Industrial Engineering Journal
ISSN: 0970-2555
Volume : 52, Issue 8, No. 4, August : 2023

ENHANCE THE STRENGTH OF CONCRETE USING QUARRY DUST AND FLY ASH

Deshmukh Parag Chandrakant P. G. Student, Department of Civil Engineering, SKN Sinhgad College of Engineering, Korti, Pandharpur- 413304. Maharashtra : deshmukhparagc@gmail.com
C. M. Deshmukh[b], Y. P. Pawar[c] Assistant Professor in Civil Engineering Department, SKN Sinhgad College of Engineering, Korti, Pandharpur- 413304. Maharashtra, India.

Abstract

With developing countries experiencing a peak in infrastructural growth, there is a significant surge in the demand for concrete to meet these infrastructural needs. Concrete holds a pivotal role in the construction industry. However, a challenge arises as river sand, a crucial component in concrete production, becomes both expensive and scarce. This scarcity is a result of diminishing natural sand sources and the drive to reduce concrete production costs. This has led to a growing necessity to explore alternative materials to replace sand as fine aggregates in concrete production. In this context, Quarry rock dust emerges as a viable economical substitute for river sand. Additionally, Fly Ash, a byproduct, can serve as a filler material, effectively reducing the total void content in concrete. Any reduction in early strength caused by the inclusion of fly ash is counterbalanced by the addition of quarry dust. The current study delves into the outcomes of an experimental investigation involving the incorporation of Quarry rock dust and fly ash into cement concrete. This study scrutinizes the impact of varying proportions of quarry dust and fly ash in cement concrete on parameters like compressive strength, split tensile strength, and flexural strength. The experimental tests adhered to the procedures outlined in the Indian standard code. The comprehensive effects of different percentages of Quarry dust and fly ash in cement concrete are meticulously examined. The results of each experimental variation are organized in tabular form and thoroughly analyzed. The study yields significant insights, leading to noteworthy conclusions about the performance of these alternative materials in concrete production.
Keywords: Fly Ash, Quarry dust, Flexural strength, Split tensile strength.

1. Introduction

The fundamental constituents of traditional concrete comprise cement, sand, and aggregate. The qualities of the aggregate exert a notable influence on concrete's longevity and performance, thus underscoring the significance of fine aggregates [1-2]. Among these, riverbank-derived sand ranks as the most widely utilized fine aggregate. However, the cost-intensive transportation from natural sources renders common river sand financially burdensome [3-4]. Furthermore, the extensive depletion of these sources poses environmental challenges. Given the unattractive feasibility of river sand due to environmental and logistical constraints, it becomes imperative to discover an alternative or substitute for the concrete industry. A promising route toward this goal involves embracing eco-friendly practices, particularly in the creation of construction materials. This entails repurposing waste generated by manufacturing industries, capitalizing on its considerable resource potential and energy recovery capacity. The term 'green' in this context denotes the utilization of sustainable materials like stone dust or recycled stone, as well as reused, renewable, and/or recyclable products, all of which are non-toxic in nature. In recent years, substantial progress has been made in repurposing various industrial byproducts such as fly ash, silica fume, rice husk ash, and foundry waste to mitigate environmental pollution. Additionally, considerable attention has been directed toward identifying an alternative source for replacing natural aggregates in concrete. Consequently, extensive research has been conducted to assess the suitability of quarry dust in traditional concrete [5-8].

Quarry dust, a waste material originating from the stone crushing industry, presents an abundant supply of approximately 200 million tons per annum. Despite its abundance, it poses challenges related to landfill disposal and implications for health and the environment [9]. The detrimental effects of river sand mining on riverbeds, the escalating expense of manufactured sand, and the convenient accessibility of quarry dust at a lower cost stand as key motivations propelling such initiatives. The research aims to assess the appropriateness of incorporating quarry dust into concrete and to develop ideal concrete blends. Various specimens including cubes, cylinders, and beams will be fabricated, each comprising different combinations of quarry dust and sand. Through systematic experimentation, the blend composition that yields the highest levels of compressive and tensile strength will be identified and adopted as the optimal mixture ratio [10-11].

