Conducting studies on concrete with quarry dust & fly ash as partial replacement of aggregate

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Abstract:

The demand for natural sand as a construction material has increased significantly in recent years, leading to its depletion and environmental concerns. This research paper investigates the use of quarry dust and fly ash as partial replacements of sand in concrete. The study aims to determine the effect of varying proportions of quarry dust and fly ash on the mechanical and durability properties of concrete. Experimental investigations were conducted on concrete mixes with replacement levels of 0%, 10%, 20%, and 30% of sand with quarry dust and fly ash. Compressive strength, split tensile strength, and flexural strength were tested at 7, 14, and 28 days. Durability properties such as water absorption and permeability were also studied.

The results showed that the addition of quarry dust and fly ash had a significant effect on the compressive, split tensile, and flexural strengths of the concrete. The compressive strength of concrete increased with the increase in quarry dust and fly ash content up to 20% and then decreased at 30% replacement. Similarly, split tensile and flexural strengths showed a similar trend. The water absorption and permeability of the concrete decreased with the increase in quarry dust and fly ash content.

Keywords: Quarry dust, fly ash, sand replacement, concrete, mechanical properties, durability properties.

DOI: 10.48047/ecb/2023.12.si4.999

1. Introduction:

Concrete is the most widely used construction material in the world due to its versatility, durability, and low cost. The primary constituent of concrete is cement, followed by aggregates such as sand and gravel. The demand for natural sand as a construction material has increased significantly in recent years, leading to its depletion and environmental concerns. The depletion of sand resources has led to the exploration of alternative materials for sand in concrete.Quarry dust and fly ash are waste materials generated from the quarrying and thermal power plant industries, respectively. These materials are abundant and can be used as partial replacements of sand in concrete. Quarry dust is a by-product of stone crushing operations and consists of fine particles that are left over after the extraction of rock from quarries. Fly ash is a by-product of burning coal in thermal power plants and is collected from the flue gas using electrostatic precipitators.

Compared to multitudinous other engineering paraphernalia analogous as brand, rubber,etc., concrete requires lower energy input for its manufacture. Currently, a large number of material amalgamations, which are desolate products of other industriousness, are being beneficially used in making quality concrete. Thus, from the consideration of energy and resource conservation and sustainability and terrain, concrete is the most favoured material.

As per the present script, the chance operation of crushed sand from limestone chases in construction is continuously adding. This modification is done in order to neutralise essential difficulties in sluice sand. Chase dust is a fine material attained as a by- product from crushing process during quarrying exertion at chase point. In the growing request, the rate of sluice sand has touched the sky and in addition to that the vacuum of sluice sand has also dropped. So, in order to overcome the problem, there is a need of an volition from surroundings analogous as Artificial waste. In this study, chase dust will be studied as a relief material of sluice- sand as a fine aggregate for concrete. Chase dust has been in use for various exertions in the construction of sedulity analogous as for road construction and manufacture of structure paraphernalia analogous as feathery aggregates, bricks, ducts and autoclave blocks. These granite fines are constantly pertained as chase or rock dust, a by- product in the manufacture of concrete aggregates during the crushing procedure of jewels. This residue generally represents lower than 1 of aggregate products. In normal concrete, the prolusion of chase dust to mixes is limited due to its high fineness. The addition of dust to fresh concrete would raise the water demand and accordingly the cement content for specified malleability and strength conditions. Thus, the successful operation of chasing dust in concrete could turn this waste material into a precious resource. Another implicit benefit in the operation of chase dust is the cost saving. Obviously, the material costs vary depending on the root. In this respect, the operation of chase dust could play a part in lowering the force cost of concrete. bedevilled sand is extremely generous in limestone chases and its use could appreciably drop the paraphernalia cost of concrete, annihilate the dust disposal cost, reduces environmental desecrations and decay of natural resources

- **Components of concrete**

Hardened concrete can be considered to have three distinct phases (a) the hardened eemen psate (HCP) nr murix, b) the aggregate, and (c) the interfacial or transition zone (12) between tie HCP and the aggregate. For optimum performance, all the three phutNes should he cusinkered explicitly. The above mentioned three phases can all have sub-riuses The HCP is about 3040% of the volume of concrete. It is a result of Portland cement and water. The quantity of water is about 7-15% and cement about 14-

21% of the vołumc. Their elusive Quantities. the strength; bence the strength is controlled by the water/cement ratio.

