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An Experimental Study on Usage of Quarry Rock Dust as Partial Replacement for Sand in Concrete

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Abstract

Concrete is the commonly used material in the construction industry. The widely used raw material in the concrete are cement, fine aggregate, coarse aggregate and water, of this common river sand is used as fine aggregate. But, now-a-days river sand is at great rate of depletion and expansive, due to which there was a need for an effective alternative. Quarry dust, has been found as an economic alternative for sand. In this paper, we have investigated the study of quarry rock dust as partial replacement of fine aggregate in concrete. Mix design has been developed for M20 grade using IS design for conventional concrete and replaced mix. Specimens on cubes, cylinders and beams were prepared for both conventional and 20%, 40%, 60% replacement with quarry dust. Tests were conducted on the specimens after 28 days curing to attain its maximum compressive, tensile and flexural strength. Graphs were drawn and results were compared with controlled mix. It is found that the effective replacement of sand with quarry dust is possible.

Keywords

Concrete, River sand, Quarry dust, Compressive strength, Split tensile strength, Flexural strength.

I. Introduction

Concrete is an assemblage of cement, aggregate and water. Quality of construction is the most important aspect under consideration in the construction sector. Crushed items always play a vital role in the quality of products. Concrete consist of cement, fine and coarse aggregate, water. Of this cement is factory made, water is naturally available, coarse aggregate is naturally available and factory crushed. Hence these components normally maintain a standard quality. Fine aggregate is often obtained from river beds. This became very scarce as the Government of Tamil Nadu has imposed ban on the mining of the same due to the environmental hazards. The quality of the river sand normally depends on its source and most of the time it varies quite a lot. As the use of fine aggregate in concrete is more than 30% of the composite, its mechanical properties affect the quality of concrete. The alternative material should be waste materials in the aspects of reduction in environmental load and waste management cost, reduction of production cost as well as augmenting the quality of concrete. Hence crushed sand has been identified as a substitute for river sand thereby solving the issue of mining of sand from river beds and improving the quality of fine aggregate. Quarry dust has been used for different activities in the construction industry such as road construction, and manufacture of building materials such as light weight aggregates, bricks and tiles. Our project presents the result of experimental investigations carried out on “Quarry sand” and the details of concrete designed using Quarry sand.

II. Materials

Cement

Cement acts as a primary binder to join the aggregate into a solid mass. It is the most important material in concrete. Some of the important factors which play vital role in selection of cement are compressive strength at various stages, fineness, heat of hydration, alkali content, tricalcium aluminate (C3A), tricalcium silicate (C3S), dicalcium silicate (C2S), tetra calcium aluminoferrate (C4AF). It is also necessary to ensure compatibility and mineral admixtures with cement. Ordinary Portland cement (53 grades) with normal consistency was used in concrete.

Table 1: Chemical Properties of Quarry Rock Dust and Natural River Sand

Instituents	Quarry Dust (%)	Natural Sand (%)
SiO_2	62.48	80.78
Al_2O_3	18.72	10.52
Fe_2O_3	6.54	1.75
CaO	4.83	3.21
MgO	2.56	0.77
Na_2O	-	1.37
K_2O	3.18	1.23
TiO_2	1.21	-
Loss of ignition	0.48	0.37

Properties of Cement

The initial setting time of cement is 1 hour 30 minutes and the specific gravity of 53 grades OPC was found as 3.1

Aggregate

Aggregates are the important constituents in concrete. It gives body to the concrete, reduce shrinkage and effect economy. Aggregates occupy 70 to 80% of the volume of concrete. The aggregates combine with cement and water to produce concrete. There are two types aggregate, coarse and fine aggregate.

Coarse Aggregate

The coarse aggregate should be 20 mm in size and the specific gravity for coarse aggregate was found as 2.78. FINE AGGREGATE Sand obtained from river beds is used as fine aggregate. The fine aggregate along with hydrated cement paste fill the space between the coarse aggregate. Specific gravity of river sand was found as 2.64.

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Properties of Aggregate

Shape and texture, Size gradation, Moisture content, Specific gravity, Unit weight and Durability and absence of deleterious materials.