In order to harness the benefits presented by quarry dust while mitigating the environmental impact of sand mining from river beds, and to establish a foundational framework applicable to various concrete types, the following objectives are pursued:

Determine the optimal proportion of Quarry Dust that can viably replace or substitute sand in concrete compositions. Determine the optimal proportion of Quarry Dust and Fly Ash that can effectively replace or substitute both sand and cement in concrete formulations. Investigate the influence of varying proportions of quarry dust and the synergistic blend of quarry dust and fly ash on the compressive, tensile, and flexural strength characteristics of concrete.

Furthermore, this research endeavors to utilize waste materials like quarry dust and fly ash to contribute towards environmental preservation by reducing pollution.

II. Materials

The Quarry Rock Dust obtained from local resource Jagdamba Crushers (P) Ltd., L, Korti Karad road, Pandharpur, Maharashtra, India, is used in concrete to cast test cubes and beams and cylinder**.** The physical properties of quarry dust were summarized in table 1.

Table 1. Physical properties of quarry dust

Sr. No	Property	Results
1.	Particle Shape, Size	4.75mm passing
2.	Fineness Modulus	4.12
3.	Silt content	2%
4.	Specific Gravity	2.97
5.	Bulk density	1893 Kg/m^3
6.	Surface moisture	Nil

The coarse aggregate's nominal maximum size should be as substantial as practical within the prescribed boundaries, yet never exceeding one-fourth of the minimum thickness of the structural element. This criterion stands, given that the concrete's placement remains unproblematic and ensures complete coverage of all reinforcement elements, effectively filling the form's corners. The aggregates utilized were sourced from crushed black trap basalt rock, conforming to IS 383-1970 specifications, with a size ranging from 20mm down to 10mm, ensuring compliance with established standards. Super plasticizer stands as a prominent type of admixture in concrete formulations [13-14]. The fundamental requirement for excellent workability serves as the cornerstone of high-quality concrete. Attaining the necessary workability levels is achievable through the utilization of plasticizers and super plasticizers [15-17]. These additives play a vital role in addressing challenging scenarios where enhanced workability is sought. It's important to note that introducing excessive water only improves fluidity or consistency, not actual workability. Super plasticizers represent a relatively recent advancement and an enhanced iteration of traditional plasticizers. Originating respectively in Japan and Germany during the 1960s and 1970s, they belong to a distinct chemical category. Unlike regular plasticizers, super plasticizers offer a unique benefit – they allow for a significant reduction in water content, potentially up to 30 percent, without compromising workability. In contrast, traditional plasticizers generally permit a reduction of only up to 15 percent while maintaining workability.

Methodology

This research project encompassed an evaluation of both the early-stage characteristics of fresh concrete and the attributes of matured concrete. The assessment included tests such as compressive, tensile, and flexural strength tests. The entire suite of tests was performed across various sample groups, as follows:

1. Conventional cement concrete.
2. Concrete samples with a substitution of quarry dust at varying rates: 15%, 35%, 55%, and 75% of the sand content.
3. Concrete with a dual substitution: 5% fly ash by the mass of cement and 15% quarry dust by the mass of sand.
4. Concrete with a dual substitution: 10% fly ash by the mass of cement and 35% quarry dust by the mass of sand.
5. Concrete with a dual substitution: 15% fly ash by the mass of cement and 55% quarry dust by the mass of sand.
6. Concrete with a dual substitution: 20% fly ash by the mass of cement and 75% quarry dust by the mass of sand.

Concrete Mix Design

The concrete mix design adheres to the guidelines outlined in the IS (Indian Standard) design method, involving a series of trial mixes to arrive at the most optimal formulation. Once the optimal mixture is ascertained, it serves as the basis for fabricating concrete samples that encompass varying levels of sand replacement by quarry dust: 0%, 15%, 35%, 55%, and 75% in cement concrete. This array of concrete specimens is prepared and subsequently subjected to assessments for compressive and tensile strength. The methodology for determining the quantity of ingredient materials and establishing mix proportions according to the design follows this sequence:

Mix design for grade M-40

Initial Parameters:

1) Cement Grade- O.P.C.53, Ultra-tech Cement, and Concrete Grade-M_{40}.
2) Specific Gravity of Cement- 3.15
3) Fine Aggregates- Sand-Zone-I
4) Specific Gravity of F.A- 2.67
5) Coarse Aggregates- 20 mm
6) Specific Gravity of C.A- 3.39

Mix Design calculations:

