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Investigation of Quarry Dust Performance in Concrete as a Fine Aggregate

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ABSTRACT

Concrete, the most widely used construction material, often faces challenges related to the depletion of natural river sand, increased construction costs, and environmental degradation. To address these issues, quarry dust—a byproduct of stone crushing—is proposed as a sustainable partial replacement for fine aggregate in concrete. This study investigates the performance of quarry dust in M25 and M30 grade concrete by replacing fine aggregate at 0%, 20%, 40%, 60%, 80%, and 100% levels. Concrete mixes were tested for slump, compressive strength, split tensile strength, flexural strength, and water absorption. Results revealed that workability decreased with higher quarry dust content, while mechanical strength improved up to 60% replacement. Notably, M30 concrete achieved a peak compressive strength of 42 MPa and M25 reached 38 MPa at 60% quarry dust replacement. The findings confirm that quarry dust enhances strength and durability when optimally used, making it a viable eco-friendly alternative to natural sand in structural concrete.

KEYWORDS: *Quarry dust, Fine aggregate replacement, Compressive strength, Sustainable concrete.*

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1. INTRODUCTION

The construction sector has seen enormous growth in the past decades, which has resulted in an increasing quantity of concrete—a common building material utilized in construction worldwide. Concrete is largely made up of cement, water, coarse aggregates, and fine aggregates such as river sand [1]. Overwhelming sand extraction has resulted in negative environmental effects such as riverbed degradation, aquatic habitat loss, and erosion [2]. The overutilization of natural resources is unsustainable and must be substituted with sustainable alternatives that satisfy both economic and environmental factors. In the light of this, quarry dust—the by-product of stone crushing during aggregate production—has realized and been embraced as a viable alternative for fine aggregates [3, 4].

Quarry dust (QD), also referred to as crusher and stone dust or, consists of very small stone dust particles that typically range below 4.75mm in diameter [5]. QD usually generated in phenomenally large quantities during the crushing process of the quarry operation. QD was regarded as waste and dumped in landfills or the environment as an unwanted problem, and in the process, causing dust pollution and land degradation [6]. As concern regarding sustainability of resources as it pertains to natural sand quarrying and overall comprehension of environmental stability grew more prevalent, scientists and engineers started exploring the viability of using QD as a partial or complete in place for sand when preparing concrete[7, 8].

This approach helped lower environment degradation as well as generate valuable products from its byproduct. The physical characteristics of quarry dust (i.e., fineness, angularity, and mineral origin) make it suitable as concrete aggregate. Its angular and rough surface is found to be responsible for mechanical interlocking between particles in the concrete, which can enhance compressive strength (CS) and durability [9]. Additionally, some QD can exhibit pozzolanic behavior and generate secondary cementitious reactions that can enhance long-term performance.

But depending on the parent rock type, the crushing process, particle size distribution and purity [10], the use of quarry dust as fine aggregate will vary. Systematic study of the QD may be required to find the optimum mix proportions and performance [11].

Figure 1: Production of Robo Sand in Site

The incentive behind this work comes from the requirement for all the sustainable and low-cost substitutes for natural river sand for concrete manufacturing. Historically, severe environmental control and the limited supply of river sand impose significant pressure – as it affects the natural environment both ecologically and economically. Quarry dust is a suitable, industrial by-product that possesses substantial availability and shows potential for offering sustainable and cost-effective alternatives as a natural river sand substitute on account of its favorable physical properties and availability. The objective of this research is to experimentally evaluate the quarry dust material performance by employing it as fine aggregate in concrete and measuring its impact on the multiple parameters. The research also attempts to determine the sustainable replacement percentages of quarry dust to deliver the best performance without compromising the constituents and key performance factors of concrete. The main contributions of this study are:

- Creating a holistic experimental protocol to evaluate the mechanical and durability properties of concrete mixes with different quarry dust content.
- Assessing the optimum level of QD in M25 and M30 grade concrete for performance and cost savings.
- Encouraging the sustainable use of QD as a fine aggregate alternative, thereby supporting environmental sustainability and waste reduction in construction.

2. Literature Review

Chitkeshwar et al., (2022) [12] examined the characteristics of quarry dust that was utilised in concrete. Concrete was made by substituting natural river sand with dust generated from rock quarries, utilising varying quantities of 0%, 25%, 50%, and 75%. The compressive and flexural strength were measured at 7, 14, and 28 days. The regression study had been conducted for concrete with varying percentages of quarry dust substitution.

