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Application of Quarry Dust and Fly Ash in the Concrete – A Review

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Abstract- The application of quarry dust and fly ash in concrete is a topic of interest in the field of civil engineering and construction materials. The use of these materials as partial replacements for traditional cement and aggregates can offer several benefits, including environmental sustainability, improved mechanical properties, and cost-effectiveness. The literature review furnishes essential foundational insights into concrete technology, encompassing both the materials employed in concrete production and placing particular emphasis on the substitution of sand with quarry dust. The attributes of sand and coarse aggregates are critically appraised, while the assessment methodologies applicable to concrete aggregates are also surveyed. Additionally, an exploration of the fundamental engineering characteristics of conventional concrete as well as concrete incorporating quarry dust is presented. This document underscores the context for seeking sand alternatives in concrete and the incorporation of quarry dust. Furthermore, a succinct overview of existing published literature concerning the utilization of quarry rock dust is included.

Keywords- Cement Concrete, Construction materials, Fly ash, Quarry dust.

I. INTRODUCTION

Quarry dust is a byproduct of the crushing process during quarrying operations. It is a fine-grained material that is often considered a waste product. However, researchers and engineers have found various applications for quarry dust in concrete.

Partial Replacement for Sand: Quarry dust can be used as a partial replacement for natural sand in concrete. It can improve the workability of concrete and reduce the amount of sand required, making it a sustainable alternative.

Improved Strength and Durability: Incorporating quarry dust in concrete can enhance its mechanical properties, such as compressive strength and flexural strength. The pozzolanic nature of quarry dust can also contribute to improved durability and resistance to chemical attack. Using quarry dust in concrete reduces the demand for natural sand, which helps in preserving riverbeds and ecosystems.

It also reduces the amount of quarry waste that needs to be disposed of. Fly ash is a byproduct of coal combustion in power plants and is rich in pozzolanic properties. It has been extensively studied for its potential benefits in concrete. Fly ash can be used as a partial replacement for cement in concrete, reducing the amount of cement required. This leads to lower heat generation during hydration and decreases the overall carbon footprint of concrete production.

Incorporating fly ash can enhance the workability of concrete, making it easier to place and finish. It also contributes to improved long-term durability by reducing the permeability of concrete and enhancing its resistance to chemical attacks. Fly ash can help mitigate alkali-silica reaction, a common problem in concrete that leads to cracking and deterioration. Combining quarry dust and fly ash in concrete can lead to synergistic effects. The pozzolanic reaction of fly ash with calcium hydroxide generated during the hydration of cement contributes to the development of additional strength and durability. The use of both materials together can optimize the benefits and create a more sustainable concrete mix.

Examining the impact of quarry dust on concrete workability, the study reveals a reduction in workability as quarry dust content rises. Moreover, a noteworthy enhancement in compressive strength is observed, with an incremental range spanning 55% to 75% depending on the degree of sand replacement with quarry dust. In the case of complete sand replacement, the resultant compressive strength is contingent upon the specific source of the quarry dust. As the proportion of quarry dust replacement in concrete gradually rises, a corresponding decline in workability is noted.

To counteract this reduction and bolster workability, a judicious approach involves substituting a small quantity of fly ash in lieu of cement. This measured addition of fly ash serves to heighten workability in the concrete mix. Utilizing crushed rock sand as a partial substitute for river sand in concrete, the study investigated sand sourced from three distinct origins. Notably, bulking of the sand was evident, with bulking percentages spanning the range of 35% to 44%. Additionally, silt content was identified within the crushed rock sand, accounting for 11% of its composition. Water absorption rates for the sand exhibited variability from 1.21% to 1.83%, while the average for crushed rock sand was higher at 2.4%.

The elevated values of specific gravity and water absorption associated with rock sand contributed to its finer nature. Upon assessing the compressive strength of cubes after 28 days, an increase of 13% was recorded for a 40% replacement rate, while a similar increase of 13.1% was noted for a 50% replacement rate.

II. LITERATURE REVIEW

Substituting fine aggregate with quarry dust, the researcher observed notable changes. As the percentage of quarry dust in the mix increased from 0% to 50%, the slump value, indicating low workability according to IS456:2000 standards experienced an augmentation. Meanwhile, the compaction factor value, at a constant water-cement ratio of 0.55, demonstrated a decline as the percentage of quarry dust increased. Analyzing the compressive strength of cubes at 28 days, enhancements of 13%, 3%, and 3.2% were evident for 20% and 30% replacements, respectively.

However, a reduction in strength by 3.9% and 13.1% was observed for 40% and 50% replacements, respectively. The investigation centered on replacing sand with quarry dust in M35 grade concrete. The M35 concrete blend employed Ordinary Portland Cement (OPC) 53 Grade with a specific gravity of 3.15, conforming to IS 12269:1987. The naturally occurring river sand, characterized by a specific gravity of 2.74, was utilized. Coarse aggregates were 20mm in size. Initially, concrete cubes were cast with 100% sand and no quarry dust. Subsequently, sand was substituted by 10%, 20%, 30%, and 40% with quarry dust.