1.Target Mean strength – (F_{ck}).

$$F_{ck} = f_{ck} + K.S$$

Where,f_{ck} = Characteristics Compressive Strength at 28 days

K = Statistical value for risk factor

Industrial Engineering Journal
ISSN: 0970-2555
Volume : 52, Issue 8, No. 4, August : 2023
S = Standard Deviation
F_{ck}= 40 + (1.65 × 5) = 48.25 N/mm^2
2. Selection of Water-Cement ratio:
So, Assumed W/C = 0.4 (As per IS 456 – 2000)
W/C As per IS 20262 we have 0.38 from graph.
Therefore, Considering W/C =0.4
3. Selection of Water & Sand content: W/C = 0.4
Taking Cement up to 400 kg/m^3
As per IS 456 for M_{40} grade minimum cement content is 360 kg/m^3
Therefore, as Weight of Cement taken are 400 kg/m^3
Weight of water = 0.4 × 400 = 160 kg water.
Assumed 1kg = 1 liter, Hence Water requirement is 186 liters for M40
Now for M40 as per IS Maximum cement content is 180 kg which is greater than calculated hence ok.
4. Calculation of C.A & F.A
$V = [(W + C/S_C) + (1/P \times F.A/S_{F.A})] \times 1/1000$
and
$V = \{(W + C/S_C) + [1/(1-P) \times C.A/S_{C.A}]\} \times 1/1000$
Now as per IS – 20262, 2% is considered as air entrapment
V = 1- 0.2 = 0.98
For 100mm slum water requirement:
= 186 + {(6/100) X 186} = 197 liters
Calculation of cement content: As water cement ratio is 0.4
Cement content = 197 / 0.4 = 492.5 kg
The volume of coarse aggregate: = 0.6 m^3
Volume of fine aggregate: = 1- .62 = 0.38 m^3

a) Volume of concrete = 1m^3
b) Volume of cement = {(mass of cement) / (specific gravity of cement)} X (1/1000) = (492.5/3.15) X (1/1000)
= 0.156 m^3
c) Volume of solution/water = {Mass of solution / sp. Gravity of solution} X(1/1000)
= (197X1000)/ 1 = 0.197 m^3
d) Volume all in aggregate = {a- (b+c)} = {1-(0.156+0.197)} = 0.647 m^3
e) Mass of coarse aggregate(20mm) = 0.647 X 0.62 X 0.6X3.39 X1000= 815.92 kg/ m^3
e) Mass of coarse aggregate(12.5mm) = 0.647 X 0.62 X 0.4 X 2.84 X 455.69 X1000
= 455.69 kg/ m^3
f) Mass fine aggregate = 0.647 X 0.38 X 2.64 X 1000
= 656.44 kg/ m^3

The Mix proportion becomes:

Water:	Cement:	Fine aggregate:	Coarse aggregate
0.40:	492.5:	656.44:	1271.61
0.40:	1:	1.33:	2.59

Results and Discussion

The outcomes of incorporating a blend of fly ash and quarry dust as partial replacements in concrete are deliberated in relation to the results observed in standard concrete. For the composite concrete mixtures, a set of three cubes were cast for different curing durations: 3, 7, and 28 days. Additionally, three cylinders were cast for a curing duration of 28 days, while three beams were cast and cured for the same period. The evaluation of these specimens was conducted utilizing a compressive testing machine with a capacity of 2000KN. 15 days compressive strength of the cubes casted for various % replacement of sand by quarry dust. Table 2 illustrate the compressive strength of concrete after 3 days.

Table 2. 3 Days compressive strength of the cubes casted for various % replacement of sand by quarry dust.

Replacement of sand by Q.D. (%)	Compressive Strength of 3 days (MPa)	Replacement of sand and cement by Q. D and FA (%)	Compressive Strength of 3 days (MPa
0%	22.96	0%	22.96
15%	24.16	15% QD 5% FA	21.00
35%	25.15	35% QD 10% FA	20.14
55%	22.66	55% QD 15% FA	19.63
75%	22.07	75% QD 20% FA	18.54