Nuruzzaman et al., (2024) [13] provided a study on the synergistic application of two by-products, specifically quarry dust (QD) and ferronickel slag (FNS), as a complete replacement for natural sand to enhance the sustainability of concrete manufacturing. QD had been utilised in increments of 25%, reaching a maximum replacement of 75%, while nickel slag constituted the remaining amount of fine aggregate. The findings indicated that the integration of QD and nickel slag as a complete replacement for sand in concrete yielded comparable results for these attributes. Notably, a mixture of 25% QD and 75% nickel slag demonstrated the most favourable substitute for sand, exhibiting compressive and cracking tensile properties of 62 MPa and 4.29 MPa, correspondingly, surpassing the initial mix by 16% and 20%.

Kabashi et al., (2024) [14] examined the direct incorporation of stone dust obtained from stone industries, namely as random samples gathered during the cutting process of stone production Experimental studies demonstrated that quarry dust served as an excellent replacement for fine aggregate and cement; however, a thorough chemical examination of the stone dust was essential before incorporation to guarantee compatibility with the concrete mixture. The study analysed the CS of concrete at different percentages of stone dust, assessing its effect on the concrete classification. Inspected replacement ratios between 5% and 12.5% for fine particles with optimal cement substitution.

Prathipati et al., (2024) [15] evaluated the mechanical characteristics of high-strength concrete (HSC) that incorporated waste from industries to determine the feasibility of utilising these materials. The workability, CS, and flexural strength of the concrete, along with its durability characteristics such as moisture absorption, permeability, density, acid strength loss, and acidic mass loss, were examined and recorded. Other components had been examined and documented as well. The findings indicated that the inclusion of fly ash and QD, each at a maximum level of 30%, positively influenced the mechanical properties of HSC.

Kaish et al., (2021) [16] examined the impact of various industrial waste materials as partial substitutes for fine aggregate on the strength characteristics of conventional concrete. This study used air-dried aluminium sludge as a substitute for fine aggregate (river sand). QD and limestone dust were used as non-reactive commercial waste materials to determine the distinct impact of alum sludge in concrete. The findings indicated that the optimal replacement ratio of fine aggregate with waste from industry was 10% for alum sludge and 15% for quarry and limestone dust, enhancing all strength attributes examined in that study.

3. Methods and Materials

The method and materials adopted in this research is a systematic process of evaluating the performance of quarry dust as a partial substitute for fine aggregate in concrete. The process starts with material collection and characterization (i.e. cement, coarse aggregate, fine aggregate, quarry dust, water). Following this, concrete mix proportions are designed, and specimens are prepared, cured, and tested for various mechanical and durability properties. The results obtained will be compared to identify the best level of replacement and overall performance influence.

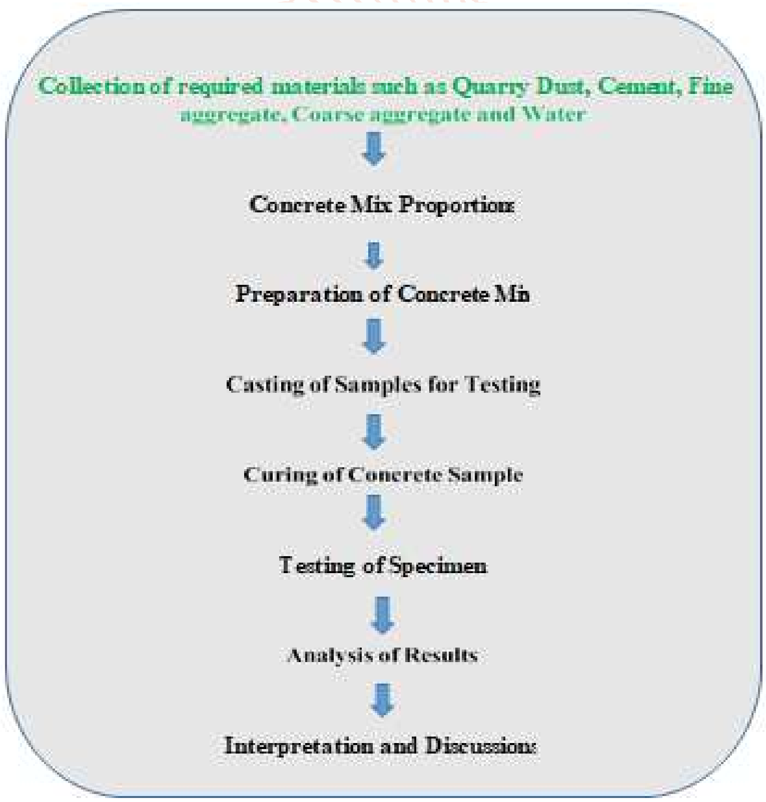


Figure 2: Proposed Framework

3.1. Material Collection and Characterization

A. **Cement:** The project work makes use of Pozzolana Portland cement (PPC), which is easily accessible in the local market. The cement that was used for the project has been subjected to testing in accordance with IS: 4031-1988 and has been determined to meet several requirements outlined in IS: 1489-1991. Particular gravity was 3.6.

