Performance Evaluation of Concrete Incorporating Quarry Dust as a Partial Replacement of Fine Aggregate with Superplasticizer

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Abstract - *Natural river sand is frequently used as a fine aggregate in concrete, but due to over-exploitation and lengthy transportation distances, it is now scarce, expensive, and environmentally problematic. Naturally occurring sand may be replaced by quarry dust, a byproduct of the stone-crushing business. This study examines the performance of M25 grade concrete that uses quarry dust in place of fine aggregate, both with and without a superplasticizer. Using quarry dust at constant water–cement ratios of 0.42, replacement amounts of 0%, 20%, 40%, and 60% by weight of fine aggregate were used. The effects of superplasticizer doses of 0% and 0.6% (by weight of cement) on the behavior of concrete were examined. Assessing qualities such as workability, compressive strength, split tensile strength, and bond strength, both fresh and hardened—was the main goal of the experimental study. The findings show that while superplasticizer improves workability and strength properties, quarry dust has a major impact on concrete performance. The results of the current study lay the groundwork for more thorough and in-depth future research while offering first insights into the viability of quarry dust as a partial substitute for fine aggregate in concrete.*

Key Words: **M25 concrete, Quarry dust, Superplasticizer 0 to 0.6%, Fine aggregate replacement, Workability, compressive strength, Split tensile strength**

1. INTRODUCTION

In civil engineering, concrete is one of the most often used building materials because of its strength, adaptability, durability, and simplicity of obtaining raw materials. It is widely utilized in infrastructure projects that include pavements, bridges, buildings, and other structural elements. The ingredients of conventional concrete are water, fine and coarse aggregates, and cement. Natural river sand is frequently utilized as fine aggregate among these components. On the other hand, excessive and unregulated river sand mining has led to major environmental issues as ecological imbalance, groundwater table decline, and riverbank erosion [1–3].

The need for natural sand has grown dramatically in recent years due to the fast urbanization and infrastructural development, especially in emerging nations like India. This has had a negative impact on the sustainability of construction methods, resulting in a shortage of river sand, higher building prices, and longer transportation distances. Therefore, finding appropriate substitute materials that can either completely or partially replace natural sand without sacrificing concrete's performance is becoming increasingly important [4–6].

A by-product of the crushing of stones in quarry operations, quarry dust is produced in abundance. There are health and environmental risks associated with quarry dust disposal. Quarry dust is a substance that has been discovered as a viable substitute for fine aggregate in concrete because of its tiny particle size, angular form, and mineral makeup. Numerous studies have documented that, up to an optimal replacement level, partially substituting quarry dust for natural sand increases aggregate packing density and compressive and tensile strength; after that, poor workability may result in a drop in strength [7, 8].

The decrease in workability caused by the high fineness and increased surface area of quarry dust is one of the main drawbacks of utilizing it in concrete. Superplasticizers and other chemical admixtures are frequently employed to solve this problem. Superplasticizers keep concrete strong and durable by improving their workability and flowability without raising the water-to-cement ratio. Therefore, combining superplasticizer and quarry dust can produce workable concrete with better mechanical performance [8].

2. METHODOLOGY

2.1 Materials Used

Cement: Standard Ordinary Portland cement that complies with applicable IS 8112: 2013regulations. Fine Aggregate: Natural sand from rivers. Quarry Dust: Utilized to partially replace fine aggregate that was obtained from a nearby stone crushing facility- Coarse Aggregate: crushed stone aggregate with 10 & 20mm. Admixture: Auramix201, a high-range water-reducing admixture, is used as a super plasticizer to enhance workability. Water: Potable, clean water is utilized for curing and mixing.

2.2 Mix Proportions

Concrete mixes for M25 grade concrete were created. Natural fine aggregate was partially substituted with quarry dust at weight percentages of 0%, 20%, 40%, and 60%. Experimental studies were conducted in the current phase of the study using superplasticizer doses of 0% and 0.6% by weight of cement, while maintaining a constant water–cement ratio of 0.42.