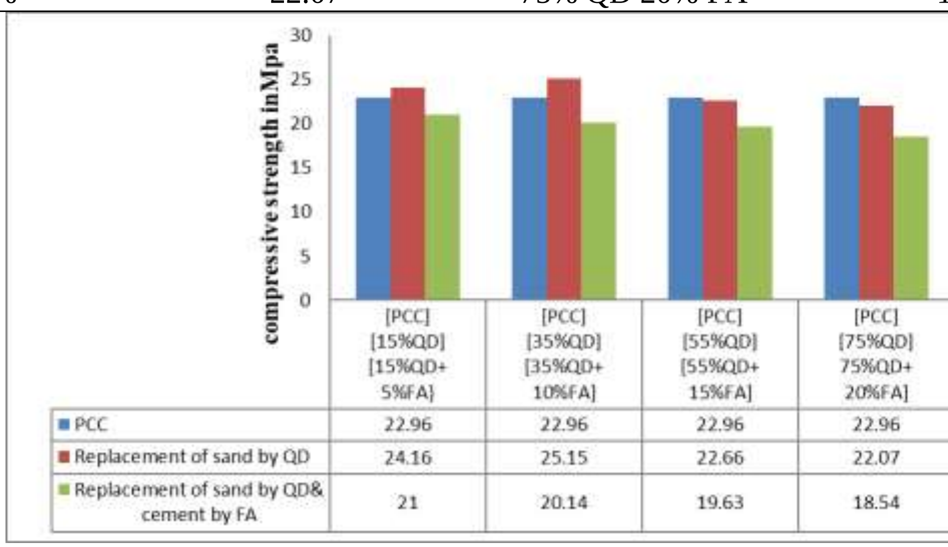

Fig.1. 3 Days compressive strength of the cubes casted for various % replacement of sand by quarry dust.

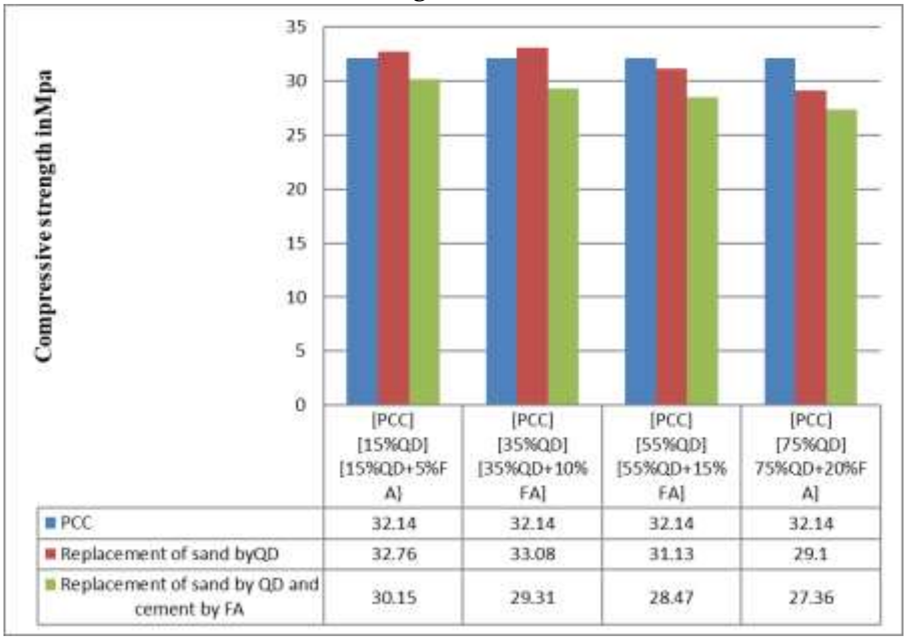

Fig 3. 7 days compressive strength of the cubes casted for various % replacement of sand by quarry dust.

28 days compressive strength of the cubes casted for various % replacement of sand by quarry dust.