The aggregates constitute 60-70% of ie. value and comprise hoth. fine and coarse aggregates. The aggregates nre inert fillers. "Concrete also contains air ,Which is a part of the Pashto phrase. comes from two sources Neary 2% af the volume of concrete is equipped alr, out of which about 1-2 is sömietines Deliberately introduced as entrained air using un air-entraining admixture. The entrained air is concrete and makes it resist freeze-jlaw eyes better, making it durable. However, it eetainiy enuses it torlucticn in stnength and density.

Materials Used :

Fly Ash

Quarry Dust

TABLe 1: Physical properties of fly ash.

Sl. number	Physical properties	Observed values
1	Specific gravity	2.51
2	Initial setting time	45 Min
3	Final setting time	280 Min
4	Consistency	35%

TABLe 2 : Chemical properties of fly ash.

Sl. number	Test conducted	Observed values (%)	Requirement as per IS: 1320-1981
1	Loss of ignition	2.32	5.0 (max)
2	Silica as SiO_2	42.04	$SiO_2 + Fe_2O_3 + Al_2O_3 = 70$
3	Iron as Fe_2O_3	4.40	—
4	Alumina as Al_2O_3	33.60	—
5	Calcium as CaO	12.73	—
6	Magnesium as MgO	0.00	5.0 (max)
7	Sulphate as SO_3	0.40	3.0 (max)
8	Lime reactivity	4 N/mm^2	4.5 (max)

TABLe 3: Physical properties of quarry dust and natural sand.

Property	Quarry dust	Natural sand	Test method
Specific gravity	2.54	2.67	IS 2386 (Part III) 1963
Bulk relative density (kg/m^3)	1800	1770	IS 2386 (Part III) 1963
Absorption (%)	1.4	1.2	IS 2386 (Part III) 1963
Moisture content (%)	Nil	Nil	IS 2386 (Part III) 1963

TABLe 4: Sieve analysis of quarry dust.

IS sieve designation	Weight retained (kg)	Percentage of weight retained	Cumulative percentage of weight retained	Percentage of fineness by weight
4.75 mm	0.40	0.040	4.00	96
2.36 mm	0.025	0.065	6.50	93.50
1.18 mm	0.117	0.182	18.20	81.80
600 micron	0.152	0.334	33.40	66.60
300 micron	0.443	0.777	77.70	22.30
150 micron	0.170	0.947	94.70	5.30