The results indicated that the compressive strength of the controlled M35 concrete was 42.2 N/mm². On replacing 10% of sand with dust, the cube's compressive strength exhibited an increase of approximately 8%. However, at a 20% replacement, there was a decrease of 22.4%, further reducing to 37% for a 30% replacement. Tensile strength was measured at 3.53 N/mm² for the controlled specimens. With 10%, 20%, 30%, and 40% replacement of sand with dust, the tensile strength values rose by about 23%, 19%, 16%, and 10% respectively. At the 28-day mark, flexural strength was assessed for both the control and test specimens. Flexural strength for 10% and 20% replacements of sand with dust was recorded as 11.2 N/mm² and 10.6 N/mm², indicating a respective increase of about 12% and 6%. Conversely, for concrete with 30% and 40% replacements of sand with dust, flexural strength decreased by 6.25% and 7.75%, yielding values of 9.375 N/mm² and 9.225 N/mm² respectively.

The study's findings highlight the potential for employing quarry dust as a complete substitute for natural sand in concrete, contingent upon appropriate preprocessing of the quarry dust. The researcher formulated mix designs for three concrete grades, using IS, HCI, USBR, RN NO4, and British methods, applicable to both conventional and quarry dust concrete. Evaluations encompassed cube and beam tests to ascertain concrete strength. The fluidity of fresh concrete was quantified through slump, compaction factor, and V-B time measurements, corresponding to water/cement ratios. Among these methods, the British approach yielded the highest slumps and compaction factors for the given water/cement ratio. However, overall workability for

Quarry Rock Dust concrete was marginally inferior to conventional concrete. The physical and chemical attributes of quarry rock dust aligned with code requirements in property assessments. In certain instances, total replacement of natural river sand with Quarry Rock Dust from quarries exhibited comparable or superior compressive and flexural strength results, with compressive and flexural strength outcomes compiled for standard cubes and beams.

However, the Indian standard method produced conservative compressive and flexural strength results for all three concrete grades. This discrepancy is primarily due to the high cement content used in conjunction with low aggregate/cement and water/cement ratios, in contrast to the approaches employed by other countries. The compressive, flexural strength, and durability studies underscore that concrete utilizing Quarry Rock Dust are roughly 10% superior to conventional concrete. In summary, the paper establishes the viability of substituting natural sand with Quarry Rock Dust as a 100% replacement in concrete.

However, practical application necessitates trial casting with the proposed Quarry Rock Dust to fine-tune water content and mixture proportions, ensuring desired workability and strength levels. Nonetheless, additional research endeavors are crucial to fully understand the practical applicability of Quarry Rock Dust as a fine aggregate.

Conducting an experimental investigation, this study presents the fluctuation in concrete strength while progressively replacing sand with quarry dust, ranging from 0% to 100% in 10% increments. M20 and M25 concrete grades were selected for examination, maintaining a consistent slump of 60mm. The compressive strength of concrete cubes was assessed at 7 and 28 days of curing under ambient conditions.

Furthermore, an assessment of the impact of temperature on concrete cubes was performed, subjecting them to 100°C on the 28th day post-casting to assess potential strength loss. Analyzing the test outcomes, it was discerned that the highest compressive strength was achieved at a 50% replacement ratio under room temperature conditions. Notably, even after accounting for the strength reduction due to elevated temperature exposure, the net strength remained surpassing the recommended threshold. This observation distinctly suggests that quarry dust can serve as an effective substitute for natural river sand in concrete mixtures, yielding enhanced strength levels at the 50% replacement threshold.

This study presents an investigation aimed at exploring the feasibility of substituting fine aggregate with quarry dust while incorporating super plasticizer at dosages of 0.5% and 1% relative to the weight of cementitious materials. The experimental design encompassed replacing traditional fine aggregate with quarry dust at varying percentages of 10%, 20%, 30%, 40%, 50%, and 100%. In each mix, super plasticizers were added at 0.5% and 1% of the cement weight. After a curing period of 28 days, the study evaluated the compression, split, and flexural strengths.

The research findings demonstrate a positive correlation between the replacement percentage and compressive strength, indicating that an increase in replacement percentage leads to higher compressive strength. Particularly noteworthy is the observation that concrete with a super plasticizer dosage of 1% exhibits greater compressive strength compared to conventional concrete. The recorded percentage increase in strength is notably 85.3% higher for specimens with 100% replacement and a super plasticizer dosage of 1%.

