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EFFECT OF STONE DUST AS A SUBSTITUENT OF FINE AGGREGATE ON THE MECHANICAL PROPERTIES OF THE ORDINARY CONCRETE

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ABSTRACT

This abstract explores the efficacy of utilizing stone dust as a partial replacement for sand in concrete mixes at varying proportions, specifically within the range of 10% to 30%. The investigation focuses on evaluating the mechanical, durability, and workability properties of concrete incorporating stone dust within this specified range. Several studies have been conducted to assess the effects of different replacement levels on concrete performance, aiming to achieve a balance between sustainability and structural integrity. Findings suggest that the inclusion of stone dust up to 30% as a sand substitute can enhance certain properties of concrete, such as compressive strength and resistance to environmental factors. However, optimization of mix proportions and consideration of potential drawbacks are crucial to ensure the overall effectiveness of this approach in promoting sustainable construction practices while maintaining desired concrete performance. It was found that incorporating stone dust in concrete improves the strength of the concrete.

Keywords: Sand, Stone Dust, Strength

1. INTRODUCTION

The problem associated with using sand in concrete production is the depletion of natural sand sources. Sand is a crucial ingredient in concrete, serving as a fine aggregate that fills the voids between coarse aggregates and binds the mixture together. However, the extensive extraction of sand from rivers, beaches, and other natural sources can lead to environmental degradation, habitat destruction, and erosion of coastal areas. Furthermore, the high demand for sand in construction projects often results in illegal sand mining, which exacerbates environmental issues and threatens ecosystems. Additionally, transportation costs associated with sourcing sand from distant locations can further increase the environmental footprint of concrete production and add to construction expenses. **Ali, M. M., & Khalil, M. I. (2016)** investigated the potential of using stone dust as a replacement for fine aggregate (sand) in concrete production. They likely conducted experiments to assess the mechanical properties, workability, and durability of concrete mixes containing varying proportions of stone dust as a partial replacement for sand. The study might have involved preparing concrete specimens with different percentages of stone dust substitution and subjecting them to tests such as compressive strength, flexural strength, and water absorption. The results would have been analyzed to determine the feasibility and effectiveness of utilizing stone dust in concrete production, aiming to contribute to sustainable construction practices and resource optimization in the concrete industry. **Palani and Jayabal (2019)** conducted experimental investigations with the objective of exploring the potential of utilizing stone dust as a partial replacement for fine aggregate (sand) in concrete. Their study likely involved a series of laboratory experiments where concrete mixes were prepared by substituting a portion of the fine aggregate with stone dust at varying percentages. During the experiments, they would have assessed various properties of the concrete mixes, including compressive strength, flexural strength, workability, and durability. These properties are crucial indicators of the performance and suitability of concrete for different construction applications (**Singh and Srivastava (2020)).**

Ukpata and Ephraim (2016) conducted a study where they evaluated the physical properties of selected aggregates and assessed how these properties influence concrete strength and abrasion resistance. This likely involved gathering different types of aggregates commonly used in concrete production, such as sand, gravel, crushed stone, and possibly stone dust. They would have subjected these aggregates to various tests to determine their physical characteristics, including particle size distribution, shape, texture, density, and specific gravity. Additionally, they might have performed tests to evaluate the aggregates' moisture content, absorption capacity, and porosity. **Dash and Mohanty (2018)** carried out experiments to investigate the feasibility of replacing fine aggregate (sand) in concrete with quarry dust and red soil. This study likely involved laboratory experiments where concrete mixes were prepared with varying proportions of quarry dust and red soil as partial substitutes for fine aggregate. The researchers would have conducted tests to evaluate the mechanical properties, workability, and durability of the concrete mixes. These tests might include compressive strength testing, flexural strength testing, slump tests to assess workability, and assessments of resistance to factors like abrasion and permeability.