Quarry Rock Dust

Crushed sand less than 4.75 mm is produced from hard granite rock using state of crushing plants. Production of quarry fines is a consequence of extraction and processing in a quarry and collected from the near-by quarry. The amount produced depends on the rock type, amount of fragmentation by blasting and type of crushing used. The product is washed to remove excess fines to get sand of excellent shape, gradation free from silt, clay and unwanted contamination. Specific gravity tests were conducted and found as 2.93.

Advantages of Quarry Dust

The advantages of quarry dust are cost effective, easily available, consumption reduces the pollution in environment and effectively used as a replacement material for river sand.

Water

Water is required for the cement to hydrate and solidify. It is an important ingredient of concrete as it chemically participates in the reaction with cement to form hydration product, C – S – H gel. The water used for concrete should be free from the undesirable salts that may react with cement and reduce their efficiency. Silts and suspended particles are undesirable as they interfere with setting, hardening and bond characteristics.

Requirements of Water In Concrete

Water used for mixing and curing shall be clean and free from injurious amounts of oils, acids, alkalis, salts, sugar, organic materials. Portable water is generally considered satisfactory for mixing concrete. Mixing and curing with sea water is not permitted. The pH value shall not be less than 6.

The permissible limits for solids in water

Table.2: Permissible limits of water

Solids	Permissible Limits (Max)
Organic	200 mg/lit
Inorganic	3000 mg/lit
Sulphates (SO4)	500 mg/lit
Chlorides (Cl)	500 mg/lit
Suspended matter	2000 mg/lit

III. Methodology

For each test that was conducted, cubes, cylinders and beams were prepared. Cubes, cylinders and beams were prepared to obtain the compressive strength, splitting tensile strength and flexural strength respectively. The specimens were casted and cured for 28 days. The 28 days cured specimens were subjected to testing and the results were obtained. Due to the compressive force, the cube of size 150 X 150 X 150 mm is subjected to a large magnitude of compressive strength near the loading region. The compressive strength was computed by the standard stress formula P/A, where P is the ultimate load in KN and A is the area in m². The split tensile strength was conducted by the cylinder specimen 150 X 300 mm and computed by using the expression $f_t = 2P/\pi LD$, where P is the ultimate load in KN, L is the depth of the cylinder in m and D is the diameter of the cylinder in m. The flexural strength was conducted by the beam of size 700 X 150 X 150 mm and computed by using the expression PL / bd², where P is the ultimate load in KN, L is the span between the rollers (40 or 60 cm), b is the breadth of the beam in m and d is the depth of the beam in m. The test for modulus of rupture is done by using the beam specimen, modulus of elasticity is done by using the cylinder specimen and modulus of rigidity is done by using the cube specimen.

IV. Results and Discussion

Results on Properties of Fresh Concrete:

Workability (Slump Value)

The measured slump values of ordinary and quarry dust replaced concrete with water cement ratio 0.5 such as Q0 (0% replacement), Q20 (20 % replacement), Q40 (40% replacement) and Q60 (60% replacement) respectively. The variations of slump value with quarry dust percentage are shown in fig.1. It is denoted that the slump value increases with increase in percentage replacement of sand with quarry dust for the same water cement ratio. Concrete does not give adequate workability with increase of quarry rock dust.

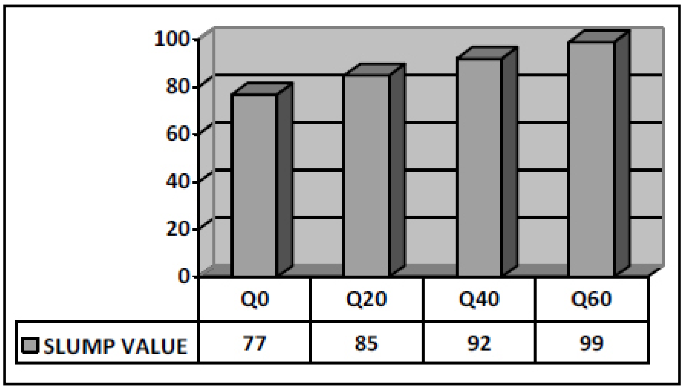


Fig.1: Variation of slump value of fresh concrete with quarry rock dust

Compaction Factor

The variation of workability is measured in terms of compaction factor with the constant water cement ratio 0.5. the values are obtained for different mixes such as Q0 (0% replacement), Q20 (20%replacement), Q40 (40% replacement) and Q60 (60% replacement). The above data represents the concrete does not give adequate workability with the increase of quarry dust as partial replacement of fine aggregate. Water requirement will be more for crushed stone dust, results in decrease workability than natural sand.

