EXPERIMENTAL INVESTIGATION OF PARTIAL REPLACEMENT OF FINE AGGREGATE BY QUARRY DUST IN CONCRETE WITH STEEL POWDER

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ABSTRACT

This research work is aimed to investigate the effects of partially replacing fine aggregate with our local additive quarry dust with steel powder in concrete at optimum replacement percentage which will help to reduce the cost of structure. Common river sand is expensive due to excessive cost of transportation from natural sources. Also large-scale depletion of these sources creates environmental problems. As environmental transportation and other constraints make the availability and use of river sand less attractive, a substitute or replacement product for concrete industry needs to be found. River sand is most commonly used fine aggregate in the production of concrete poses the problem of acute shortage in many areas. In such a situation the Quarry rock dust can be an economic alternative to the river sand. This paper presents the feasibility of the usage of Quarry Rock Dust as hundred percent substitutes for Natural Sand in concrete. Mix design has been developed for M20 grade using design an approach IS. Also the proposed work is aimed to analyse whether the strength of concrete will increase or not while adding the steel powder with concrete. Six different replacement levels namely 10%, 20%, 30%, 40%, 50% and 60% are chosen for the study concern to replacement method with 1% steel powder. A range of curing periods started from 7 days, 14 days and 28 days are considered. Tests were conducted on cubes, cylinders and beams to study the strength of concrete made of Quarry Rock Dust with steel powder and the results were compared with the Natural Sand Concrete. It is found that the compressive, flexural strength and tensile strength Studies of concrete made of Quarry Rock Dust are more than the conventional concrete. It was reported that significant increase in compressive strength, modulus of rupture and split tensile strength when 40 percent of sand is replaced by Quarry Rock Dust in concrete with 1% steel powder.

Keywords: Fine Aggregates; Natural River Sand; Quarry Dust; Concrete; Strength

INTRODUCTION

Concrete is a composite construction material made primarily with aggregate, cement and water. There are many formulations of concrete which provide varied properties and concrete is the most used man-made product in the world. Also there is a rapid growth in industrialization and construction field nowadays, so we require large amount of cement, fine aggregates and coarse aggregates for this purpose. River sand is most commonly used fine aggregate in concrete but due to acute shortage in many areas, availability, cost and environmental impact are the major concern. To overcome this crisis, partial replacement of sand with quarry dust can be economic alternative. Therefore, construction industries of developing countries are in stress to identify alternative materials to replace the demand for natural sand. On the other hand, the advantages of utilization of byproducts or aggregates obtained as waste materials are pronounced in the aspects of reduction in environmental load & waste management cost, reduction of production cost as well as augmenting the quality of concrete. In this context, fine aggregate has been replaced by quarry dust a byproduct of stone crushing unit and few admixtures to find a comparative analysis for different parameters which are tested in the laboratories to find the suitability of the replacement adhered to the Indian Standard specifications for its strength. Quarry dust, a by-product from the crushing process during quarrying activities is one of such materials. Therefore, it is desirable to obtain cheap, environmentally friendly substitutes for cement and river sand that are preferably by products. Quarry dust has been proposed as an alternative to river sand that gives additional benefit to concrete. Quarry dust is known to increase the strength of concrete over concrete made with equal quantities of river sand, but it causes a reduction in the workability of concrete when increasing the percentage of quarry dust. The use of quarry dust in concrete is desirable because of its benefits such as useful disposal of by products, reduction of river and sand consumption as well as increasing the strength parameters and increasing the workability of concrete. Iit is used for different activities in the construction industries such as road construction, manufacture of building materials, bricks, tiles and autoclave blocks. Quarry dust has been proposed as an alternative to river sand that gives additional benefit to concrete. Quarry dust is known to increase the strength of concrete over concrete made with equal quantities of river sand.