Sr. No.	Replacement of sand by Q.D. (%)	Compressive Strength of 28 days (MPa)
1	0%	41.17
2	15%	42.22
3	35%	41.09
4	55%	38.23
5	75%	36.75

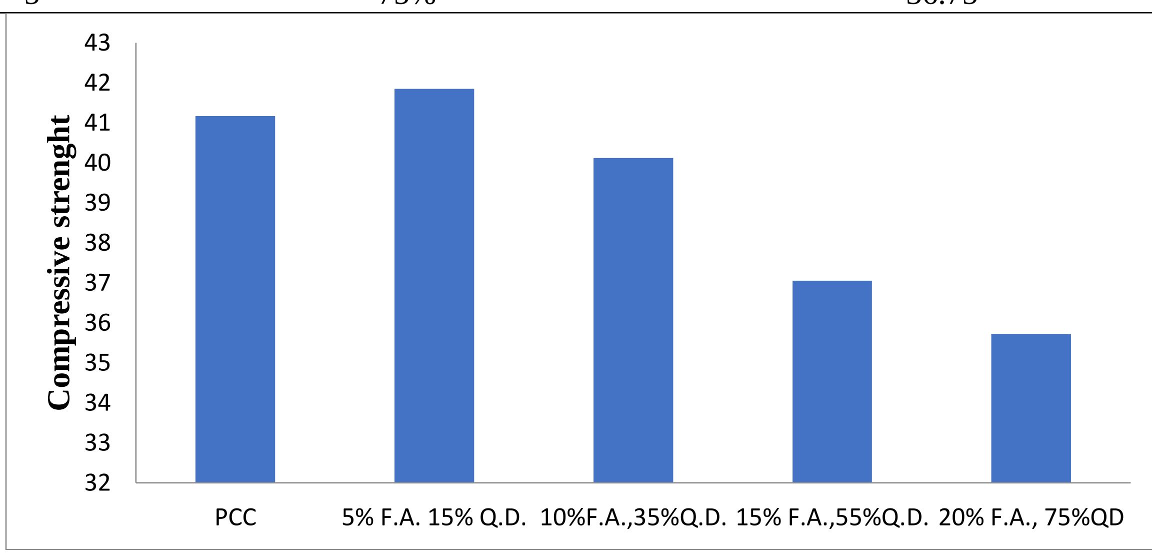

Fig 4. Comparison of 28 days compressive strength of replacement of cement and sand by fly ash and quarry dust in various %

The split tensile strength behavior of plain concrete (P.C.C.) with the addition of fly ash and quarry dust can be an interesting study in the field of concrete technology. Both fly ash and quarry dust are commonly used as supplementary cementitious materials and fine aggregates, respectively, in concrete mixtures to improve certain properties of concrete. The split tensile strength is an important mechanical property that can be affected by the inclusion of these materials. Here is how the split tensile strength behavior might behave when varying the percentages of fly ash and quarry dust in P.C.C.:

Effect of Fly Ash:

Fly ash is a byproduct of coal combustion and is often used as a partial replacement for cement in concrete. It generally enhances the workability and durability of concrete. When used in P.C.C., fly ash reacts with calcium hydroxide produced during cement hydration, leading to additional hydration products. This can improve the microstructure of the concrete and fill in pore spaces, making the concrete denser and less permeable.

As the percentage of fly ash increases in the concrete mix, the following effects on split tensile strength can be observed: Initially, there might be a slight reduction in split tensile strength due to the dilution effect of fly ash. As the fly ash content increases, the split tensile strength might start to improve due to the pozzolanic reaction and densification of the microstructure. However, at very high percentages of fly ash, the strength might start to decrease again due to the reduced cementitious content and potential loss of bonding between particles.

Effect of Quarry Dust:

Quarry dust is a byproduct of the crushing process during quarrying operations and is often used as a replacement for fine aggregates (sand) in concrete. It is generally considered to have angular and rough particles, which can improve the interlocking between particles and contribute to higher strength. As the percentage of quarry dust increases in the concrete mix, the following effects on split tensile strength can be observed: The split tensile strength might initially increase due to the improved particle packing and interlocking caused by the angular nature of the quarry dust particles. With further increase in quarry dust content, there might be a peak in split tensile strength as the particle interlocking and mechanical properties of the mix are optimized. However, if the quarry dust content becomes too high, there might be a decrease in strength due to the excessive fines content and potential weakening of the cementitious matrix.

Combined Effect:

The split tensile strength behavior of P.C.C. with varying percentages of both fly ash and quarry dust will depend on the interplay between the effects of these materials on the microstructure and mechanical properties of the concrete. It's important to note that the behavior described above is a general trend and can vary based on the specific properties of the fly ash, quarry dust, cement, and other materials used in the concrete mix. Actual results would depend on factors such as the quality of materials, mix design, curing conditions, and testing methods. To study the split tensile strength behavior of P.C.C. against varying percentages of fly ash and quarry dust, laboratory testing would be required. This might involve preparing concrete mixtures with different combinations of these materials, casting test specimens, and conducting split tensile strength tests on them.