Abdullah, Mohd Mustafa Al Bakri, et al. (2018) focuses on the application of quarry dust as a soil stabilization agent to enhance the engineering properties of soils commonly used in highway construction. It aims to address issues such as soil strength improvement, reduction in soil plasticity, and enhancement of soil durability through the addition of quarry dust. **Gowri, S., and R. Anuradha** investigates the impact of incorporating quarry dust and waste polyethylene terephthalate (PET) on the properties of concrete. It explores the potential of these materials as partial replacements for fine aggregates in concrete production. The study likely includes experimental analysis to assess various properties of concrete, such as workability, strength, durability, and sustainability. The findings of this research contribute valuable insights into sustainable concrete production practices and may have practical implications for the construction industry. **Indhuja, V., and R. K. Marimuthu** presents an experimental study on the replacement of fine aggregate with quarry dust. Published in the International Journal of ChemTech Research, the study likely involves laboratory experiments to assess the feasibility and effects of using quarry dust as a partial or complete replacement for fine aggregate in concrete production. The research aims to evaluate the impact of varying proportions of quarry dust on concrete properties such as workability, strength, durability, and sustainability. The findings of this study contribute valuable insights into the potential of quarry dust as an alternative material in concrete production, addressing both technical and environmental aspects. **Iyer, Subramanian, and P. M. Shanmugavadivu** presents an experimental investigation into the effect of using quarry dust as a partial replacement for fine aggregate in concrete. Published in the International Journal of Innovative Research in Science, Engineering, and Technology, the study aims to assess how varying proportions of quarry dust influence properties such as workability, strength, durability, and other relevant factors of concrete. The findings of this research contribute to understanding the feasibility and effectiveness of utilizing quarry dust as a sustainable alternative material in concrete production. **Nanda, R. P., et al. (2019)** investigates the effect of using crusher dust, stone waste, and tire wastes as granular pavement materials. Published in the International Journal of Pavement Engineering, the study likely evaluates the performance of these alternative materials in pavement construction, focusing on aspects such as strength, durability, and environmental sustainability. The findings of this research provide insights into the potential of utilizing crusher dust, stone waste, and tire wastes as substitutes for conventional granular materials in pavement applications, addressing both technical and environmental considerations.

2. MATERIAL & METHODOLOGY

The ingredient proposed for the study is Portland cement, sand, coarse aggregate and stone dust.

Cement – In this research the PPC has been used for all considered mixes accordance to (BIS:1489 (Part 1) 1991). The cement is sieve for the enhanced quality from the 90-micron sieve. Table 1 signifies the physical properties of the PC used in the work.

Table 1 Property of the PC

Properties	Experimental Values	Limits of IS1489-1:1991
Fineness (m^2/kg)	362.8 m^2/kg	> 300 m^2/kg
Soundness (%)	0.235%	> 0.8%expansion for unaerated Portland Cement
IST (minutes)	32 minutes	about 1800 sec
FST (minutes)	238 minutes	About 10 hour

Shrinkage Drying (%)	0.049	> 0.15%

Sand – The obtained sand was collected from the bhilai, Chhattisgarh market having size between 0.06 – 0.116 cm. The sand properties is evaluated with help of standard according to (BIS:1489 (Part 1) 1991). The sand shows distinct properties shown in table 2 and grading is shown in table 4.

Table 2 Properties of sand

Properties	**Evaluated Data**
FM	2.49
Absorption (in %)	2.835 %
Nominal (in mm)	2
Spec. Gravity	2.579

Stone Dust- Stone dust is often considered as waste material generated during various industrial processes such as stone crushing, quarrying, or mining operations. It is produced when stones are crushed into smaller fragments or dust particles during these processes. Historically, stone dust has been viewed as a nuisance and disposed of as waste, leading to environmental concerns such as air and water pollution. The properties of stone dust is shown in table 3. This can be reduced, when replaced by sand in the making of concrete. The material is been collected from nearby junkyard/scrapyard of district Bhilai, Chhattisgarh, India.

Table 3 Properties of stone dust

Property	**Stone dust**
Specific gravity	2.105
Density (kg/m^3)	1425
Water absorption capacity	3.126
Coefficient of uniformity	3.819
Coefficient of gradation	0.765
Fineness modulus	2.529

2.1 Study Objective

The work is for the investigation of mechanical properties of ordinary concrete due to incorporation of different proportions of stone dust in replacement of sand.

3. METHODOLOGY

3.1 Test Stipulation required for Mix-Design

The test Stipulation required for Mix-Design for the sand, cement and coarse aggregate are such that the determination of consistency of cement according to IS 4031:1988 is done and found to be 31.9% and the specific gravity of cement as per IS 4031:1988-Part 11 is 2.345 using flask apparatus.

3.2 Sieve Analysis of Aggregates

The sieve analysis test is done based on IS 383 are as follows-

Table 4 Sieve Analysis of Fine Aggregate

Sieve Sizes	Mass Retained	Percentage Retained	Percentage Cumulative Retained	Percentage Fine	Avg. Percentage Passing
10 mm	0	0	0	100	100
4.75 mm	13	2	2	98	98.06
2.36 mm	55	8.45	10.45	89.55	89.63
1.18 mm	97	14.9	25.35	74.72	74.72
600 µm	204	31.34	56.68	43.36	43.32
300 µm	159	24.42	81.11	18.88	18.89
150 µm	91	13.98	95.08	4.94	4.94

Fineness Modulus = Fineness Modulus = Sum (Cumulative percentage retained)/100 = **2.704.** Based on the above result, we can say as per IS 383 that the fine aggregate is in Zone-II**.**

