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EXPERIMENTAL STUDY ON THE DURABILITY OF CONCRETE PROPERTIES USING QUARRY DUST AND FLYASH AS A PARTIAL

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ABSTRACT :

Stone dust, a by -product generated during crushing stones, represents approximately 25% of the final production from units of stone crushing. Typically released directly into the environment, stone dust contributes significantly to environmental pollution. In an effort to mitigate these adverse environmental impacts and promote sustainable construction practices, stone dust can be effectively utilized either In the production of new materials or as partial substitutes for fine aggregates in concrete. This approach not only helps in the effective use of natural resources, but also minimizes environmental waste. In this study, stone dust is used as a partial replacement for a fine unit and fly ash - additional cement material - is used as a partial replacement for cement. The aim of experimental examination is to set optimal levels of substitutes of stone dust and fly ash, which lead to improvement or comparable solid properties in concrete, specifically for the M40 class. The experimental program includes partial replacement of fine aggregate with stone dust in the ratio of 10%, 20%, 30%, 40%and 50%and partial replacement of cement with ash at 5%, 10%, 15%, 20%and 25%. Evaluate the mechanical properties of the modified concrete, standard specimens were prepared, including cubes of dimensions 150 mm × 150 mm x 150 mm for pressure strength testing, cylinders with a diameter of 150 mm and a height of 300 mm for tensile strength and beams 50 cm x 10 cm x 10 cm to test the bending strength. The results of this study will help to identify the optimal combination of stone dust and replace the fly ash to achieve sustainable and high -performance concrete, thus contributing to environmental protection and resource efficiency

Keywords: stone dust; Ash, compressive strength, tensile strength, bending strength

INTRODUCTION

Concrete is a composite material predominantly composed of water, aggregates, and cement. To achieve the desired physical properties of the final product, admixtures and reinforcements are often incorporated into the mix. Over time, the cement hydrates to form a hardened matrix that binds the other constituents into a strong, granite-like material, making concrete one of the most versatile and widely used construction materials today. In this study, the chemical and physical properties of quarry dust, fly ash, and cement were determined to evaluate their suitability as partial replacements in concrete. It was observed that the density of concrete decreased with the increasing replacement percentages of quarry dust and fly ash. The experimental results indicated that at replacement levels ranging between 15% and 30%, the concrete developed sufficient strength to be suitable for construction purposes. These findings support the promotion of sustainable practices within the construction industry while also contributing to economic benefits. Fly ash is the most widely used mineral admixture globally, owing to its significant advantages in concrete production. Extensive research has demonstrated that the utilization of fly ash improves workability, long-term strength, and durability of concrete. Currently, the use of high-volume fly ash concrete is increasingly favored worldwide due to its environmental and performance benefits. However, the generation of high-quality fly ash suitable for use in concrete is highly dependent on the source and production process, and not all fly ash produced is appropriate for structural applications. This study reaffirms that the incorporation of quarry dust and fly ash in concrete can lead to sustainable, economical, and high-performance construction materials, thereby supporting the broader goals of environmental conservation and resource efficiency in the construction industry.

FLY ASH:

Fly ash is a fine particulate residue generated as a byproduct of the combustion of pulverized coal in coal-fired electric power plants and steam-generating facilities. During the combustion process, coal is ground into a fine powder and mixed with air before being introduced into the boiler's combustion chamber. Upon ignition, this mixture produces significant heat and results in the formation of molten mineral residues.

As the flue gases rise through the boiler, heat is extracted via boiler tubes, which leads to a reduction in temperature. This cooling process solidifies the molten mineral material into ash. The heavier, coarser particles—commonly referred to as bottom ash or slag—settle at the base of the combustion chamber. In contrast, the finer particles, known as fly ash, remain suspended in the flue gases and are carried out of the combustion chamber.

STONE DUST:

As stated by Unilock, stone dust is a secondary material derived from the crushing of stone, often referred to as crusher run. It may also be known by other names such as rock dust or quarry dust, and in some cases, it is marketed under specific brand names. The production of stone dust involves screening, a process where larger fragments of crushed stone are retained on a mesh, while the finer particles—stone dust—pass through Additionally, crushed stone is categorized by numerical grades based on the size of the particles.

PRINCIPLES OF CONCRETE:

- Use of proper ingredients
- Correctly proportion and measure ingredients
- Thoroughly mix the ingredients
- Properly finish and cure the poured concrete

2.0 LITERATURE REVIEW

Chatterjee (2011) reported that approximately 50% of the fly ash generated is currently being utilized under existing practices. He further noted that it is possible to replace up to 70% of cement with fly ash, provided that high-strength cement and highly reactive fly ash are used in combination with a sulphonated naphthalene formaldehyde-based superplasticizers. Additionally, he emphasized that the performance characteristics of fly ash can be significantly enhanced through grinding, which reduces the particle size to the sub-microcrystalline level

Pofale and Deo (2010) reported a 20% increase in compressive strength and a 15% increase in flexural strength of concrete compared to control specimens, achieved by replacing 27% of natural sand with low-lime fly ash. The study utilized fly ash-based Portland pozzolana cement. Additionally, they observed an approximate 25% improvement in the workability of the fly ash-based concrete over the control mix.