B. **Fine aggregate:** Local river sand that is in accordance with the IS: 383-1970 grade 2 specification and locally available. Locally available clean river sand would be utilized. Sand would be sieved through an IS 4.75mm for all casting of specimens.

C. **Coarse aggregate:** The aggregate for the project was crushed annular granite that was quarried locally. The coarse aggregate used in the project work was 60% 20mm aggregate and had a specific gravity of 2.7.

(a) Cement (b) Coarse aggregate

(c) Fine aggregate (d) Quarry dust

Figure 3: Material used

D. **Water:** Water for use in concrete works should not have any toxic quantity of dirt, acids, alkalis, or other inorganic pollutants; further, it should not have any quantity of iron or vegetation that could dissolve the concrete or cause corrosion in the reinforcement.

E. **Quarry dust:** Superplasticizer was needed to achieve sufficient workability in quarry dust mixtures due to the high surface area and water requirement with quarry dust tending to have a greater surface area and hence a higher water requirement. Superplasticiser lowers the water / cement volume ratio while imparting flow ability to cement the concrete at the compaction stage and offer sufficient strength in concrete. This present research is asking that quarry dust be used in place of a certain percentage of the gravel in the concrete. It is hoped that the study will present a comparison of the concrete performance when using quarry dust. The quarry dust was obtained from stone crushes in the local town of Sirsa.

3.2. Mix Design

The mix design of M25 and M30 concrete was carried out as per IS: 10262-2009. Quarry dust was replacing the fine aggregate physically in six levels i.e. 0%, 20%, 40%, 60%, 80% and 100%. The water-cement ratios were 0.45 for M25 and 0.43 for M30.

Table 1: Quantity of Material for Mix Design

Grade of Concrete	Materials	Proportion by Weight	Weight in Kg/m3
M25	Cement	1	397
Fine Aggregate	1.40	555	
Coarse Aggregate	3.05	1210	
W/C	0.45	180	
M30	Cement	1	405
Fine Aggregate	1.32	534	
Coarse Aggregate	2.85	1154	
W/C	0.43	175	

3.3. Specimen Preparation

The concrete mixed ingredients were all dry blended and then water and superplasticizer were added. The specimens were cast in standard molds:

- **Cubes (150 mm × 150 mm × 150 mm)** for compressive strength
- **Cylinders (150 mm × 300 mm)** for split tensile strength
- **Beams (100 mm × 100 mm × 500 mm)** for flexural strength

Each specimen was vibrated using a table vibrator to eliminate air voids. Molds were demolded after 24 hours.

3.4. Curing Process

Once the concrete has set, it begins to develop strength, and that strength grows with time. The initial 28 days is when strength will be 90% to 95% of the final strength, and that 28-day strength is called design strength - and is employed for design. The strengthening is due to the hydration of the cement, and hydration can only occur in water-filled capillaries. Concrete may be cured using water applied on the surface, being frequently misted, being covered with burlap or similar material to prevent the moisture from escaping, or steam curing. In this project, once the mold is filled with fresh concrete and left to set overnight, the specimen is then extracted from the mold and submerged in the clean water of the curing tank where it remains until testing is completed.

(a) (b)

Figure 4: (a) Mixing of concrete and (b) Curing of Cube at Standard temperature in water

3.5. Testing Procedures

- **Workability Test**: Slump test was performed according to IS: 1199-1959 to find the consistency and flow.
- **Compressive Strength Test**: Performed on the cube specimens using a compression machine according to IS: 516-1959 [17].
- **Split Tensile Strength Test**: Conducted on cylindrical specimens using the formula:

$$T_{sp} = \frac{2P}{\pi DL}$$

- **Flexural Strength Test**: Three-point bending test on beam specimens to assess modulus of rupture.
- **Water Absorption Test**: Water absorption tests were carried out according to IS: 15658:2006 for evaluating durability by determining the percentage of water absorbed by concrete samples.