Literatures review

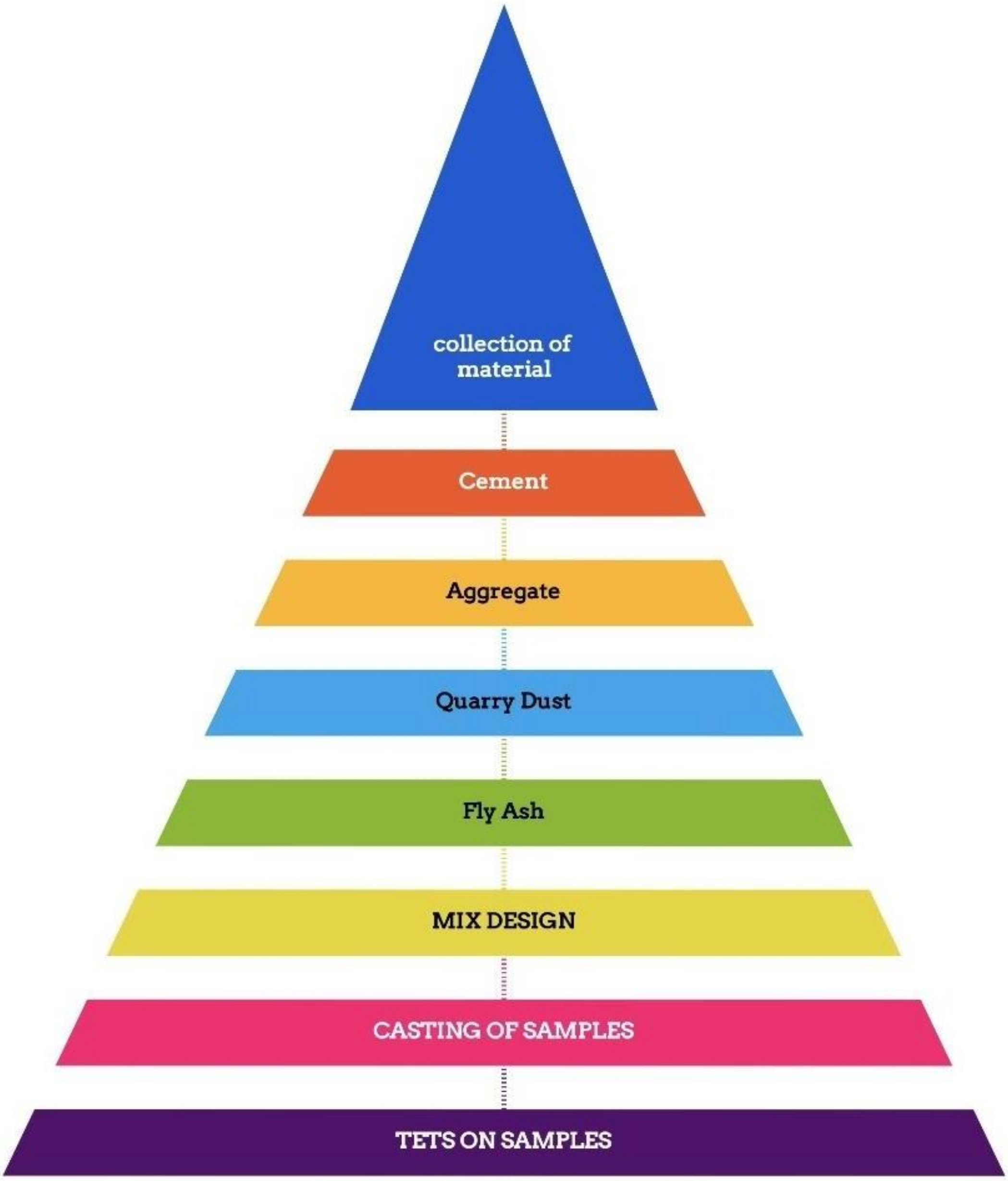
- The use of quarry dust and fly ash as partial replacements of sand in concrete has been studied by many researchers over the years. In a study conducted by Kumar et al. (2018), the compressive strength, split tensile strength, and flexural strength of concrete were investigated with partial replacement of cement with quarry dust and fly ash. The results showed that the optimum replacement levels of quarry dust and fly ash were 20% and 10%, respectively.

- Muthukumar and Manoharan (2017) investigated the effect of fly ash and quarry dust on the properties of concrete. The study showed that the addition of quarry dust and fly ash improved the compressive strength and split tensile strength of concrete, with the optimum replacement levels of 25% and 20%, respectively.

- In another study by Naganathan and Uthayakumar (2018), the strength properties of concrete were investigated with partial replacement of fine aggregate using quarry dust and fly ash. The results showed that the addition of quarry dust and fly ash improved the compressive strength, split tensile strength, and flexural strength of concrete, with the optimum replacement levels of 20% and 10%, respectively.