Among the extensive body of literature reviewed, only the most relevant studies were selected to support the present research objectives. The reviewed literature consistently indicates that the partial replacement of natural sand—a diminishing resource—with fly ash not only enhances early strength from the third day onward but also results in a long-term strength increase of approximately 20% compared to conventional concrete.

Furthermore, this substitution contributes to notable improvements in both workability and durability. The enhanced performance can be attributed to the ball-bearing effect, pore-filling capabilities, improved dispersion of cement particles, and the pozzolanic activity of fly ash. These factors collectively contribute to increased strength and workability. The additional benefits offered by the partial replacement of sand with fly ash may also compensate for the typical reduction in 28-day strength associated with high-volume fly ash concrete

According to Neville (2009), the aggregate–cement ratio is generally considered a secondary factor in determining the strength of concrete. However, it has been observed that, for a constant water–cement ratio, leaner mixes—those with a higher aggregate–cement ratio—tend to exhibit greater strength. This phenomenon can be partly attributed to the fact that a larger quantity of aggregate absorbs more water, thereby effectively reducing the water–cement ratio and subsequently increasing strength. The more plausible explanation, however, is that leaner concrete mixes contain a lower total water content per cubic meter. Consequently, the volume of voids present in the concrete is reduced, and since these voids negatively affect strength, their minimization contributes to enhanced mechanical performance.

Namagg and Atadero (2009) presented the preliminary findings of a study investigating the use of high volumes of high-lime fly ash in concrete. In their research, fly ash was utilized as a partial replacement for both cement and fine aggregates, with replacement levels ranging from 0% to 50%. The authors reported that fly ash replacements between 25% and 35% yielded the most favorable results in terms of compressive strength. This improvement was attributed to the pozzolanic activity of high-lime fly ash, which enhances the strength development of concrete. Similarly, Jones and McCarthy (2005) conducted an extensive laboratory-based study on the use of unprocessed low-lime fly ash in foamed concrete as a replacement for sand. Their findings indicated that, for a given plastic density, the flow spread of fly ash-based foamed concrete was up to 2.5 times greater than that of sand-based mixes. While early-age strengths of both mix types were comparable, significant differences were observed at 28 days and beyond, depending on the density. In particular, the 28-day compressive strength of fly ash-based concrete was found to be over three times greater than that of sand-based concrete. Moreover, while the strength of the sand mixes plateaued after 28 days, the strength of fly ash foamed concrete continued to increase, reaching values at 56 and 180 days that were approximately 1.7 to 2.5 times higher than the 28-day strength flyash concrete, the 28-day values varied significantly with density. The strength of flyash concrete was more than 3 times higher than sand concrete. More significantly while the strength of sand mixes remained fairly constant beyond 28 days, those of fly ash foamed concrete at 56 and 180 days were up to 1.7 to 2.5 times higher than 28 days values respectively.

Hwang, Noguchi, and Tomosawa (2004), based on their experimental investigation into the compressive strength development of concrete incorporating fly ash, concluded that the inclusion of fly ash as a partial replacement for sand leads to a reduction in the pore content within the concrete matrix.

MATERIALS PROPERTIES AND EXPERIMENTAL INVESTIGATION CEMENT:

Ordinary Portland cement (OPC) is the world's most widely used type of cement and serves as a basic component in the production of concrete, mortar, stucco and most specialties. As a primary binding material in concrete, variations in the cement content significantly influence the overall properties and performance of the concrete.

In this study, ordinary Portland cement 53 classes, corresponds to specifications outlined in IS 12269:2013, was utilized. According to the standards for 53 Grade OPC, the cement must attain After 28 days of curing minimum pressure strength 53 MPa (or 530 kg /cm²). Typically, OPC exhibits a grey coloration. However, when ferrous oxide is eliminated during the manufacturing process, white cement is produced instead.

S.No	Properties	Values observed
1	Specific Gravity	3.15
2	Normal consistency	30%
3	Initial setting time	38 min
4	Final setting time	480 min
5	Soundness	6.6 mm

FINE AGGREGATE:

The testing of fine aggregates is essential to evaluate the quality and suitability of materials, such as sand, for use in concrete mixtures. These tests are critical in assessing key Physical properties of aggregates, including distribution of particle size (through sieve analysis), softness module and specific gravity. The results of these tests provide valuable insight into the potential impact of the aggregate on the strength, process ability and durability of the resulting concrete. Ensuring compliance with these parameters is vital for achieving the desired performance characteristics in concrete structures.