3.6. Analysis and Interpretation

- Test results for each mix and curing period were compared to determine:
- Effect on strength and workability by increasing quarry dust.
- Optimum replacement level yielding the optimum combination of strength, durability and sustainability.
- Variations of M25 and M30 mixes at various levels of quarry dust.

This methodology allowed for a comprehensive evaluation of quarry dust's performance in structural concrete applications.

4. Result and Discussion

The figure 5 represent the slump of M-25 and M-30 grade concrete mixtures to which varying proportion of quarry dust has been incorporated as a part replacement of fine aggregate. In (a), slump value of M-25 concrete slowly withdraws in the range of approximately 108 mm at 0 percent quarry dust to approximately 72 mm at 100 percent replacement indicating a reduction in the workability as the amount of quarry dust used increases. The same is true for M-30 concrete from (b) where slump has decreased with a corresponding size shift so that 0% quarry dust has a slump of approximately 98 mm while 100% is around 65 mm. Figure 6 compares both M-25 and M-30 mixes against one another and once again establishes that with an increase in percentage of quarry dust between 0% and 100%, both slump values decrease simultaneously. Specifically, M-25 shows slightly higher slump values compared to M-30 at every level of replacement, suggesting that a higher proportion of quarry dust negatively affects the workability of concrete.

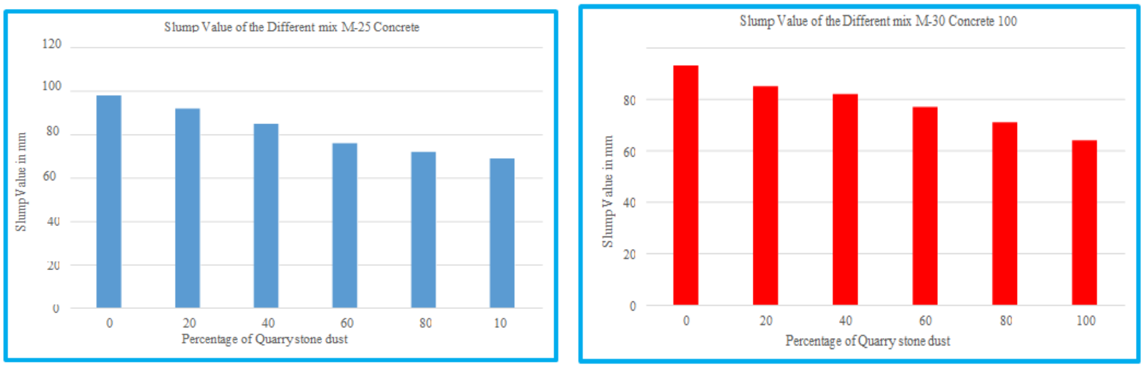
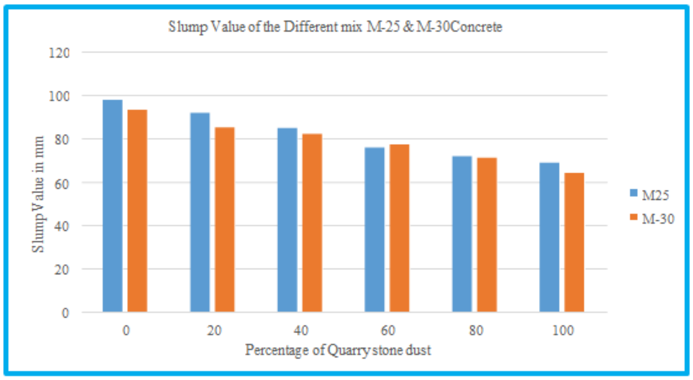
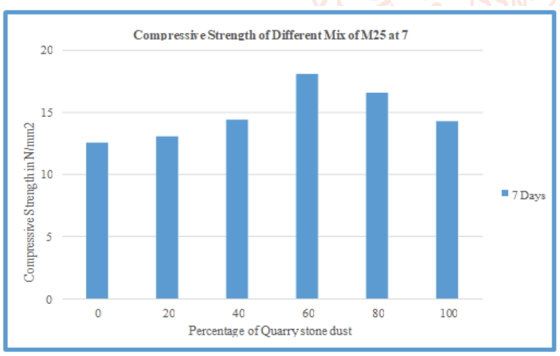