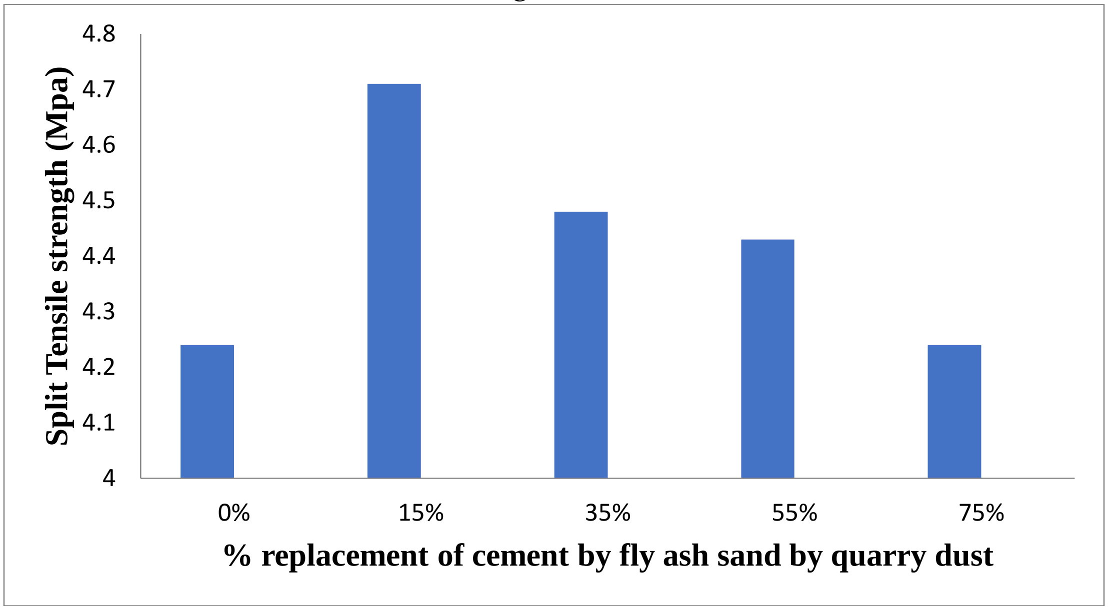

Fig. 5. Replacement of sand by quarry dust for various % for split tensile strength

The flexural strength behavior of conventional concrete (without quarry dust and fly ash) compared to concrete with varying percentages of quarry dust and fly ash can provide insights into how these supplementary materials affect the mechanical properties of concrete. Flexural strength, also known as modulus of rupture, is the ability of a material to withstand bending forces.

Here's how the flexural strength behavior might change when varying the percentages of quarry dust and fly ash in the concrete mix:

Effect of Quarry Dust:

Quarry dust is often used as a partial replacement for fine aggregates (sand) in concrete. Its angular and rough particles can contribute to improved interlocking and mechanical properties of the concrete. In terms of flexural strength: The inclusion of quarry dust in concrete can lead to an increase in flexural strength, especially at moderate replacement levels. This is due to the improved particle packing and interlocking, resulting in enhanced load-carrying capacity.

The angular nature of quarry dust particles can lead to better stress transfer within the matrix, which might result in higher flexural strength values. However, excessive use of quarry dust might cause a decrease in flexural strength due to the excess fines content and potential weakening of the cementitious matrix.

Effect of Fly Ash:

Fly ash is a pozzolanic material that is often used as a partial replacement for cement in concrete. It can contribute to densification of the microstructure and improve durability. In terms of flexural strength: The addition of fly ash can lead to improvements in flexural strength, especially at early ages. This is due to the pozzolanic reaction and the formation of additional cementitious compounds that enhance the mechanical properties. The refined microstructure resulting from the incorporation of fly ash can enhance the bonding between particles and increase the overall strength. At higher replacement levels, the flexural strength might plateau or decrease due to potential dilution effects and reduced cementitious content.

Combined Effect: When both quarry dust and fly ash are used in concrete together, their combined effects on flexural strength will depend on their individual contributions and interactions:

In some cases, the synergistic effect of the improved particle packing from quarry dust and the densification from fly ash can lead to enhanced flexural strength.