2.3 Specimen Curing and Casting

All the concrete samples were made using the specified mix ratios. The components were precisely weighed and properly combined to create a uniform concrete mixture. After being put into greased moulds, fresh concrete was thoroughly compressed to remove any air spaces. Tests of compressive strength were conducted using cube specimens of 150 × 150 × 150 mm. cylindrical specimens of 150 mm in diameter and 300 mm in height were made for the split tensile strength testing. Bond strength tests were conducted using 150 × 150 × 150 mm cube specimens. Reinforcement was inserted in the center of the cube specimens for this reason. Following the designated curing time, the binding strength was determined.

All specimens were allowed to remain in the moulds for a full day at room temperature following casting. Prior to testing, the specimens were demolded and cured in clean water. For the concrete's compressive strength, split tensile strength, and bond strength to be reliably evaluated, proper curing was done to guarantee sufficient cement hydration and strength development.

2.4 Specimen Testing

Workability Test (Slump Test): The slump test was used to assess how workable fresh concrete was. Three layers of freshly mixed concrete were poured into the slump cone, with each layer being evenly crushed. The concrete's height decrease was measured as the slump value (in millimetres) when the cone was raised vertically. To investigate the impact of superplasticizer and quarry dust on workability, this test was conducted for every combination.

Compressive Strength Test: Cube specimens were subjected to compressive strength tests utilizing a compression testing apparatus. The load was evenly distributed until it failed. The following equation was used to compute the compressive strength: **($f_c = P/A$)** where, fc = Concrete's compressive strength (MPa), P = Highest applied load (N), A = Cube cross-sectional area (mm^2). For each concrete mix proportion, cube and cylindrical specimens were tested.

Table -1: Mix Proportions

S. No.	Quarry Dust %	W/C	Adm.	Adm. Dosage
C1	0%	0.42	NO	0
C2	0%	0.42	YES	0.6
C3	20%	0.42	NO	0
C4	20%	0.42	YES	0.6
C5	40%	0.42	NO	0
C6	40%	0.42	YES	0.6
C7	60%	0.42	NO	0
C8	60%	0.42	YES	0.6

3. RESULTS & DISCUSSION

3.1 Workability (Slump Test)

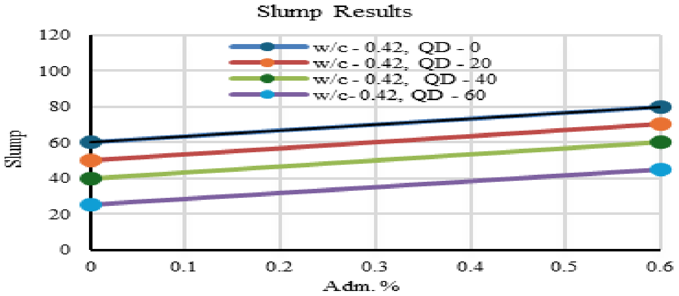
The slump test results for concrete mixes with varying percentages of quarry dust at a constant water–cement ratio of 0.42 are shown in Table 2. As quarry dust replacement rose from 0% to 60%, the slump value for mixes without admixture dropped from 60 mm to 25 mm, suggesting a notable decline in workability. The primary cause of this decline is quarry dust's smaller particle size and larger surface area, which raises water requirements and decreases fresh concrete's flowability. Higher slump values for all quarry dust replacement levels were achieved with 0.6% superplasticizer. An increase in slump from 80 mm at 0% quarry dust to 45 mm at 60% quarry dust demonstrated how much the admixture enhanced workability. Superplasticizer helped keep the concrete workable without raising the water-to-cement ratio, even though the slump still reduced with increased quarry dust concentration.

Overall, the findings show that when quarry dust content rises, workability decreases; however, the addition of superplasticizer considerably makes up for this loss and enhances the workability of quarry dust concrete.