Figure 5: Slump Value of the Quarry dust for M-25 and M-30 Concrete

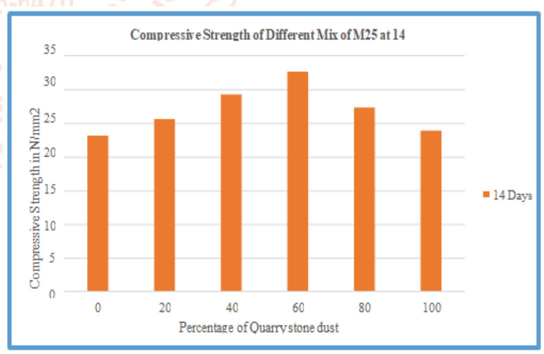


Graph 6: Slump Value of the Different mix M-25 & M30 Concrete

The compressive strength of M25 concrete at 7, 14 and 28 days using varying percentages of quarry stone dust is illustrated by figure 7 (a), (b), and (c) respectively. At 7 days, strength increases up to approximately 13MPa (0% quarry dust) and 60% down to approximately 15.5 MPa (60 % quarry dust) before decreasing a bit. Highest strength of about 24 MPa is achieved at a 60 percent replacement on day 14. Similarly, on day 28, the highest compressive strength is about 32 MPa at 60 percent indicating substantial increase in strength with moderate quarry dust content.



(a)



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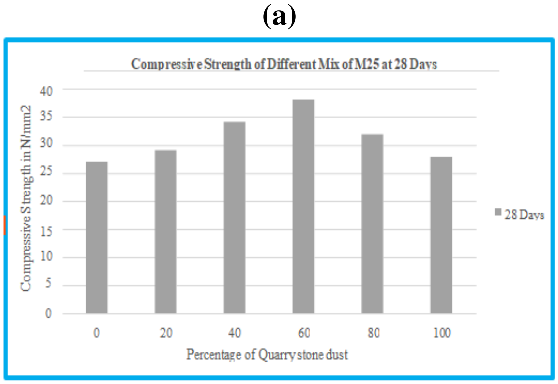
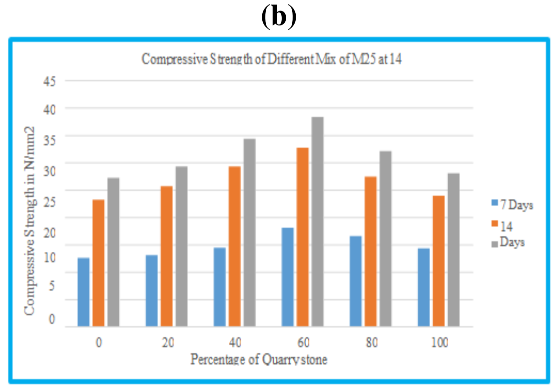


(c)