Similarly, in the case of split tensile strength, the study notes a progressive rise as the replacement percentage increases. Remarkably, concrete incorporating a super plasticizer dosage of 1% again outperforms conventional concrete. The percentage increase in strength is even more pronounced, reaching 327% for specimens with 100% replacement and a super plasticizer dosage of 1%.

The investigation extends to flexural strength, where the results indicate a consistent pattern of strength increase as replacement percentages rise. Like the other strength properties, flexural strength is superior in concrete with a super plasticizer dosage of 1%, surpassing conventional concrete. The percentage increase in strength for specimens with 100% replacement and a super plasticizer dosage of 1% is notably elevated, reaching 388%.

In conclusion, the study establishes that quarry dust can serve as a viable alternative to natural river sand.

The physical and chemical attributes of quarry dust align with the requirements of fine aggregate. Importantly, the study highlights that quarry dust, when used in conjunction with super plasticizer, enhances the mechanical properties of concrete.

Utilizing Quarry dust as a viable substitute for river sand has proven to confer conditional advantages to concrete. This study focused on assessing the strength and corrosion-resistant attributes of concrete containing quarry dust as fine aggregate, in conjunction with organic inhibitors namely Triethanolamine and Diethanolamine. The inhibitors were added at varying percentages of 1%, 2%, 3%, and 4% by weight of cement. The test parameters encompassed compressive strength, split tensile strength, flexural strength, and bond strength.

The outcomes of the compressive strength tests after a 28-day curing period revealed intriguing insights. Incorporating 1% Triethanolamine demonstrated a 9.8% increase in compressive strength. Notably, an addition of 2% of this inhibitor led to a significant 13% enhancement, constituting the peak increase in strength.

Furthermore, the addition of Triethanolamine at 3% and 4% yielded increases of 7.2% and 0.7%, respectively, albeit comparatively lower than the 2% dosage. Similarly, the addition of Diethanolamine at a 2% dosage yielded the most substantial increase in strength values, specifically a noteworthy 12.45%. Turning to the split tensile strength test results at the 28-day mark, the addition of 2% Triethanolamine and Diethanolamine exhibited maximum strength improvements, registering increases of 14.55% and 11.43%, respectively. The flexural strength test results, also conducted after 28 days of curing, unveiled the pronounced impact of Triethanolamine and Diethanolamine at a 2% dosage. These inhibitors yielded the most significant strength enhancements, namely 12.68% and 10.38%, respectively.

Lastly, the bond strength test results at 28 days displayed intriguing trends. Specimens with 2% addition of both Triethanolamine and Diethanolamine exhibited maximum increases in bond strength, boasting improvements of 15.28% and 13.38%, respectively. However, increasing the inhibitor dosage to 3% and 4% resulted in a marginal decline in strength values.

In an empirical investigation, crushed stone dust was employed as fine aggregate, either partially or completely, in conjunction with varying concrete grades. Two fundamental mixtures were adopted to attain M25 and M30 concrete grades. Through their analysis, the researchers determined the physical and chemical attributes of quarry rock dust. Their findings substantiated that the utilization of crushed stone dust waste is a viable approach to replace natural sand in concrete.

The discerned physical and chemical properties of quarry rock dust adhered to code provisions in property assessments. The findings suggested that natural river sand could be entirely replaced by quarry rock dust, potentially yielding equivalent or superior outcomes compared to reference concrete composed of natural sand. This experimental study further uncovered enhancements in compressive strength, flexural strength, and split tensile strength of concrete when incorporating quarry rock dust.

The results demonstrated that both compressive and flexural strength were notably 10% to 12% higher than those of conventional concrete. Additionally, the research delved into the drying shrinkage strains of quarry rock dust concrete. These strains were relatively greater than those of conventional concrete in the early stages; however, at later stages, they exhibited comparable strain levels to conventional concrete.

In summary, this study underscores the viability of utilizing crushed stone dust as a substitute for natural sand in concrete formulations. The resulting improvements in strength properties, particularly compressive and flexural strength, validate the potential of quarry rock dust as a beneficial alternative material in concrete production. Utilizing quarry dust as a competent filler material instead of fine aggregate emerges as an effective approach.

This substitution not only serves to decrease the cost of concrete production by partially replacing natural river sand but also presents a sustainable alternative. The study's focus centered on the design mix of M25-grade concrete, encompassing replacement levels of 0%, 20%, 25%, 30%, and 35% of quarry dust.

These replacement levels were designated as M1, M2, M3, M4, and M5, respectively, and subjected to a battery of laboratory analyses, including slump tests, compaction factor tests, compressive strength assessments, split tensile strength evaluations, and flexural strength measurements of the hardened concrete. The investigation took particular interest in evaluating workability variations, quantified through the compaction factor, while maintaining a constant water-cement ratio of 0.44.