Table -2: Slump Test Result

S.N.	Quarry Dust	w/c	Ad-0%	Ad.-0.6%
1	0	0.42	60	80
2	20	0.42	50	70
3	40	0.42	40	60
4	60	42	25	45

Chart -1: Slump Variation of slump with quarry dust content at w/c = 0.42



3.2 Cube Compressive Strength Test

The compressive strength findings of M25 concrete mixes with varying percentages of quarry dust, both with and without superplasticizer, at a constant water–cement ratio of 0.42 are shown in Table 3. Compressive strength data for both early and later ages are included in the results. The average compressive strength for mixes without admixture doses from 26.31 N/mm^2 for the control mix (0% quarry dust) to 28.47 N/mm^2 at 20% replacement and then to 30.46 N/mm^2 at 40% replacement. The filler effect of quarry dust, which strengthens the connection between cement paste and aggregates and increases particle packing density, is responsible for this strength gain. However, the average compressive strength dropped to 24.40 N/mm^2 with 60% replacement of quarry dust. This might be because larger quarry dust content results in less workability and inappropriate compaction. Higher compressive strength values were noted for all mixtures when 0.6% superplasticizer was applied. An average strength of 27.13 N/mm^2 was attained by the control mix, which rose to 29.36 N/mm^2 at 20% quarry dust and a maximum of 32.09 N/mm^2 at 40% replacement. The compressive strength (25.17 N/mm2) was marginally greater than that of the similar mix without admixture, even after 60% replacement of quarry dust. Superplasticizer increased workability and guaranteed higher compaction, which led to increased strength.

According to the compressive strength data, the ideal percentage of quarry dust replacement for M25 concrete is 40%. By making up for the loss of workability brought on by a greater quarry dust content, the use of superplas5ticizer further increases compressive strength.

Table -3: Compressive Strength Result

S. No.	Description			Cube wt. (gms)	Density (gm/cc)	Load (KN)	7 Days Comp res-sive strength (N/mm2)	7 Days Avg. Comp res-sive Strength N/mm²	Cube wt (gms)	Density (gm/cc)	Load (KN)	28 Days Comp res-sive strength (N/mm2)	28 Days Avg. Comp res-sive Strength N/mm²
	Quarry Dust %	Admixture	W/C										

1	0	0	0.42	8218	2.43	606	26.93	26.31	8166	2.42	772	34.31	33.99
				8250	2.44	593	26.36		8185	2.43	763	33.91	
				8064	2.39	577	25.64		8011	2.37	759	33.73	
2	0	0.6	0.42	8218	2.43	617	27.42	27.13	8196	2.43	778	34.58	34.83
				8205	2.43	600	26.67		8096	2.4	801	35.6	
				8073	2.39	614	27.29		8005	2.37	772	34.31	
3	20	0	0.42	7982	2.37	656	29.16	28.47	7901	2.34	798	35.47	36.4
				8179	2.42	623	27.69		8097	2.4	828	36.8	
				8367	2.48	643	28.58		8295	2.46	831	36.93	
4	20	0.6	0.42	8298	2.46	672	29.87	29.36	8179	2.42	841	37.38	37.05
				8315	2.46	665	29.56		8241	2.44	838	37.24	
				8013	2.37	645	28.67		7096	2.1	822	36.53	
5	40	0	0.42	8085	2.4	699	31.07	30.46	8004	2.37	862	38.31	39.01
				8391	2.49	679	30.18		8292	2.46	888	39.47	
				8185	2.43	678	30.13		8100	2.4	883	39.24	
6	40	0.6	0.42	8299	2.46	724	32.18	32.09	8142	2.41	929	41.29	40.59
				8390	2.49	726	32.27		8284	2.45	911	40.49	
				8096	2.4	716	31.82		8007	2.37	900	40	
7	60	0	0.42	8279	2.45	567	25.2	24.4	8165	2.42	727	32.31	31.78
				8365	2.48	545	24.22		8245	2.44	701	31.16	
				8255	2.45	535	23.78		8196	2.43	717	31.87	
8	60	0.6	0.42	8250	2.44	567	25.2	25.17	8152	2.42	719	31.96	31.99
				8232	2.44	578	25.69		8167	2.42	742	32.98	
				8398	2.49	554	24.62		8297	2.46	698	31.02	