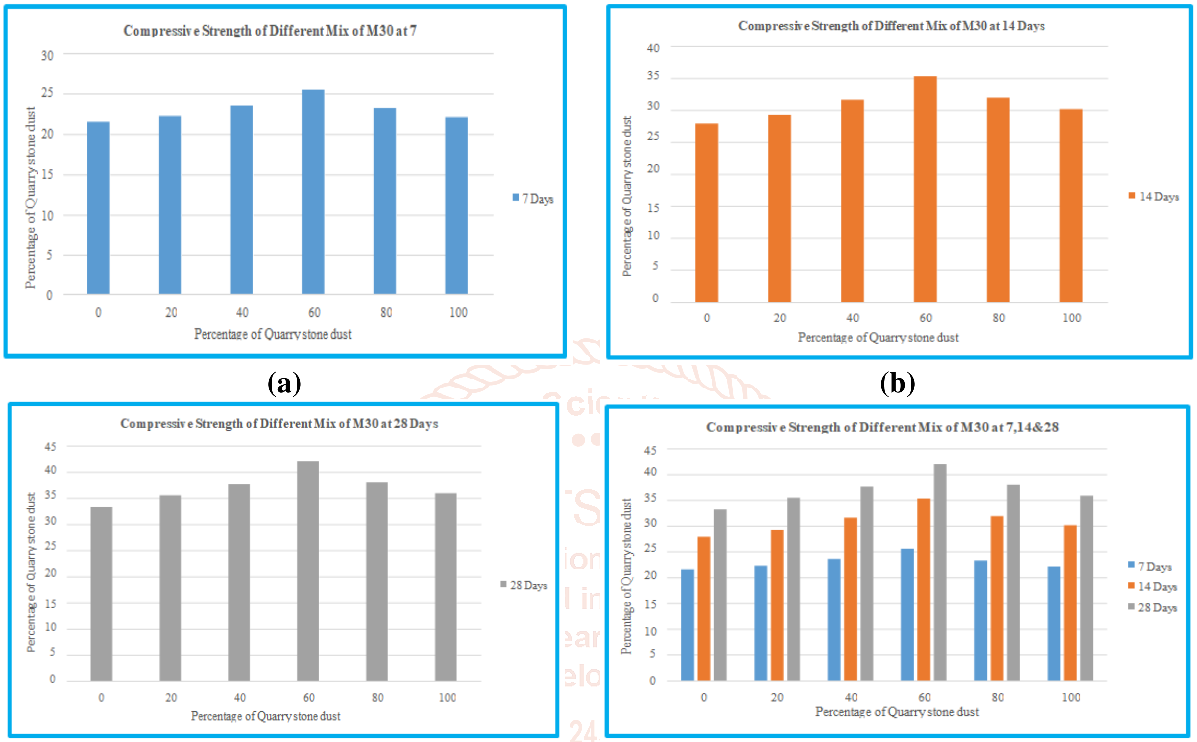


(d)

Figure 7: Effect of quarry stone dust on compressive strength of M25 concrete at (a) 7- days and (b) 14- days (c) 21-days and (d) at 7,14 & 28 days

Figure 7 (d) positions compressive strength at 7-, 14- and 28-days side by side. It verifies the trend of consistency with an increase with the curing duration and an optimal strength of 60 of quarry dust across all ages. Beyond the percentage of 60 percent, there is a very slight drop showing that maybe too much quarry dust has a negative impact on the compressive strength.

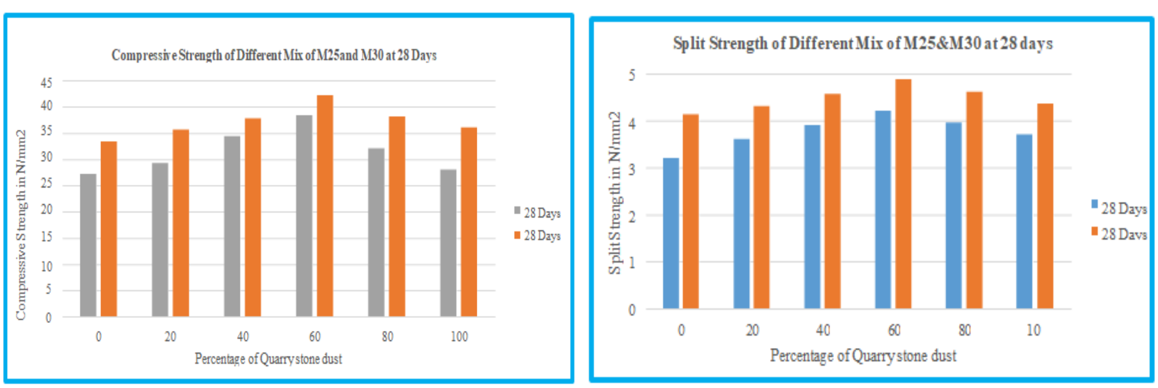
In Figure 8 compressive strength of M30 concrete at 7, 14, and 21 days respectively at various percentages of the quarry dust, by (a), (b), and (c) respectively. At 7 days of curing the strength increases by approximately 23 MPa at 0 percent to a near maximum of 26 MPa at 60 percent. The highest compressive strength is at 60 percent quarry dust and 14 days with a reading of approximately 32 MPa. Similarly, the relative strength also has its maximum of approximately 39 MPa at 60 days, which also shows the optimal replacement at the same position.



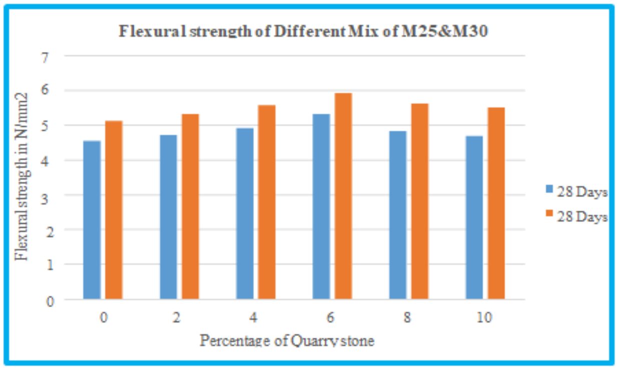
(a) (b) (c) (d)

Figure 8: Effect of quarry stone dust on compressive strength of M30 concrete at (a) 7- days and (b) 14- days (c) 21-days and (d) at 7,14 & 28 days

Figure 8 (d) provides a comparison of the three curing periods (7 days, 14 days, 21 days). With age and up to 60% quarry dust content, there is a consistent increase in strength but beyond the latter, there is minor reduction. The trend indicates that, at 60% quarry dust by means of fine aggregate replacement, early and later-age concrete strength of M30 concrete can be further strengthened successfully.