3.3 Mix-Design for Conventional M20 Grade concrete

- The Target Mean Strength for Mix Proportioning is given by $f'_{ck} = f_{ck} + 1.65S \text{ or } f'_{ck} = f_{ck} + X$, *whichever is higher* where,f'ck = target avg compressive strength after twenty-eight days of curing, fck = characteristic compressive strength at twenty-eight days of curing, S = standard deviation for M20 grade = 4 N/mm^{2}given in IS 10262:2019, table 2.Therefore, **target strength= 20 + 1.65 x 4= 26.6 N/mm^2**
- The air entrapped in concrete varies based on size of aggregate given in table 3, IS 10262:2019. The approximate entrapped air in this case is considered to be 1 percent for 20 mm size of CA.
- The maximum free water-cement ratio as given in IS456:2000 table 5is 0.5 under severe condition. The actual free water-cement ratio for target strength of 26.6 N/mm^{2}and curve 1 as per figure 1 given IS 10262:2019 **is0.4**. This value is lower than the maximum.
- The selection of water content is given in table 4 of IS 10262 based on 20 mm maximum size of aggregate and 50 mm slump value is 186 kg. Here, for 120 mm slump value the following water content is increased by 3 percent for each 25 mm slump which is equal to **186 + (186*9)/100 = 202.74 kg.**
- Super plasticizers are utilized to reduce the water content hence the above value is reduced for 23 % on trial based while utilization of super plasticizer is 1% by weight of cement.

Therefore, the final water content = 202.74 X 0.77 = 156.11 kg = 156 kg

- The calculation of cement content = $(Water\ content)/(Water - Cement\ ratio) = 156/0.40$ =**390 Kg/m^3.** The minimum cement content as per Table 5 in IS 456:2000 is **320 kg/m^3** in severe exposure condition. Hence, the calculated value is greater than the recommended value.
- For mix-portioning of concrete, increase in Cementitious content is considered based on trials and experience. Here, an increase of 10 % cementitious material is been considered = **390 X 1.10 = 429 Kg/m^3**
- Water-cementitious ratio = $Water\ content\ /Cementitious\ Content$ = **156 /429 = 0.363**

- For mix-portioning of concrete having fly ash, the current trail has 30 percent fly ash of total cementitious content. Hence, fly ash content = **429 X 0.30 = 128.7 Kg/m^3 = 129 Kg/m^3**
- Cement content = 429 – 129 = **300 Kg/m^3**
- The minimum cementitious content as per Table 5 IS 456:2000 is **320 kg/m^3** in severe exposure condition. Hence, the calculated value is greater than the recommended value (i.e., 429 kg/m^3).
- The volume of coarse aggregate corresponding to Table 5, IS 10262:2019 for 20 mm seize of aggregate and sand of zone II for W/c of 0.50 is **0.62**. At present trial W/c is **0.40**, there is a decrease in W/c ratio by **0.22**, the proportion of volume of CA is increased by **0.044** (i.e., at the rate of ± 0.01 for every ± 0.05 change in water-cement ratio). Therefore, the modified proportion of volume of CA for the water-cement ratio of 0.40 **= 0.62 + 0.044 = 0.666**.
- Volume of sand content = Total Volume of aggregate – Volume of CA = **1- 0.666 = 0.334.**
- Determination of mix per unit volume of concrete are as follows -

Concrete volume = 1 m^3

Entrapped Air Volume = 0.01 m^3

Volume of Cement = $\frac{Mass\ of\ Cement}{Specific\ Gravity\ of\ Cement} X \frac{1}{1000} = \frac{300}{2.35} X \frac{1}{1000}$ = **0.127 m^3**

Volume of Fly Ash = $\frac{Mass\ of\ Fly\ Ash}{Specific\ Gravity\ of\ Fly\ Ash} X \frac{1}{1000} = \frac{129}{2.1} X \frac{1}{1000}$ = **0.0614 m^3**

Volume of Water = $\frac{Mass\ of\ Water}{Specific\ Gravity\ of\ Water} X \frac{1}{1000} = \frac{156}{1} X \frac{1}{1000}$ = **0.156 m^3**

Volume of Super plasticizer (where 1% by mass of cementitious material is used)

$$= \frac{Mass\ of\ Chemical\ Admixture\ (Superplasticizer)}{Specific\ Gravity\ of\ Admixture} X \frac{1}{1000}$$

$$= \frac{4.29}{1.145} X \frac{1}{1000} = \mathbf{0.0037 m^3}$$

Volume of all in aggregate = [(Total Volume – Volume of air entrapped) – (Volume of Cement + Volume of Fly Ash + Volume of Water + Volume of Super plasticizer)] = [(1-0.01) - (0.127+ 0.0614 + 0.156 + 0.0037)] = **0.6419 m^3.**

Mass of CA= Volume of all in aggregate X Volume of CA X Specific Gravity of CA X 1000 = 0.6419 X 0.666 X 2.785 X 1000 = **1190.6 = 1191 kg.**