The literature suggests that the use of quarry dust and fly ash in concrete can improve the mechanical and durability properties of concrete, as well as reduce the environmental impact and cost of construction. However, the optimum replacement levels of these materials may vary based on the specific source and characteristics of the materials, as well as the mix design and curing conditions used. Further research is needed to investigate the long-term durability and performance of concrete made with quarry dust and fly ash, as well as to explore the use of these materials in other applications such as geotechnical engineering and pavement construction.

3 **Experimental Methodology:**



The experimental program involved the casting of concrete cubes, cylinders, and beams with varying proportions of quarry dust and fly ash as partial replacements of sand. The concrete mix was designed using the American Concrete Institute (ACI) method.

CONCRETE MIX DESIGN

For M20 grade of concrete, concrete mix design is prepared as per IS 10262:2009 -

Water content = 198 liter /m3

Cement content = 396 kg/m3

Water - cement ratio = 0.5

Aggregates:

Coarse aggregate fraction= 0.62

Fine aggregate fraction= 1- 0.62=0.38

Mix Calculation –

a) Volume of concrete = 1m3

b) Volume of cement = (396/3.15) x (1/1000)

= 0.126 m3

Volume of water = (198/1) x (1/1000)

= 0.198 m3

Volume of aggregates in all -

= 1-0.126-0.198

= 0.68 m3

Coarse aggregate = d) x fraction of coarse aggregate

x Specific gravity (G) of coarse aggregate x 1000

= 0.68 x 0.62 x 2.73 x 1000

= 1150.97 kg/m3

Fine aggregate = d) x fraction of fine aggregate x

Specific gravity (G) of fine aggregate x 1000

= 0.68 x 0.38 x 2.63 x 1000

= 679.59 kg/m3 Table.4. Proportions for 1m3

Mix proportion is – 1: 1.71: 2.91

Results

Workability (slump value)

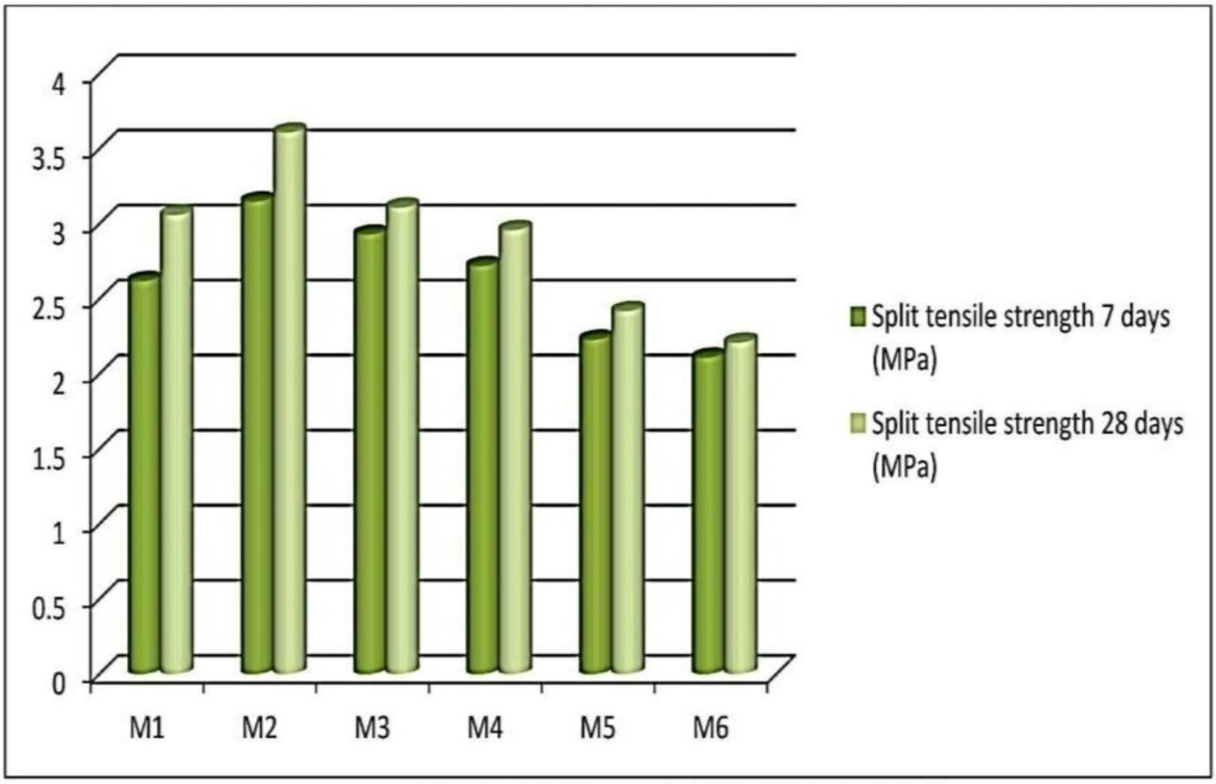
The measured slump values of quarry dust & fly ash with constant water/cement ratio i.e. w/c ratio (0.45) are 75, 78, 79, 81, 82 and 84 mm for different mixes such as M1 (0% quarry dust), M2 (10% quarry dust), M3 (20% quarry dust), M4 (30% quarry dust), M5 (35% quarry dust), M6(40% quarry dust) respectively. It should be noted that slump was maintained between 75 -85 mm with the addition of Plasticizer . Plasticizer was added to the mix in order to make it workable. Plasticizer was added in a certain amount effective with the weight of cement as shown below. The variations of slump value with quarry dust percentage are also shown below. It is observed that the percentage of plasticizer decreases with the increase in percentage of quarry dust and this is because the workability increases with the increase in percentage of quarry dust.

