts with the free lime to form additional calcium silicate hydrate (CSH) material, thereby making the concrete stronger and more durable.

Key words: Stone dust, Crushed fine aggregate, Compressive strength, split tensile strength, Flexural strength.

1. INTRODUCTION

Concrete is one of the seemingly simple but actually complex material. The properties of the concrete mainly depend on its constituents. The main important materials used for making concrete are cement, fine aggregate, coarse aggregate and water. The properties of cement, sand, crushed stone and water influences the quality of concrete. In addition to this, workmanship, quality control and method of placing also plays leading role on the properties of concrete.

It is a versatile construction material due to its reasonable cost and easy availability its consumption is increasing day-by-day. Increasing construction activities requires production of more and more quantity of concrete, which needs more and more natural sand and coarse aggregate. During the process of production of coarse aggregate in crushing plants, a huge quantity of stone dust is produced which is considered worth less for any substantial use. This stone dust being a waste material can be attempted to use in concrete making, as partial or full replacement of fine aggregate. Sand which is used as fine aggregate for concrete must be free of impurities, such as salts, clay or other foreign materials. The three key characteristics of sand are particle shape, gradation and void ratio. Sand is mainly used as inert material to give volume in concrete for economy. The strength of concrete can also be affected by the quality fine aggregate. Replacement of normal sand by stone dust will assist both solid waste minimization and waste recovery. Stone dust is easily available in large quantities from crusher units. Diminishing of natural sand resources have increased and the efforts to identify substitutes for natural sand as a constituent of Portland cement concrete. The use of crusher stone dust in making concrete and by partial or full replacement of natural river sand not only provides economy in the construction but at the same time solves the problem of disposal of stone dust.

The use of stone dust in concrete as partial replacement of fine aggregate will be an alternative material instead of conventional fine aggregate. This will results in conservation of natural resources upto some extent, besides helping in environment protection and disposal of stone dust in abundance. The presence of stone dust in concrete increases the water demand. Attempts have been made to investigate the possibility of use of stone dust as partial replacement of sand in concrete. Due to its benefits such as useful disposal of these by-products, reduction in use of natural sand consumption as well as increasing the strength parameters and increasing the workability of concrete was noted. Every year 175 million tons of stone dust is generated by the stone cutting plants and is dumped as waste leading to serious environmental and dust pollution. So it is necessary to dispose the stone dust waste quickly and efficiently. One of the possible uses lies in the construction industry, Aggregates is one of the main ingredients in concrete production. It accounts for about 75% of any concrete mix. The strength of concrete produced depends on the properties of aggregate used. In the present study, an attempt is made to explore the possible use of stone dust in concrete, as partial replacement of fine aggregate. An experimental program was conducted to determine the effect of stone dust on strength of concrete. Tests were conducted on cubes and beams to study the strength of concrete made of Stone dust and the results were compared with the Natural Sand Concrete.

Cement manufacture contributes greenhouse gases both directly through the production of carbon dioxide when calcium carbonate is heated, producing lime & carbon dioxide and indirectly through the use of energy, particularly if the energy is sourced from fossil fuels. The cement industry produces about 5% of global man made CO_2 emissions, of which 50% is from the chemical process, and 40% from burning fuel. The amount of CO_2 emitted by 1the cement industry is nearly 1.0 tons of CO_2 for every 1.0 ton of cement produced.

In this pursuance, the researchers met with some industrial by products, which offer significant technical, economical and ecological benefits when used in concrete industry. Pozzolanas can be incorporated into concrete in two different ways; one approach is to use it at the manufacturing plant, and the other is to use as a mineral admixture for the preparation of concrete.

2.MATERIALS

2.1Cement:

In the present investigation Ordinary Portland Cement (OPC) of 53 grade confirming to IS: 12269-1987 specifications was used. The physical properties are given in Table;1

Table 1: Physical properties of Ordinary Portland Cement

S.NO	Particulars	Results
1	Normal Consistency	32 %
2	Fineness of cement	6 %
3	Setting time	
	Initial setting time	30 min
	Final setting time	10 hours
4	Specific gravity of cement	3.15
5	Soundness of cement	6 mm

2.2 Stone Dust:

The Stone dust used in the investigation is obtained from the quarry at Chandragiri near Tirupati Andhra Pradesh. Stone Dust is obtained by sieving stone dust through 90 micron sieve. X-ray diffraction method (XRD) is conducted on stone dust it shows that it contains 93% SiO2. Reference XRD, it is ensured that due to the presence of SiO2, stone dust posses pozzolanic property. This SiO2 reacts with calcium hydroxide and forms calcium-silicate-hydrate gel which enhances strength properties of concrete.