However, finding the optimal combination of these materials to achieve the highest flexural strength requires careful mix design and testing.

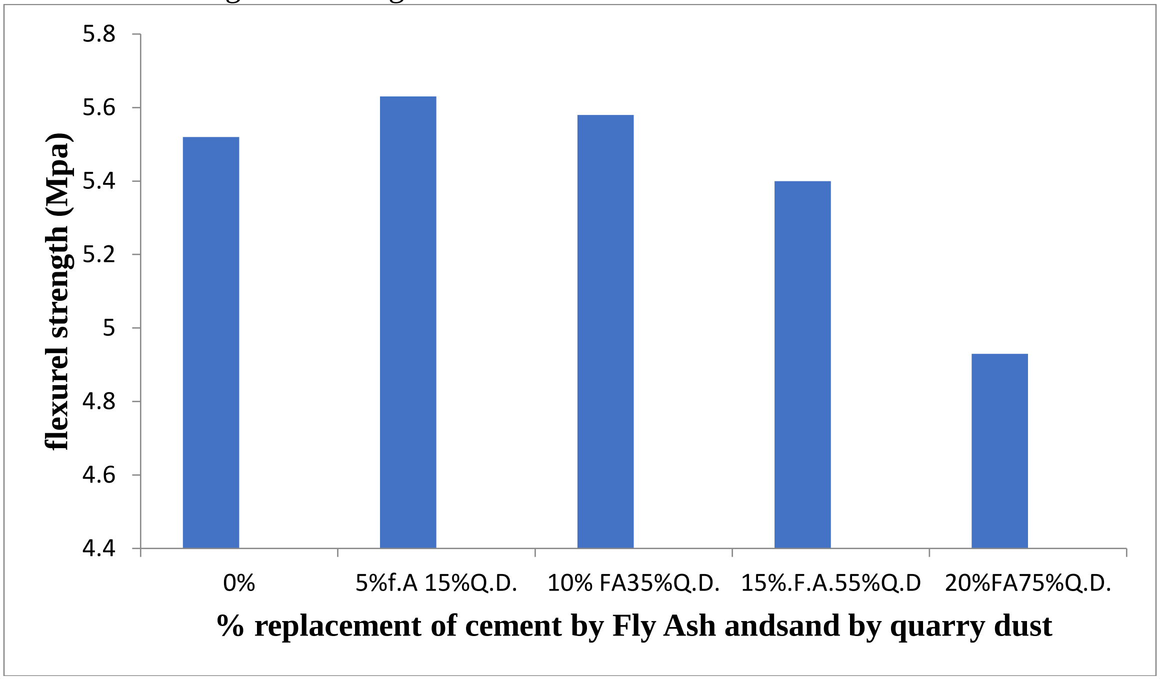

Fig 6. Concrete replacement of sand by quarry dust and cement by fly Ash for various % for flexural strength

Conclusion:

Based on the outcomes observed during the experimental analysis, it can be deduced that due to the limited availability of sand at an affordable price for use as fine aggregate in cement concrete, various factors prompt the exploration of alternative materials. In this context, quarry dust emerges as a viable option to substitute sand, particularly due to its notably low cost. The highest compressive strength value at 28 days is achieved with a 15% replacement of sand by quarry dust, measuring 42.22 Mpa. When using a 35% replacement of sand with quarry dust, the compressive strength reaches 41.09 Mpa, which is very close to the compressive strength of plain cement concrete (PCC) at 41.17 Mpa**.** The combined split tensile strength involving both quarry dust (QD) and fly ash exhibits its highest value at a mixture of 15% QD and 5% fly ash, registering at 4.71 MPa. With an increase in the proportions of QD and fly ash, the strength begins to decrease. However, at the maximum percentages tested, which are 75% QD and 20% fly ash, the strength is noted at 4.24 MPa. This is comparable to the split tensile strength of plain cement concrete (PCC).

The maximum flexural strength achieved at a 15% replacement of quarry dust (QD) is 6.25 MPa. As the percentage of replacement increases, the strength gradually declines; however, it remains higher than the strength of plain cement concrete (PCC), which measures 5.52 MPa. Up to a 35% replacement of sand with quarry dust, the strength remains at 5.65 Mpa.