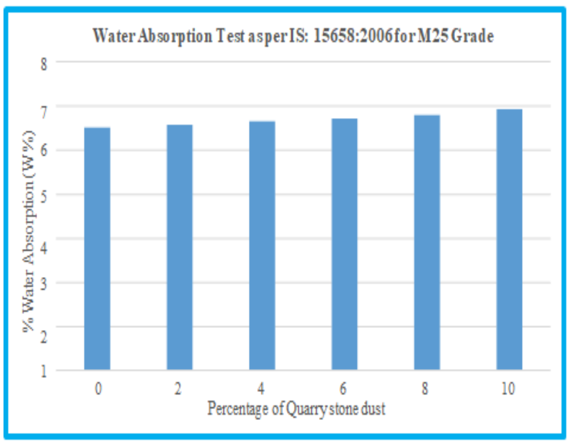
(a) (b)



(c)

Figure 9 Effect of quarry stone dust of M25 and M30 concrete at 28 day on (a) compressive strength, (b) Split Tensile strength and (c) Flexural Strength

Figure 9 indicate the mechanical properties of the M30 and M25 concrete mixes utilizing quarry dust. (a) indicates that 28 days compressive strength is optimal at about 42 MPa and 38 MPa of the M30 and M 25 mortar respectively at 60 percent replacement of quarry dust and (b) indicates split tensile strength which also reaches its highest levels, approximately 4.4 MPa in M30 and 4.1 MPa in M25, at a comparable point, too, 60 percent replacement. Figure 9 (c) indicates that flexural strength increases steadily as quarry dust proportion increases to a maximum level of 6.3 MPa (M30) and 5.8 MPa (M25) at 10 percent quarry dust proportion which indicates better flexural performance at lower replacement levels.



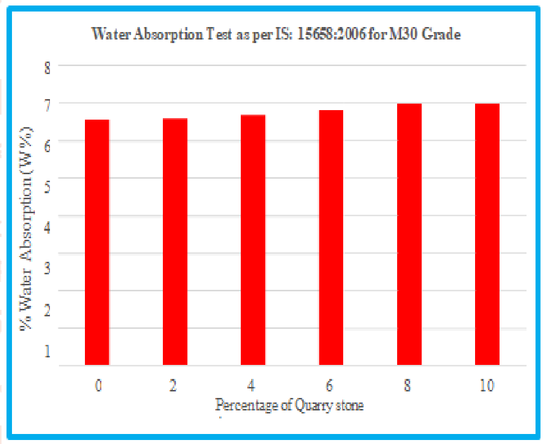


Figure 10: Effect of quarry stone dust on Water Absorption (a) M25 concrete and (b) M30 concrete

Figure 10 indicate the influence of quarry stone dust on M25 and M30 grade concrete water absorption. In both grades, a slight increase in water absorption was observed with an increase in quarry dust content. In the case of M25 concrete (graph a), water absorption went up from about 6.5% at 0% replacement to nearly 6.9% at 10%. While M30 concrete (graph b) recorded a water absorption rate going up from about 6.3% to 6.8%, over the same range of replacement. It can therefore be concluded that the addition of quarry dust reduced slightly the resistance of concrete to moisture transmission.

5. Conclusion

The experimental investigations clearly show that quarry dust can replace natural fine aggregate in concrete without compromising strength and durability if it is kept within optimal ratios. The outcome of the experiment was that the substitution of river sand with quarry dust at 60% or below enhanced the mechanical performance of M25 and M30 concrete with a tremendous compressive strength of 42 MPa for M30 concrete and a tremendous compressive strength of 38 MPa for M25 concrete at this replacement level. At 60% replacement, a slow reduction in concrete mix strength and workability was realized meaning that excessive use of quarry dust had adverse effects on concrete mixing, strength and workability due to the fact that quarry dust requires more water for mixing and is less cohesive. It must also be pointed out that the slump test values proved to show a significant reduction in the fresh concrete mixes' workability with increasing quarry dust and even the split tensile and flexural strengths also performed well up to the ideal replacement levels for quarry dust. The rising absorption rates in concrete mixes with higher proportions of quarry dust were appreciable, but they were still within acceptable ranges. In general, the results validated the sustainable and cost-effective use of quarry dust as an alternative to natural sand in normal concrete.