The obtained compaction factor values for the different mixtures were as follows: M1 (0% quarry dust) - 0.83, M2 (20% quarry dust) - 0.85, M3 (25% quarry dust) - 0.86, M4 (30% quarry dust) - 0.88, and M5 (35% quarry dust) - 0.91.

Turning to the compressive strength results, the authors noted significant trends over various curing periods (7, 14, and 28 days). Specifically, for mixture M1 with 0% quarry dust, the compressive strength at 28 days of curing stood at 36.33 MPa for 53-grade concrete. With a 20% incorporation of quarry dust (M2), the 28-day compressive strength reached a maximum of 38.23 MPa for 53-grade concrete. Further increasing the dust content to 25% (M3) yielded a 28-day compressive strength of 39.23 MPa for 53-grade concrete. However, once the dust content exceeded 35%, there was an observed decline in compressive strength. In summary, this study underscores the utility of quarry dust as a promising replacement for fine aggregate, thereby showcasing potential benefits in terms of both cost reduction and enhancing concrete strength properties.

In conclusion, this study highlights that the incorporation of Quarry dust into concrete, combined with specific organic inhibitors, can substantially enhance various strength parameters. Notably, the 2% dosage of Triethanolamine and Diethanolamine consistently yielded the most significant strength improvements across the evaluated tests.

This paper presents an experimental study that delves into the ramifications of entirely substituting sand with quarry dust. The initial phase involved the examination of cement mortar cubes crafted with varying proportions of quarry dust (CM 1:3, CM 1:2, and CM 1:1). The findings from these experiments indicated that the inclusion of quarry dust, within a fine to coarse aggregate ratio of 0.6, led to an enhancement in both compressive properties and elastic modulus. To assess the compressive strength attributes, 7.05 × 7.05 × 7.05 mm mortar cubes were subjected to tests.

Compressive strength was evaluated in line with IS: 516-1959 standards at 3, 7, and 28 days of curing. Notably, the 28-day compressive strength of mortar cubes (CM 1:1) with 100% sand replacement by quarry dust was 11.8% higher than conventional cement mortar cubes. However, the compressive strength of cement mortar exhibited a decreasing trend across the 3, 7, and 28-day periods in comparison to the reference concrete.

The split tensile properties of concrete specimens were examined for various binder contents and F/C ratios ranging from 8 to 13. The study unveiled that, for a binder content of 300 kg/m^3, split tensile values fluctuated between 1.91 to 3.15 MPa. The highest split tensile strength, reaching 3.15 MPa, was recorded at 56 days for an F/C ratio of 0.6. Similarly, at a binder content of 350 kg/m^3, the peak split tensile strength ranged from 2.48 to 3.33 MPa. Overall, a split tensile strength of 3.33 MPa was achieved for quarry dust concrete with an F/C ratio of 0.6.

The incorporation of quarry dust yielded a substantial increase in split tensile strength, registering an improvement of 18.6% compared to reference concrete. Regarding the modulus of elasticity, at 100% replacement of sand with quarry dust and a binder content of 300 kg/m^3 with an F/C ratio of 0.6, the maximum value observed was 10.24% higher than the reference concrete.

However, the usage of quarry dust in normal concrete might be limited when it exhibits high fineness, as this characteristic can lead to heightened water demand. This study highlights the positive effects of incorporating quarry dust as a complete replacement for sand. Improved compressive strength, split tensile strength, and modulus of elasticity are evidenced, with notable gains observed under specific conditions of binder content and F/C ratio.

III. CONCLUSION

The application of quarry dust and fly ash in concrete has the potential to improve the properties of concrete while reducing the environmental impact of construction materials. However, careful mix design and testing are essential to ensure that the desired properties are achieved. Local availability, specific project requirements, and applicable standards should be considered when deciding on the proportions of quarry dust and fly ash in the concrete mix.

The research findings and discussions from various test results lead to several conclusions aimed at achieving the primary objectives of this investigation: The addition of fly ash exceeding 30% in Portland cement for foam concrete production leads to a reduction in density, adversely affecting workability and impacting the hardening properties of the material.

The expansion behavior observed in foamed concrete during early stages indicates potential challenges in maintaining continuous hydration in the presence of moisture content. The optimal fly ash content for enhancing short-term compressive strength in foamed concrete ranges between 20% to 25%. Based on comprehensive experimental tests across various mixes, the optimal composition entails 30% fly ash alongside 30% quarry dust stone powder, accompanied by a 6% foam content.

Consequently, it is highly recommended to consider this form of cellular concrete for applications like non-load-bearing walls or partition walls. This foam concrete variation proves especially suitable for the construction industry, as it effectively minimizes the structural member's self-weight when compared to traditional brick masonry walls. This recommendation stems from the fact that it incorporates 30% fly ash as a replacement for Portland cement and 30% quarry dust as a replacement for river sand.

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