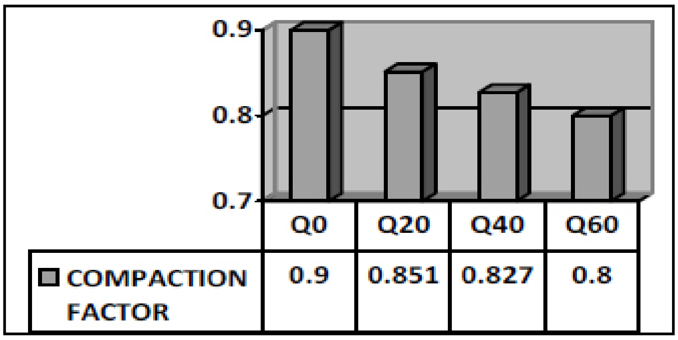


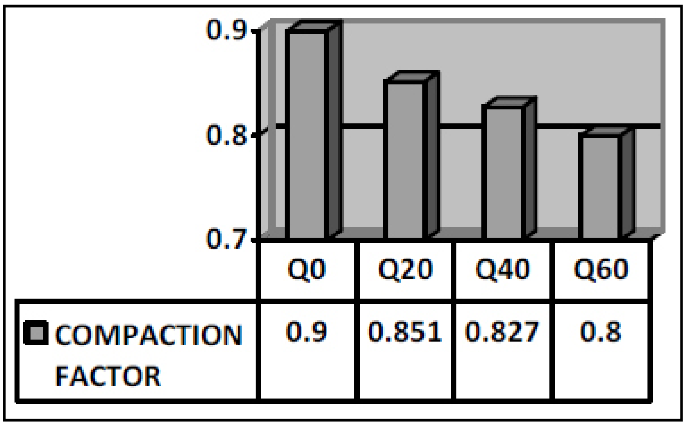
Fig.2:Variation of compaction factor of fresh concrete with quarry rock dust

Results on Properties of Hardened Concrete

Compressive Strength

For cube compression testing of concrete 150 X 150 X 150 mm cubes was used. All the cubes were tested in saturated condition after wiping out the surface moisture. Three cubes for each mix of quarry sand with river sand were tested at the age of 28 days curing using universal testing machine.

The results of compressive strength of cubes for 28 days curing are shown in fig.3. It is observed that the compressive strength of cubes at 28 days curing for controlled concrete Q0 is 23.25N/mm^2. For Q20 i.e., 20% replaced quarry dust, the 28 days curing increases 27.71 N/mm^2 and 40% replaced quarry dust, the 28 days curing increases 31.45 N/mm^2. For Q60 i.e., 60% replaced quarry dust, the 28 days curing decreases to 26.21N/mm^2.