2.3 Fine Aggregate:

The locally available natural sand is procured and is found to be conformed to grading zone-II of IS 383-1970.the physical properties of Fine aggregate given in Table 2

Table 2: Physical Properties Of Fine Aggregate.

S.No	Particulars	Results
1	Specific gravity	2.61
4	Bulking of sand	4%
5	Fineness Modulus	2.6

2.4 Coarse Aggregate:

Machine crushed granite aggregate conforming to IS 383-1970 consisting 20mm and below maximum size of aggregates has been obtained from the local quarry. It has been tested for physical properties given in Table 3

Table 3: Physical Properties Of Coarse Aggregate.

S.No	Particulars	Results
1	Crushing value	19.689 %
2	Impact value	16.380 %
6	Specific gravity	2.681
7	Water absorption	0.3%

2.5 Crushed Fine Aggregate:

The Crushed fine aggregate is the by-product which is formed in the processing of the granite stones which broken downs into the coarse aggregates of different sizes. Crushed fine aggregate is collected from local stone crushing units of Chandragiri near, Tirupati, Andhra Pradesh. The properties of Crushed fine aggregate are shown in Table 3.5, the sieve analysis of Crushed fine aggregate is given in Table 4

Table 4: Properties of Fine Aggregate (Crushed Fine Aggregate)

S.No	Property	Values
1	Specific Gravity	2.55
2	Fineness Modulus	3.15
3	Grading of Crushed fine aggregate	Zone – I

2.6 Water:

As per IS 456:2000[25], water used for mixing and curing shall be clean and free from injurious amounts of oils, acids, alkalis, salt, sugar, organic materials or other substances that may be deleterious to concrete or steel .

3. MIX DESIGN

The mix design of concrete done based on IS :10262-2009.the following table 5 given mix proportions

Table 5: Mix Proportions

Item	Cement	Fine aggregate	C oarse aggregate	Water
Quantity (Kg/m^3)	340	646	1198	170
Proportion	1	1.9	3.52	0.5

The flowing table 6 given different types of mixes

Table 6: Ingredients Of M20 Grade of Concrete Used For Different Types of Mixes

S.No	Cement (%)	Stone Dust (%)	Fine Aggregate (%)	Crushed Fine Aggregate (%)	Coarse Aggregate (%)	Types of Mix
1	100	-	100	0	100	Normal Mix
2	90	10	100	0	100	M-1
3	80	20	100	0	100	M-2
4	70	30	100	0	100	M-3
5	80	20	75	25	100	M-4
6	80	20	50	50	100	M-5
7	80	20	25	75	100	M-6
8	80	20	0	100	100	M-7

5. EXPERIMENTAL METHODS

Compression test is one of the most common test conducted on hardened concrete, partly because it is most important and it is easy to perform further most of the desirable characteristic properties of concrete are qualitatively related to its strength. The compression test was carried out using 2000 KN compression testing machine.The compressive strength of the GPC was conducted on the cubical specimens for all the mixes after 7, 28 and 90 days of curing as per code

$$f'_c = P/A$$

Splitting Tensile Strength (STS) test was conducted on the specimens for all the mixes after 28 days of curing as per code. Three cylindrical specimens of size 150 mm x 300 mm were cast and tested for each age and each mix. The load was applied gradually till the failure of the specimen occurs. The maximum load applied was then noted. Length and cross-section of the specimen was measured. The splitting tensile strength (f_{ct}) was calculated as follows:

$$f_{ct} = 2P/(\Pi\, l\, d)$$

Flexural strength test was conducted on the specimens for all the mixes at different curing periods as per code. Three concrete beam specimens of size 100 mm x 100 mm x 500 mm were cast and tested for each age and each mix. The load was applied gradually till the failure of the specimen occurs. The maximum load applied was then noted. The distance between the line of fracture and the near support 'a' was measured. The flexural strength (f_{cr}) was calculated as follows: When 'a' is greater than 13.3 cm for 10 cm specimen, f_{cr} is

$$f_{cr} = (P \times l) / (b \times d^2)$$

When 'a' is less than 13.3 cm but greater than 11.0 cm for 10 cm specimen, f_{cr} is

$$f_{cr} = (3 \times P \times a) / (b \times d^2)$$

6. RESULTS & DISCUSSIONS

6.1Compressive Strength of Concrete:

The results of the cube compressive strength of M20 grade concrete for various combinations of Stone Dust and Crushed fine aggregate for different curing periods are obtained. Concrete Cubes of size 150 mm × 150 mm × 150 mm are tested for the compressive strength at the age of 3, 7, 28, 56 and 90 days. Each value of the cube compressive strength indicates the average of three test results. The variations of compressive strength at 3 days, 7 days, 28 days, 56 days and 90 days results are presented in table 7 below.