Reference

[1] Baalbaki, W., Benmokrane, B., Chaallal, O and Aitcin, P.C (1991). Influence of coarse aggregate on Elastic properties of High-performance concrete, ACI Materials Journal, 88(5):499-503.

[2] Alsharari, Fahad. "Utilization of Industrial, Agricultural, and Construction Waste in Cementitious Composites: A Comprehensive Review of their Impact on Concrete Properties and Sustainable Construction Practices." Materials Today Sustainability (2025): 101080.

[3] Ilangovana, R., N. Mahendrana, and K. Nagamanib. "Strength and durability properties of concrete containing quarry rock dust as fine aggregate." ARPN Journal of Engineering and Applied Sciences 3, no. 5 (2008): 20-26.

[4] Ho, D.W.S., Sheinn, A.M.M., Ng, C.C and Tam C.T (2002). The use of quarry dust for SCC applications, Cement and Concrete Research 32 (2002) 505– 511.

[5] Raman, S. N., Zain, M.F.M., Mahmud, H. B and Tan, K. S (2004). Suitability of quarry dust as partial replacement material for sand in concrete,

[6] Pathe, Anup Kumar, P. Kumar Kushwaha, and Jiji M. Thomas. "Review on performance of quarry dust as fine aggregate in concrete." Int. Res. J. Eng. Technol 7 (2020): 517-521.

[7] Silva, Leandro S., Mayara Amario, Carina M. Stolz, Karoline V. Figueiredo, and Assed N. Haddad. "A comprehensive review of stone dust in concrete: mechanical behavior, durability, and environmental performance." Buildings 13, no. 7 (2023): 1856.

[8] Safiuddin. Md., Raman, S.N and Zain, M.F.N (2007). Utilization of Quarry waste fine aggregate in concrete mixtures, Journal of applied Science Research, 3(3):202- 208

[9] Shyam Prakash, K., and Ch Hanumantha Rao. "Study on compressive strength of quarry dust as fine aggregate in concrete." Advances in Civil Engineering 2016, no. 1 (2016): 1742769.

[10] Reddy, M.V and Reddy, C.N.V.S (2007). An Experimental Study on use of Rock Flour and Insulator Ceramic Scrap in Concrete, IE (I) Journal – CV, 88: 47-50.

[11] Dobiszewska, Magdalena, Orlando Bagcal, Ahmet Beycioğlu, Dimitrios Goulias, Fuat Köksal, Maciej Niedostatkiewicz, and Hüsamettin Ürünveren. "Influence of rock dust additives as fine aggregate replacement on properties of cement composites—a review." Materials 15, no. 8 (2022): 2947.

[12] Chitkeshwar, Anup K., and P. L. Naktode. "Concrete with rock quarry dust with partial replacement of fine aggregate." Materials Today: Proceedings 62 (2022): 6455-6459.

[13] Nuruzzaman, Md, Jaydon Almeida, Md Tanvir Ehsan Amin, and Prabir Kumar Sarker. "Performance of sustainable green concrete incorporating quarry dust and ferronickel slag as fine aggregate." Materials 17, no. 10 (2024): 2326.

[14] Kabashi, N. A. S. E. R., E. N. E. S. Krasniqi, and M. I. L. O. T. Muhaxheri. "OPTIMIZING FINE AGGREGATE AND CEMENT REPLACEMENT WITH STONE DUST: IMPACT ON CONCRETE COMPRESSIVE STRENGTH." Proc. Int. Struct. Eng. Constr 11 (2024): 1-6.

[15] Prathipati, SRR Teja, Yeswanth Paluri, Kunamineni Vijay, and V. Bhavita Chowdary. "Evaluating the feasibility of blending fly ash and quarry dust in high-strength concrete to develop a sustainable concrete: A Study on the Mechanical and Durability Properties." In IOP Conference Series: Earth and Environmental Science, vol. 1086, no. 1, p. 012060. IOP Publishing, 2022.

[16] Kaish, A. B. M. A., Temple Chimuanya Odimegwu, Ideris Zakaria, and Manal Mohsen Abood. "Effects of different industrial waste materials as partial replacement of fine aggregate on strength and microstructure properties of concrete." Journal of Building Engineering 35 (2021): 102092.

[17] IS: 516, 1959, 2004 Indian Standard methods of tests for strength of concrete, Bureau of Indian Standards, New Delhi, 24.