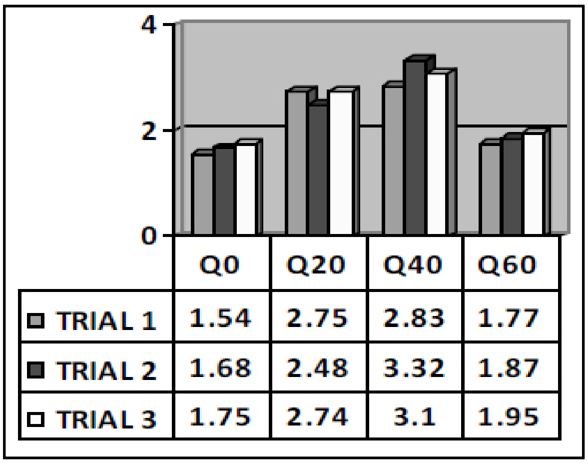


	Q0	Q20	Q40	Q60
COMPACTION FACTOR	0.9	0.851	0.827	0.8

Fig.3: Graph showing compressive strength

Split Tensile Strength

This is an indirect test to determine the tensile strength of cylindrical specimens. Splitting tensile strength tests were carried out on cylinder specimens of size 150 x 300 mm length at the age of 28 days curing, using universal testing machine. The load was applied gradually till the specimens split and readings were noted. The results of split tensile strength of cylinders for 28 days curing are shown in fig.4. It is observed that the split tensile strength of cylinders at 28 days curing for controlled concrete Q0 is 1.7N/mm^2. For Q20 i.e., 20% replaced quarry dust, the 28 days curing increases 2.66 N/mm^2 and 40% replaced quarry dust, the 28 days curing increases 3.083 N/mm^2. For Q60 i.e., 60% replaced quarry dust, the 28 days curing decreases to 1.86 N/mm^2.

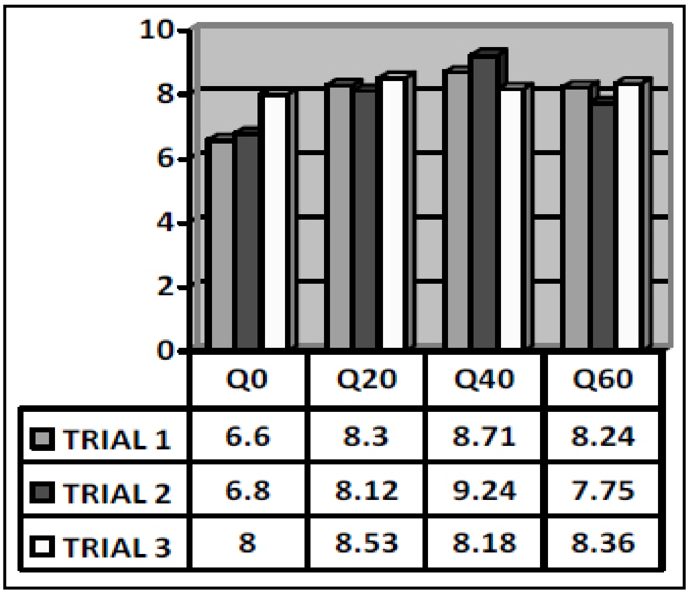


	Q0	Q20	Q40	Q60
TRIAL 1	1.54	2.75	2.83	1.77
TRIAL 2	1.68	2.48	3.32	1.87
TRIAL 3	1.75	2.74	3.1	1.95

Fig.4: Graph showing Split tensile strength

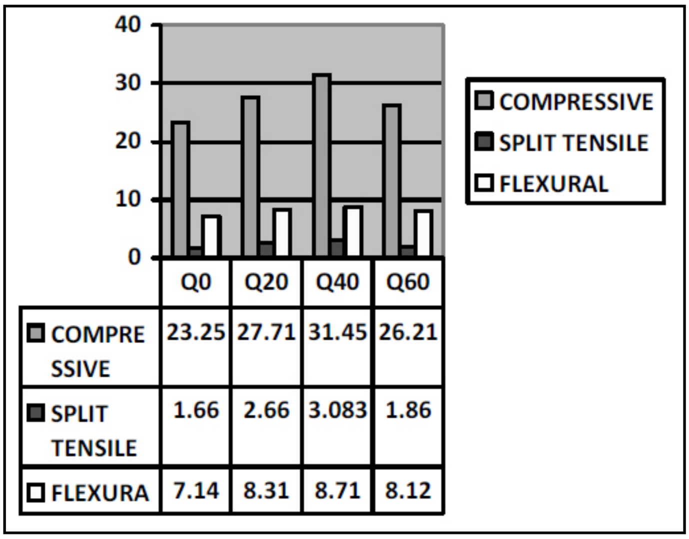
Flexural Strength

Beam specimens of size 70 X 15 X 15 cm were used casted and tested to determine the modulus of rupture at the age of 28 days. The bearing surfaces of the supporting and loading rollers are wiped and clean and any loose sand or other material removed from the surfaces of the specimen where they are to make contact with the rollers. The specimen is then placed in the machine in such a manner that the load is applied to the uppermost surface as cast in the mould, along two lines spaced 13.3 cm apart. The axis of the specimen is carefully aligned with the axis of loading device. The load is applied without shock and increasing continuously at a rate such that the extreme fibre stress increases approximately 0.7kg/sq.cm/min. The load is increased until the specimen fails