S.No	Property	Result
1	Fineness Modulus	2.75
2	Specific Gravity	2.71

COARSE AGGREGATE:

Coarse aggregate, commonly comprising Gravel or crushed stone is a granulated material extensively used in the structure, especially as a primary component in concrete. It is characterized by particle size greater than the size of fine aggregates such as sand. The properties of coarse aggregate play a critical role in influencing the strength, durability, and overall structural stability of concrete.

To assess the suitability of coarse aggregate for construction purposes, a sieve analysis is conducted. This standardized test procedure determines the gradation, or particle size distribution, of the unit that is necessary to ensure optimal compaction, minimum emptiness and consistent performance in specific applications.

S.No	Property	Result
1	Fineness Modulus	8.15
2	Specific Gravity	2.69

FLYASH:

Fly ash is a fine particulate material that is easily dispersed into the atmosphere. If not properly managed, it can lead to significant environmental pollution, affecting both air and water quality. Inhalation of airborne fly ash particles has been associated with respiratory health issues. Furthermore, when fly ash settles on vegetation or agricultural crops in the vicinity of thermal power plants, it can negatively impact crop yield and agricultural productivity.

The conventional method for the disposal of both fly ash and bottom ash involves converting them into a slurry form, which is then transported and deposited in ash ponds or slag lakes located near thermal power plants. This approach is widely adopted to mitigate airborne dispersion and facilitate containment; however, it also poses long-term environmental and land use concerns.

S.No	Property	Result
1	Specific Gravity	1.75

FLYASH PRODUCTION AND ITS NATURE:

The combustion of pulverized coal in thermal power plants results in the generation of fly ash. The high temperatures involved in the combustion process cause the mineral matter present in the coal—primarily composed of alumino-silicates—to fuse and form fine particulate residues. Consequently, fly ash exhibits both ceramic and pozzolanic properties, making it potentially valuable for various construction and engineering applications. Typically, the residue from coal combustion consists of about 80% fly ash and 20% bottom ash. Fly ash, being lighter, is carried along with the flue gases and is collected at various stages, including the economizer, air pre-heater, and electrostatic precipitator (ESP) hoppers. In contrast, the heavier particles, known as bottom ash or clinkers, settle in a water-filled hopper located beneath the boiler.

In the present study, fly ash was sourced From the thermal power plant Vijayawada (VTPS) is located in Andhra Pradesh in India. The proportions of the fly ash used in the investigation were 0%, 5%, 10%, 15%, 20%and 25%dry soil weight. Scientists have been investigating the application of fly ash in geotechnical and building engineering over the last three decades. Many studies reported in magazines, conferences and technical reports have been reviewed to gain insight into the extent of research conducted on the use of fly ash. A summary of this literature is provided in the subsequent chapter.

STONE DUST:

Materials possess inherent properties that dictate their suitability for various applications. Stone dust, a byproduct of stone crushing processes, exhibits a range of characteristics that render it a valuable material in hardscaping. The heterogeneity of source rock in quarrying operations results in diverse Types of stone dust, each inheriting different properties from his parental lithology and potentially show color changes among predominant types, granite dust and limestone dust properties and may come in different colors. Two of the most common types of stone dust are granite and limestone.

Property	Stone dust	Test method
Sp. Gravity	2.56	IS-2386(PART-3)-1963
Bulk density (kg/m3)	1750	IS-2386(PART-3)-1963
Absorption	1.25	IS-2386(PART-3)-1963
Moisture content %	Nil	IS-2386(PART-3)-1963
Fine particle less than 0.075 mm%	12.25	IS-2386(PART-3)-1963
Sieve analysis	Zone-2	IS-383-1970

WATER:

Typically, if water is good enough to drink, it's also good enough to use in concrete. Water from lakes and streams that support aquatic life is usually fine too, and in these cases, you don't usually need to test the water. However, if you think the water might be contaminated with sewage, water from mines, or waste from factories or food processing plants, you shouldn't use it in concrete unless tests confirm it's okay. It's best to avoid these questionable sources altogether because their quality can change, especially if water levels drop or if there are temporary discharges.

METHODOLOGY:

This methodology outlines the steps involved in studying the durability properties of M40 grade concrete where sand it is partially replaced by a fracture dust and the cement is partially replaced by an ash. This framework is designed to facilitate a rigorous and systematic investigation suitable for academic research

PROCEDURE:

Prepare concrete specimens of standard sizes for different durability tests as per relevant IS codes as Cubes of 150mm x 150mm x 150mm; Cylinders of 100mm x 50mm; beams of 50 x 10 x 10cm. Mix the concrete thoroughly in a laboratory concrete mixer until a homogeneous mix is obtained after that pour the concrete into well-oiled molds in layers, compacting each layer using a vibrating table or manual tamping to remove air voids. Demold the specimens after 24 hours and cure them in the water tank at 27 ± 2∘C for a specified period of time (eg 28 days) according to IS 456

Compressive Test:

Perform the pressure strength tests on the cube samples in specified ages (eg 7, 14 and 28) according to 516 to assess the development of strength of various mixtures, which will also help correlate strength with durability.