Compressive Strength

Concrete mix	Stone Dust (%)	Crushed fine aggregate (%)	Compressive Strength (N/mm^2)				
			3 days	7 Days	28 Days	56 Days	90 Days
Normal mix	0	0	13.2	21.6	26.8	30	32.03
SD 10% +CFA 0%	10	0	13.57	22.05	27.52	31.14	32.9
SD 20% +CFA 0%	20	0	13.83	22.91	28.44	32.5	34.2
SD 30% +CFA 0%	30	0	12.98	20.78	26.03	29.8	32
SD 20% +CFA 25%	20	25	14.12	23.5	28.2	33.16	34.7
SD 20% +CFA 50%	20	50	14.86	23.91	29.87	34.2	36.5
SD 20% +CFA 75%	20	75	13.03	21.02	26.95	31.3	33.16
SD 20% +CFA 100%	20	100	11.14	19.9	24.12	27.7	30.32

6.2 Split Tensile Strength

The Split Tensile Strength variation for the tested mixes Concrete Cylinders of size 150 mm diameter and 300 mm height are cast to obtain the Split Tensile strength at the age of 28 days. The variations of Split Tensile strength at 28 days for different replacements are given in Table 8.

Table 8: Split Tensile Strength

Concrete mix	Stone Dust (%)	Crushed fine aggregate (%)	Split tensile strength (N/mm)
Normal mix	0	0	3.2
M-1	10	0	3.26
M-2	20	0	3.335
M-3	30	0	3.1
M-4	20	25	3.38
M-5	20	50	3.46
M-6	20	75	3.08
M-7	20	100	2.77

The Split Tensile Strength of Conventional Control Concrete is 3.2 MPa. Results indicate that as the Stone Dust increases more than 20%, the tensile strength decreases. At 20% SD content the split tensile strength is 3.335Mpa.It is also observed that for the combination of 20% Stone Dust & 50% Crushed fine aggregate the maximum Split Tensile Strength is 3.46MPa. All Mix Combinations are insignificant because the percentage change in split tensile strength with respect to control mix is less than 10%.

6.3 Flexural Strength

The flexural strength variation for all mixes is shown in Figure 6.11. Concrete Beams of size 500 mm Length and 100mm × 100 mm Cross-section area are cast to test the Flexure strength of Concrete at the age of 28 days. The variations of Flexural Strength at 28 days for different replacements are shown in Table 9

Table 9: Flexural Strength

Concrete mix	Stone Dust (%)	Crushed fine aggregate (%)	Split tensile strength (N/mm)
Normal mix	0	0	3.2
M-1	10	0	3.26
M-2	20	0	3.335
M-3	30	0	3.1
M-4	20	25	3.38
M-5	20	50	3.46
M-6	20	75	3.08
M-7	20	100	2.77

The Flexural Strength of Conventional Control Concrete is 3.5MPa.From the results it is observed that at 20% of Stone Dust content the flexural tensile strength is 3.62MPa. It is also observed that for the combination of 20% of Stone Dust & 50% crushed fine aggregate content maximum flexural strength is 3.835MPa.All Mix Combinations are insignificant because the percentage change in flexural strength with respect to control mix is less than 10%.

7. CONCLUSIONS

Based on experimental investigation the following conclusions are drawn

[1] The Compressive Strength at 28 days for M 20 design mix controlled concrete is obtained as 26.8 MPa.

[2] The Compressive Strength at 28 days for 20% Stone Dust replacement in OPC is observed as 28.44 MPa.

[3] Further the compressive strength at 28 days for 20% Stone Dust replacement in OPC and 50% replacement of Crushed fine aggregate in Fine Aggregate is observed as 29.87MPa. The compressive strength increases at SD 20% and CFA 50% by 11.4% compared to control concrete.

[4] The Split Tensile Strength at 28 days for the M 20 design mix controlled concrete is obtained as 3.2 MPa.

[5] The Split Tensile Strength at 28 days for 20% Stone Dust replacement in OPC is observed as 3.335 MPa.

[6] The Split Tensile Strength at 28 days for 20% Stone Dust replacement in OPC and 50% replacement of Crushed fine aggregate in Fine Aggregate is observed as 3.46MPa.

[7] The Flexure Strength at 28 days for the M 20 design mix controlled concrete is obtained as 3.5 MPa.

[8] The Flexure Strength at 28 days for 20% Stone Dust replacement in OPC is observed as 3.62 MPa.

[9] The Flexure Strength at 28 days for 20% Stone Dust replacement in OPC and 50% replacement of Crushed fine aggregate in Fine Aggregate is observed as 3.835MPa.

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