Table 5.Result of slump test

Sl. No.	**Stone dust content (%)**	**Fly ash content (%)**	**Slump (mm)**
1	0	0	89
2	15	0	81
3	30	0	73
4	45	0	58
5	60	0	55
6	15	5	93
7	30	10	86
8	45	15	78
9	60	20	70

Split tensile strength

The results of split tensile strength of cylinders for (7, 28) days curing are shown in table. It should be noted that in mix M1 split tensile strength decreases as the days of curing are increased from 7days to 28 days. But as the percentage replacement of quarry dust reaches the value 10%, split tensile strength in mix M2, M3, M4, M5, M6 starts increasing with the increase in days of curing from 7 days to 28 days. Further is illustrated in the graph below.



Compressive strength

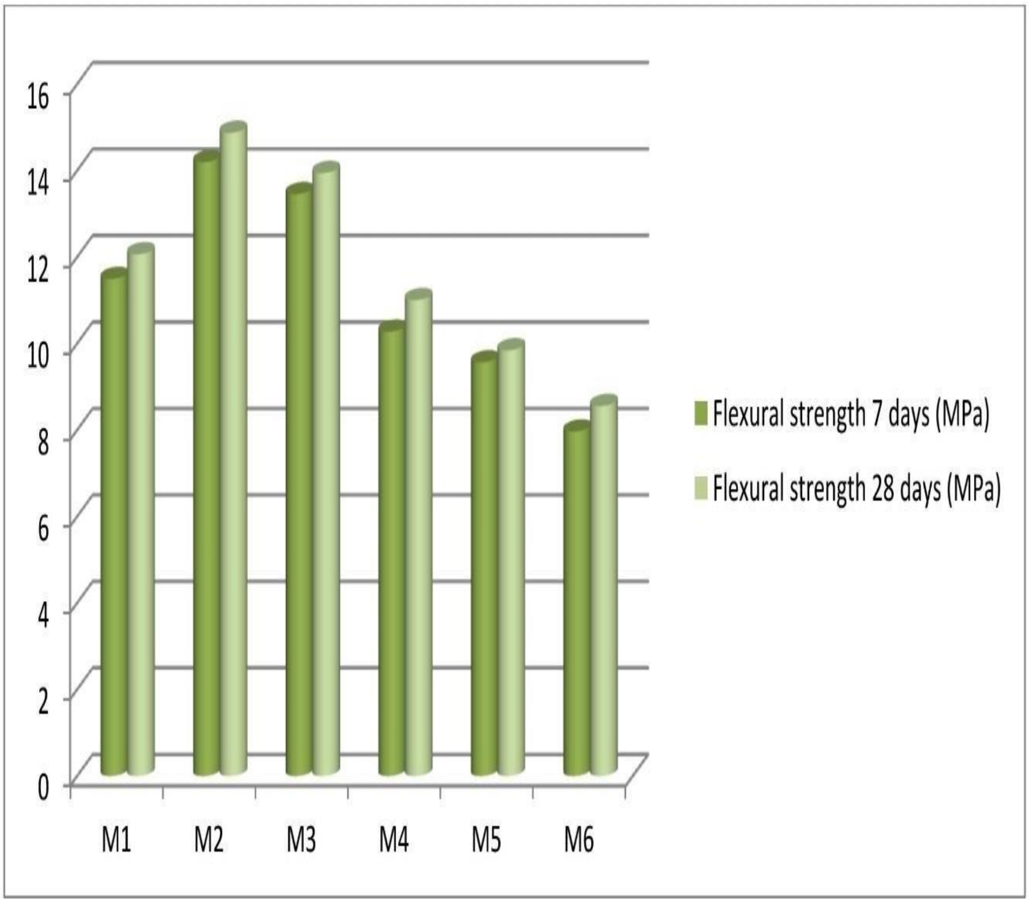
The results of compressive strength of cubes for (7, 28) days curing are shown in table. It should be noted that in mix M1, M2 and M3 compressive strength increases as the days of curing are increased from 7days to 28 days. But as the percentage replacement of quarry dust reaches the value 30%, compressive strength in mix M4, M5, M6 starts decreasing with the increase in days of curing from 7 days to 28 days. Further is illustrated in chart below

Table.2. Compressive strength of cubes

Sl. No.	**Stone dust content (%)**	**Fly ash content (%)**	**Compressive strength after 28 days curing in N/mm^2**
1	0	0	22.89
2	15	0	25.11
3	30	0	26.29
4	45	0	21.36
5	60	0	19.55
6	15	5	20.80
7	30	10	24.25
8	45	15	25.32
9	60	20	22.05

Flexural strength

The results of Flexural strength of beams for (7, 28) days curing are shown in table. It should be noted that in mix M1, M2 and M3 Flexural strength increases as the days of curing are increased from 7days to 28 days. But as the percentage replacement of quarry dust reaches the value 30%, Flexural strength in mix M4, M5, M6 starts decreasing with the increase in days of curing from 7 days to 28 days. Further is illustrated in graph /chart below.