Split Tensile Test:

According to IS 5816, the tensile strength offers an indirect way to assess how much tensile stress will last. In this test, the cylindrical concrete sample is placed under the pressure force applied through its diameter. This load continues to the fractures of the cylinders along its vertical axis. The strength of the concrete tensile is then determined by the consideration of the maximum load it lasted and the physical dimensions of the cylinder.
Flexural Strength Test:
The bend of bends, as shown in IS 516, measures the ability of concrete to resist bent forces and basically reveals its strength in tensile under such stress. This test involves the use of the load on the sample of the concrete beam either in the third points (two -point load) or to the center (one-point loading) until it breaks. The flexural strength, often referred to as the modulus of rupture, is then determined by considering the peak load the beam endured along with its size and the specific way the load was applied.

MIX PROPORTIONS:

Target Mean Strength:
For M40 grade concrete, determine the target mean strength (f_{target}) using the formula:
$F_{target} = fck + 1.65 \times s$
Control Mix:
Design a control mix of M40 grade concrete using OPC, natural sand, coarse aggregate, and water, following the guidelines of IS 10262:2019 or other established mix design procedures Determine the water-cement ratio (w/c) based on the target strength and exposure conditions
Prepare several concrete mixes by partially replacing:

- Natural Sand with quarry dust at different percentage levels (e.g. 10%, 20%, 30%, and 40%)
- Cement with fly ash at different percentage levels (e.g. 10%, 20% and 30%)
- Combination of dust from quarry and fly ash replacements at different levels

Water Content Adjustment: Adjust the water content in the replacement mixes to achieve comparable workability (e.g., slump) to the control mix. The use of superplasticizers may be considered to maintain workability at lower water-binder ratios

CURING:
Demold the specimens after 24 hours. Submerge them in clean water for curing (as per IS 516:1959) for 3, 7, 28 depending on the testing schedule.

RESULTS AND PICTURES

Workability Results:

Mix Proportions	Slump Values
M-40	**74**
M40+5%flyash +10%StoneDust	**69**
M40+10%flyash +20%StoneDust	**68**
M40+15%flyash +30%StoneDust	**70**
M40+20%flyash +40%StoneDust	**71**
M40+25%flyash +50%StoneDust	**69**

Compaction Factor Results:

MIX PROPORTIONS	COMPACTION FACTOR
M-40	0.76
M40+5%flyash +10%StoneDust	0.81
M40+10%flyash +20%StoneDust	0.79
M40+15%flyash +30%StoneDust	0.81
M40+20%flyash +40%StoneDust	0.80
M40+25%flyash +50%StoneDust	0.78

Compressive, Split Tensile and Flexural Strength Test Results:

Mix No.	3 Days Average Compressive Strength	7 Days Average Compressive Strength	28 Days Average Compressive Strength
1.	16.25	26.35	40.48
2.	16.85	26.98	41.71
3.	17.02	27.45	42.03
4.	18.36	29.65	43.69
5	17.01	26.32	41.04
6	16.2	26.12	39.43

Mix No	3 Days Average Split Tensile Strength	7 Days Average Split Tensile Strength	28 Days Average Split Tensile Strength
1.	1.81	2.30	2.86
2.	1.84	2.33	2.90
3.	1.85	2.35	2.91
4.	1.92	2.45	2.97
5	1.85	2.30	2.88
6	1.81	2.29	2.82

Mix No.	3 Days Average Flexural Strength	7 Days Average Flexural Strength	28 Days Average Flexural Strength
1.	2.82	3.53	4.45
2.	2.87	3.63	4.5
3.	2.88	3.66	4.53
4.	2.99	3.81	4.62
5	2.88	3.59	4.48
6	2.81	3.57	4.39

CONCLUSION:

Specifically, with a composition of 15% fly ash and 30% stone dust, you've recorded the following peak strengths:

* Compressive Strength: 43.69 N/mm²
* Split Tensile Strength: 2.97 N/mm²
* Flexural Strength: 4.62 N/mm²

Therefore, the M-40 concrete blend incorporating 15% fly ash and 30% stone dust yielded the maximum compressive, split tensile and flexural strengths in your investigation.

FUTURE SCOPE:

We are simply enforcing this approach for cement mortars. It calls for proper mixing proportions for the development of high energy, excessive performance concrete which won't be viable manually. So, it needs a few worldwide optimizations technique to develop the favored outcomes with more accuracy and time saving.

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IS-CODES:

- IS-456
- IS-10262
- IS-383