Mass of FA = Volume of all in aggregate X Volume of FA X Specific Gravity of FA X 1000 = 0.6419 X 0.334 X 2.669 X 1000 = **572.2 = 572 kg.**

The proportions required after the mix -design for 1 cube (150 mm) is given in table below-

Table 5 Proportion of Concrete Mix Trials for 1 cubic meter

Case ID	Cement (kg/m^3)	Coarse Aggregate (kg/m^3)	Sand(kg/m^3)	Stone Dust (kg/m^3)	Water(kg/m^3)
CONV	1.013	4.02	1.93	-	0.36
SD10	1.013	4.02	1.93	0.193	0.36

SD20	1.013	4.012	1.5457	0.386	0.36
SD30	1.013	4.012	1.35	0.58	0.36

4. Report

4.1 Compressive Strength Reports for M20 concrete cases

As per the guidelines of the compressive test of concrete in IS 516:1959, the following trail case study are evaluated by experimental techniques for twenty-eight days. Below table shows the compressive strength data for M20 concrete having stone dust partially replaced by 10-30 percent.

Table 6 Observation of Compressive Strength

Case ID	After 7 days (N/mm2)	After 14 days (N/mm2)	After 28 days (N/mm^2)
CONV	8.95	16.79	23.95
SD10	9.56	17.97	25.68
SD20	11.48	20.75	29.62
SD30	12.34	22.82	32.45

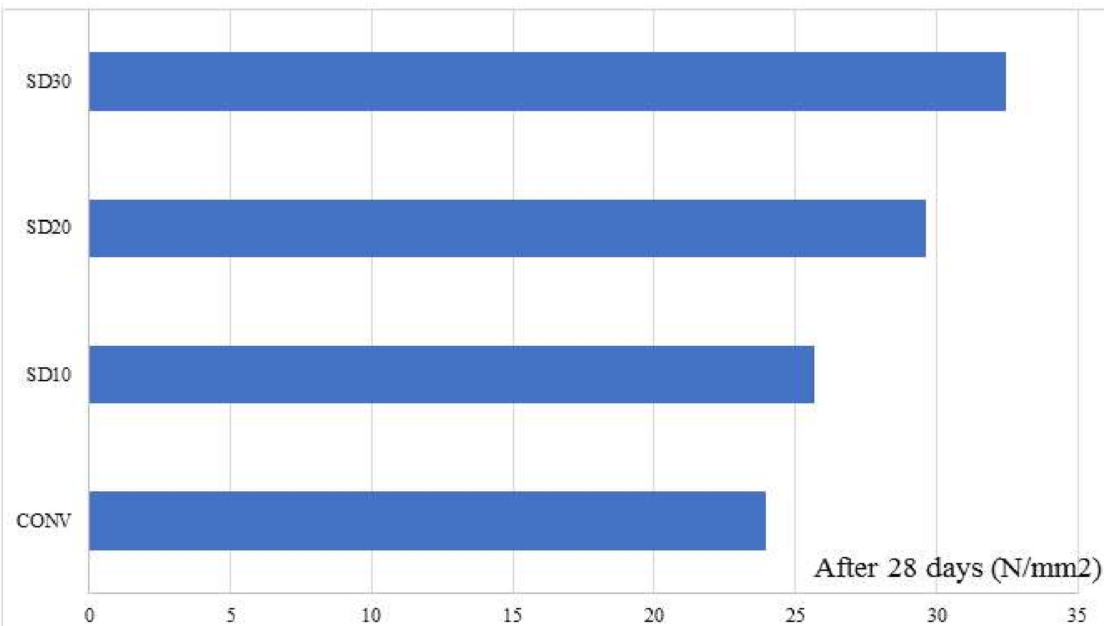

Fig. 1 Compressive Strength

From the above experimental investigation, the maximum compressive strength for SD30 shows value of 32.45 N/mm^2. The compressive strength for SD30 is 26% more than CONV.

4.2 Tensile Strength

Tensile strength is a measure of the maximum stress that a material can withstand while being stretched or pulled before breaking. It is typically expressed in units of force per unit area, such as pounds per square inch (psi) or pascals (Pa).The formula for tensile strength (TS) can be expressed as:

Tensile Strength (TS) =Failure Load (F) /Original Cross-sectional Area (A)

Where: Failure Load (F) is the maximum force or load applied to the material before it breaks.

Original Cross-sectional Area (A) is the cross-sectional area of the material before applying the load.

Table 7 Observation of Tensile Strength

Case ID	Tensile Strength (MPa)
CONV	1.72
SD10	1.98
SD20	2.158
SD30	2.85

5. CONCLUSIONS

It is been seen that addition of stone dust in place of sand is giving better performance in terms of strength. The optimum replacement level of natural river sand with stone dust is beyond 30%. However, strength of concrete made using stone dust is higher at every replacement level than the referral concrete.

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