REVIEW OF LITERATURE

Lohani et al.,In this journal they used the design mix of M20 grade concrete with replacement of 0%, 20%, 30%, 40%, and 50% of quarry dust organized as M1, M2, M3, M4 and M5 respectively have been considered for laboratory analysis viz. slump test, compaction factor test, compressive strength (cube, cylindrical sample), split tensile strength, flexural strength, modulus of elasticity, water absorption of hardened concrete. Curing days started from 7, 28, 91. The durability of concrete was studied by immersing the concrete cube in 5% solution of $MgSo_4$, 5% solution of NaCl and 2N solution of HCl for 28 days and 91 days and results were compared with the standards to achieve the desired parameters. Finally they concluded thorough reaction with the concrete admixture, quarry dust, improved pozzolanic reaction, micro aggregate filling and concrete durability. As the properties are good as sand, the quarry dust is used as fine aggregate in replacement with sand in the cement concrete.

M. Devi et al., In this journal they studied the strength and corrosion resistive properties of concrete containing quarry dust as fine aggregate along with organic inhibitors namely Triethanolamine and Diethanolamine at 1%, 2%, 3% and 4% by weight of cement. They used the design mix of M20 grade concrete with 100% replacement of sand by quarry dust. The specimens were tested for compressive strength, split tensile strength, flexural strength, and bond strength in addition to water absorption. Curing days started from 7, 14, 28 days. The resistance to corrosion is evaluated based on the performance of the concrete for the penetration of chloride ions by means of Polarization Technique, Rapid Chloride Penetration Test (RCPT) and Gravimetric weight loss method. From the results obtained, it is found that replacement of sand by well graded quarry dust along with super plasticizer increases the strength of concrete; with the addition of inhibitors it offers very good resistance against chemical attack and increases corrosion resistance in addition to overall properties of concrete. The optimum percentage addition of the organic inhibitors by weight of cement in concrete containing quarry dust as fine aggregate was also determined. Considering strength as well as durability criteria, the optimum percentage of Triethanolamine and Diethanolamine to be added in concrete containing quarry dust as fine aggregate is 2% for delaying corrosion and to increase the strength and other durability characteristics.

PROPERTIES OF MATERIALS

Ordinary Portland Cement

Ordinary Portland Cement (OPC) is a material that sets hard when in contact with water. When mixed with water, its molecules combine with water molecules to form crystals. These crystals interlock with each other and with the surfaces of any aggregate added to the mix. The material possesses an early set, known as the initial set, which time can be made use when OPC is mixed and used quickly in small quantities and a final setting time of not more than ten hours. Further hardening is brought about by continued reaction and is rapid in the early stages but slower with the passage of time.

Table I Properties of cement

S. No	***Description of tests***	***Values***
1	Specific gravity	3.15
2	Normal consistency	34%
3	Initial setting time	30 mins

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Fine Aggregate

Sand is also known as fine aggregate whose particles pass through 4.75mm mesh sieve but are completely retained on 0.07mm mesh. Particles that are finer than 0.06mm come under silts and are considered as harmful ingredients.

Tables II Physical Properties of Fine Aggregate

Physical Properties	Values
Specific gravity	2.7
Fineness Modulus	4.17

Coarse Aggregate.

Table III Physical Properties of Coarse Aggregate

Physical Properties	Values
Specific gravity	2.9
Fineness Modulus	3.6

Water

- Salinity of water should be checked.
- pH of water should be close to neutral (i.e) between 6 and 8.5

STEEL POWDER

Fig 1 Steel powder

Properties

It is possible to produce components via powder metallurgical processes that have physical properties that approach those of analogous wrought materials. However, to achieve this requires repressing and resintering to be carried out, which in turn add to the cost of production. Properties of powder metallurgy parts can also be influenced by post heat treatments.

Typical Properties of Powder

Typically parts produced by powder metallurgy will have tensile strengths approximately 75% of those of produced/machined from wrought stock. Doe to the porosity of powder metallurgy parts, the hardness will often appear lower then parts produced from wrought materials. However, the hardness of the actual particles will be harder, and be almost equivalent to wrought materials. The porosity and relatively lower sectional bonding area also lead to lower ductility's compared to wrought materials.