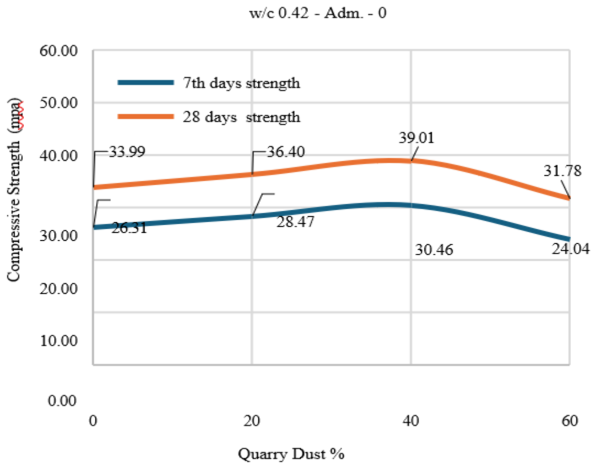


Chart -2: Effect of quarry dust on compressive strength 0-Adm. (7&28 days)

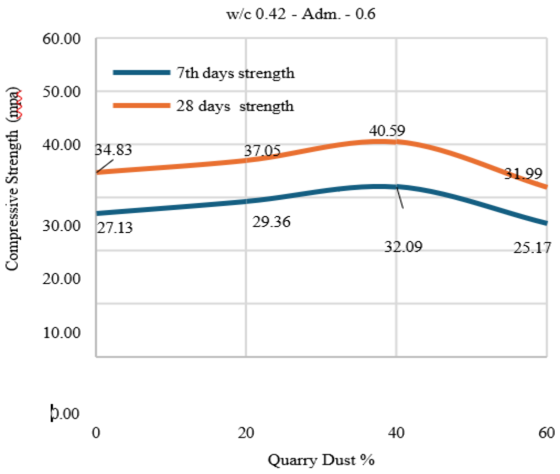


Chart -3: Effect of quarry dust on compressive strength 0.6-Adm. (7&28 days)

3.3 Split Tensile Test

The split tensile strength findings of concrete mixes with varying percentages of quarry dust as a partial substitute for fine aggregate, both with and without superplasticizer, at a constant water-to-cement ratio of 0.42 are displayed in Table 4. The outcomes of the 7-day and 28-day tests were examined.

Up to 40% more quarry dust was added to mixtures without mixing, increasing the split tensile strength. With 20% replacement, the 28-day split tensile strength rose from 2.9 MPa for the control mix (0% quarry dust) to 3.2 MPa, and at 40% quarry dust, it peaked at 3.6 MPa. The increased particle packing and enhanced interfacial binding between cement paste and aggregates made possible by quarry dust are primarily responsible for this improvement. However, the strength dropped to 3.1

MPa with 60% replacement of quarry dust. This might be because of too poor compaction and lower workability at higher quarry dust contents. All mixtures exhibited increased split tensile strength values upon the addition of 0.6% superplasticizer. The 28-day strength of the control mix was 3.0 MPa, rising to 3.4 MPa at 20% quarry dust and reaching a maximum of 3.7 MPa at 40% replacement. Even with 60% quarry dust replacement, the split tensile strength (3.2 MPa) was marginally greater than that of the admixture-free equivalent mix. Better workability and better compaction were provided by the superplasticizer, which increased tensile performance.