.

References

1. Chandana Sukesh, Katakam Bala Krishna, P.Sri Lakshmi Sai Teja, S.Kanakambara Rao., "Partial Replacement of Sand with Quarry Dust in Concrete", International Journal of Innovative Technology and Exploring Engineering (IJITEE) ISSN: 2278-3075, Volume-2, Issue-6, May 2013
2. Manguru G.n., Karugu C.K.,Oyawa,W.O., Abuodha S.O. and Mulu P.U.," Partial Replacement

of Natural River Sand with Crushed Rock Sand in Concrete Production", Research, Vol. 1, No. 2, 2012

3. Lohani T. K. Etal, "Optimum utilization of Quarry dust as partial replacement of sand in concrete" Int. Journal of Applied Science and Engineering Research. Vol. 1 No 2, 2012(IJASER) ISSN2277-9442
4. A Krishnamoorthi, and G.Mohankumar, "Properties Of Green concret Mix by Concurrnt Mix of Fly Ash and Quarry Dust", IOSR Journal of Engineering (IOSRJEN) Vol. 3 Issue 8(Augaust. 2013).V3 PP 48- 54
5. Dr P. B. Sakthivel, C.Ramya, M Raj, "An Innovative Method of Replacing River Sand by Quarry Dust Waste in Concrete for sustainability", International Journal of Scientific & Engineering Research Volume 4, Issue 5, May-2013, ISSN 2229-5518
6. R. Ilangovana, N. Mahendrana, and K. Nagamanib , "Strenght and Durability Properties of Concrete Containing Quarry Dust as Fine Aggregate", ARPN Journal of Engineering and Applied Sciences VOL. 3, NO. 5, OCTOBER 2008, ISSN 1819-6608
7. G.Balamurugan, Dr.P.Perumal, "Use of Quarry Dust to Replace Sand in Concrete –An Experimental Study",International Journal of Scientific and Research Publications, Volume 3, Issue 12, December 2013 1 ISSN 2250-3153
8. Anitha selva sofia S.D., Gayathri R., SwathiG.,"Prince arulraj G., ,Experimental INvestigation on Quarry Dust Concrete with Chemical Admixure". International Journal of Latest Research in Science and Technology Volume 2,Issue 2 :Page No.91-94, March - April (2013), ISSN (Online):2278-5299
9. Prof M Devi, prof V. Rajkumar, Dr K. Kanan, "Inhibitive Effect of Organic Inhibitors in Concrete Containing Quarry Dust as Fine Aggregate", International Journal of Advances in Engineering Sciences Vol.2, Issue 1, Jan, 2012
10. Er. Lakhan Nagpal, Arvind Dewangan, Er Sandeep Dhiman, Er. Sumit Kumar, "Evaluation of Strength Characteristics of Conrete Using Crushed Stone Dust as Fine Aggregate", International Journal of Innovative Technology and Exploring Engineering (IJITEE) ISSN: 2278-3075, Volume-2 Issue-6, May 2013
11. Sudhir S.Kapgate And S.R.Satone, "Effect of Quarry Dust as Partial replacement of sand in Concrete" Indian Streams Research Journal Volume 3, Issue. 5, June. 2013 ISSN:-2230-7850
12. A. Sivakumar and Prakash M., "Characteristic studies on the mechanical properties of quarry dust addition in conventional concrete," Journal of Civil Engineering and Construction Technology Vol. 2(10), pp. 218-235, October 2011 ISSN 2141-2634 ©2011 Academic Journals
13. Dr. M Devi, "Significance of Fibres in Enhancing Strength and Corrosion Resistance of Fly Ash Blended Quarry Dust Concrete", International Conference on Biological, Civil and Environmental Engineering (BCEE-2014) March 17-18, 2014 Dubai (UAE)
14. IS 2386: Part 3 : "Methods of Test for Aggregates for Concrete" Part 3, 1963.
15. IS 4031: Part 4: "Methods for physical test for hydraulic cements", Bureau of Indian standards, New Delhi, 1988.
16. IS 516:1959, "Method of Test for Strength of Concrete", Reaffirmed 2004, Bureau of Indian standards, New Delhi.
17. IS: 10262-1982, Recommended Guidelines for concrete mix design, Bureau of Indian Standards (BIS), New Delhi, India.