4.CONCLUSION

From the test result it is clear that the workability of concrete decreases as the percentage of stone dust is increased but by inclusion of fly ash with stone dust workability increases. By 30% replacement of sand with stone dust concrete gives better compressive strength. When Stone dust and fly ash is used combined it also increases the compressive strength of concrete.

The use of quarry dust and fly ash as partial replacements of sand in concrete has been investigated in this research paper. The results showed that the addition of quarry dust and fly ash had a significant effect on the mechanical and durability properties of concrete. The compressive, split tensile, and flexural strengths of concrete increased with the increase in quarry dust and fly ash content up to 20%, and then decreased at 30% replacement. The water absorption and permeability of the concrete decreased with the increase in quarry dust and fly ash content.

Based on the results, it can be concluded that quarry dust and fly ash can be used as partial replacements of sand in concrete. The optimum replacement levels of quarry dust and fly ash were found to be 20%. The use of these waste materials in concrete not only reduces the environmental impact but also helps in reducing the cost of construction.

Overall, the use of quarry dust and fly ash in concrete can be a sustainable solution for the construction industry, provided that the properties of these materials are properly understood and controlled. Further research can be conducted to investigate the long-term durability and performance of concrete made with quarry dust and fly ash, as well as to explore the use of these materials in other applications such as geotechnical engineering and pavement construction.

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