Table -4: Split Tensile Strength 7 & 28 Days

Sr. No.	Description			7-Day Load (kN)	7-Day Load (kN)	28-Day Load (kN)	28-Day Strength (MPa)
	Quarry Dust %	Adm.	W/C				
1	0	0	0.42	155	2.2	205	2.9
2	0	0.6	0.42	163	2.3	212	3
3	20	0	0.42	177	2.5	226	3.2
4	20	0.6	0.42	184	2.6	240	3.4
5	40	0	0.42	198	2.8	254	3.6
6	40	0.6	0.42	205	2.9	262	3.7
7	60	0	0.42	170	2.4	219	3.1
8	60	0.6	0.42	177	2.5	226	3.2

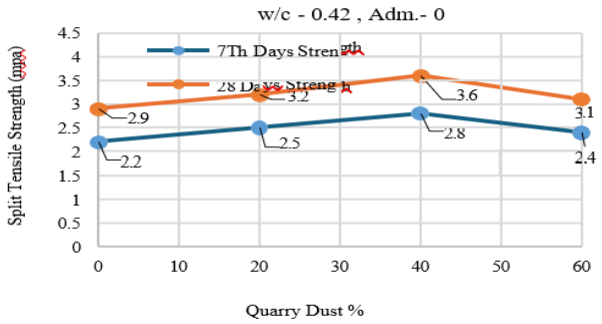


Chart -4: Effect of Quarry Duston Split Tensile Strength 0% Adm.7 & 28 Days

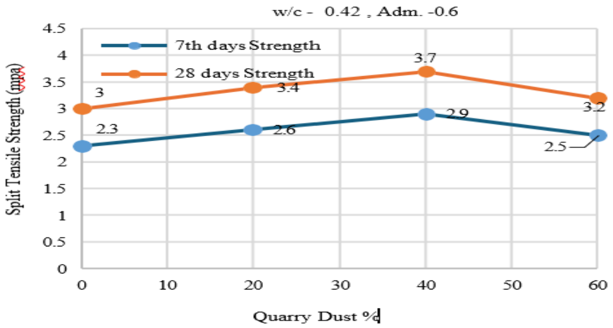


Chart -5: Effect of quarry dust on split Tensile 0.6%-Adm. (7 & 28 days)

3.4 Bond Strength Test

The binding behavior between the surrounding concrete and the reinforcing steel bars is assessed using a bond strength test. For composite action, efficient stress transmission, and overall structural performance of reinforced concrete elements, a proper steel-to-concrete connection is necessary. When evaluating bond strength, one of the most used techniques is the pull-out test. This test involves centrally embedding a steel reinforcing bar with a predetermined diameter in a concrete specimen with a defined embedment length. The specimen is put in a testing machine once it has been cured for the necessary amount of time. There, it is held securely while a tensile force is supplied to the steel bar's projecting end. The load is progressively raised until the bar pulls out of the concrete or bond failure takes place. The strength of the concrete, the surface properties of the reinforcing bar, the length of the embedment, the quality of compaction, the curing conditions, and the kind of materials used in the concrete mix are some of the variables that affect the bond strength. By increasing the interfacial transition zone and particle packing between steel and concrete, the presence of fine particulates such as quarry dust may affect bond behavior. Like this, adding chemical admixtures can improve workability and improve compaction around the reinforcing bar.

Bond strength test findings determine whether modified concrete mixes are suitable for reinforced concrete applications and offer valuable information regarding the interaction between steel and concrete. This test is very helpful to make sure that bond performance is not negatively impacted when alternative materials are utilized in concrete.

4. CONCLUSIONS

a) The fresh and hardened qualities of concrete are greatly impacted when natural sand is partially substituted with quarry dust. Concrete's workability gradually declines as the ratio of quarry dust replacement increases, according to the findings.
b) The workability of concrete mixes including quarry dust is improved by adding superplasticizer, even at greater replacement levels, according to slump test findings, without raising the water–cement ratio.
c) The present study's results on compressive strength indicate that strength increases with moderate replacement levels of quarry dust, whereas strength decreases with greater replacement percentages.
d) Quarry dust affects the compressive and tensile behavior of concrete, as seen by the pattern that split tensile strength follows in tandem with compressive strength.
e) The study's findings are predicated on a small number of mix combinations with a set super-plasticizer dose and a consistent water–cement ratio. The combined effects of varying water-to-cement ratios and greater superplasticizer doses need to be further investigated.
f) The current study's results offer initial under-standing of the behavior of quarry dust concrete and form the foundation for more in-depth experimental investigations that will be conducted in the study's final stage.

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