	Q0	Q20	Q40	Q60
TRIAL 1	6.6	8.3	8.71	8.24
TRIAL 2	6.8	8.12	9.24	7.75
TRIAL 3	8	8.53	8.18	8.36

Fig.5: Graph showing flexural strength



	Q0	Q20	Q40	Q60
COMPRESSIVE	23.25	27.71	31.45	26.21
SPLIT TENSILE	1.66	2.66	3.083	1.86
FLEXURA	7.14	8.31	8.71	8.12

Fig.6: Graph showing the comparison of compressive, split tensile and flexural strength

V. Conclusion

All the experimental data shows that the addition of the industrial wastes improves the physical and mechanical properties. The results are of great importance because of this king of innovative concrete requires large amount of fine particles. Due to this high fine fines of quarry dust it provided to be very effective in assuring very good cohesiveness of concrete. From the above study it is concluded

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that the quarry dust may be used as a replacement material for fine aggregate. Quarry dust have been used for different activities in the construction industry such as road construction and manufacture of building materials. As the properties are good as sand, the quarry dust is used as fine aggregate in replacement with sand in cement concrete. From the various laboratory investigations made for characteristics study of quarry dust concrete and studies conducted as explained in Chapter IV, following conclusions are drawn.

1. Non- availability of sand at reasonable costs as fine aggregate in cement concrete for various reasons, search for alternative material stone crusher (quarry) dust qualifies itself as a suitable substitute for sand at very low cost.
2. Aggregates with higher surface area are requiring more water in the mixture to wet the particle surfaces adequately and to maintain a specific workability. The increase in water content in the mixture will adversely affect the quality of concrete.
3. The measured slump values of quarry dust concrete with constant water cement ratio 0.5 are found to be 77, 85, 92 and 99 for different mixes Q0 (0% replacement), Q20 (20% replacement), Q40 (40% replacement), Q60 (60% replacement) respectively. It is observed that the slump value increases with increase in percentage replacement of quarry rock dust. Due to the flaky particle shape and higher percentage of fines, concrete does not give adequate workability and concrete tends to segregate. The above slump value correspond to low degree of workability and suitable for construction of tiles, bricks, canal lining as per IS 456–2000.
4. The measured compaction factor value for quarry dust concrete with constant water cement ratio 0.5 are found to be 0.9, 0.85, 0.83, 0.8 for different mixes Q0 (0% replacement), Q20 (20% replacement), Q40 (40% replacement), Q60 (60% replacement) respectively. The above value shows that concrete do not give adequate workability with the increase of quarry rock dust as fine aggregate. The above compaction factor corresponds to low degree of workability.
5. The compressive strength of cubes with 28 days curing of controlled specimen Q0 is observed as 23.25 N/mm2. For 20% quarry dust replaced specimen i.e., Q20, the strength has been increased to 19.18% and for 40% quarry dust replaced specimen i.e., Q40, the strength has been increased to 35.26% but for 60% quarry dust replaced specimen i.e., Q60, the strength has been increased only upto 12.73%
6. The split tensile strength of cylinders with 28 days curing of controlled specimen Q0 is observed as 1.66 N/mm2. For 20% quarry dust replaced specimen i.e., Q20, the strength has been increased to 60.24% and for 40% quarry dust replaced specimen i.e., Q40, the strength has been increased to 85.72% but for 60% quarry dust replaced specimen i.e., Q60, the strength has been increased only upto 12.05%
7. The flexural strength of beams with 28 days curing of controlled specimen Q0 is observed as 7.14 N/mm2. For 20% quarry dust replaced specimen i.e., Q20, the strength has been increased to 16.39% and for 40% quarry dust replaced specimen i.e., Q40, the strength has been increased to 21.98% but for 60% quarry dust replaced specimen i.e., Q60, the strength has been increased only upto 13.73%
8. The water absorption percentage of quarry dust concrete decreased for dust content 0 – 20% and then it started to increase for 40% and 60% of dust contents. Lower the particle size will result in faster absorption and greater surface area with results in faster evaporation leading to concrete setting quickly.
9. It was observed that the density of concrete increases with increase in percentage of dust content. As the expected compressive strength increases with increase in density of concrete.

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