Physical properties

- Unit mass of steel ρ -7850kg/m^3
- Modulus of elasticity -2.0×10^5N/mm^2
- Possion's ratio μ - 0.3
- Modulus of rigidity, G -0.6769×10^5N/mm^2
- Cofficient of thermal expansion-12×10^{-6}/°C

Mechanical properties

- Yield stress f_y
- The tensile or ultimate stress f_u

CASTING AND CURING OF SPECIMENS

For ordinary concrete, fine aggregate and cement were weighted and mixed thoroughly: the coarse aggregate was then added and mixed with the above. The required amount of water added and mixed thoroughly to get uniform concrete mass. Hand mixing process is adopted for mixing the concrete.

Concrete compaction in the mould is done by hand compaction as per Indian Standards Procedures. Tamping rod has to be used for hand compaction of concrete. When compacting by hand, the standard tamping bar is used and the strokes of the bar are distributed in a uniform manner over the cross section of the mould. Compaction eliminates air bubbles and brings enough fine material both to the surface and against the forms to produce the desired finish. While tamping is carried out, care should be taken that the rod should penetrate the full layer of the last layer placed and to some extent into lying to ensure proper bond. Curing is the process in which the concrete is protected from loss of moisture and kept within a reasonable temperature range. The result of this process is increased strength and decreased permeability. Curing is also a key player in mitigating cracks in the concrete, which severely impacts durability. Curing is used to include maintenance of a favorable environment for the continuation of chemical reactions.

Fig 2. Curing of Specimen

For preparing the specimens for determine the Compressive strength of cubes, Tensile strength of cylinder and Flexural strength of beams. The fresh concrete was filled in the mould. Care should be taken to see that the concrete was compacted perfectly. All the moulds were remoulded after 24 hours of casting and cured. The compressive strength of cubes are tested on 7^{th}, 14th and 28^{th} days. The split tensile strength of cylinders are tested on 7^{th} ,14^{th} and 28^{th} days. The flexural strength of beams are also tested on 7^{th} ,14^{th} and 28^{th} days.

COMPRESSIVE STRENGTH TEST:.

The compressive strength of concrete is defined as the load which causes the failure of specimen, per unit area of cross-section in uniaxial compression under given rate of loading. The strength of concrete is expressed as N/mm^2.

For structural design the compressive strength is taken as the criterion of quality of concrete and working stress are prescribed as per codes in terms of percentages of the compressive strength as determined by standard tests. The cube specimens were tested for compressive strength at the end of 7 days, 14 days and 28 days. The specimens stored in water were tested after drying the specimens. The projecting fines were removed if any.

The axis of the specimen was carefully aligned with the center of thrust of the spherically seated plate. The load was applied without shock and increase continuously until the resistance of the specimen to the increasing load brake down and the greater load could be borne by the specimen. The maximum load by the specimens was recorded.

Fig 3. Compressive Strength Test

SPLIT TENSILE TEST :

The test specimen shall consist of concrete cylinders of 150 mm in diameter & 300 mm long. The same compressive test machine is used for finding tensile strength also. Placing a cylindrical specimen horizontally between the loading surfaces of a compression-testing machine carries out this test and the load is applied until failure of the cylinder, along the vertical diameter. When the load is applied along the

vertical diameter of the cylinder. It is subjected to a horizontal stress of $\frac{2P}{\pi DL}$

Where
P- Compressive load on the cylinder, L-length of the cylinder
D-Diameter

The loading condition produces a high compressive stress immediately below the two generators to which the load is applied. But the larger portion corresponding to depth is subjected to a uniform tensile stress is acting horizontally. It is estimated that the compressive stress is acting for about1/6 depth and the5/6 depth is subjected to tension.

Fig 4. Split Tensile Strength Test

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FLEXURAL STRENGTH TEST:

The system of loading used in finding out the flexural tension is central point loading and three points loading. In central point loading, maximum fiber stress will come below the point of loading where the bending moment a maximum. If the largest nominal size of the aggregate does not exceed 20 mm, specimens 100mm x 100mm x 500mm may be used.

Remove beam from the curing tank and wipe off excess surface water with a damp cloth –Place the beam in the testing machine so that the top surface is facing towards you. This ensures that top and bottom surfaces of the beam are parallel so that loading is uniform across the width. Loading is applied through 2 rollers, each at a distance of L/3 from the supports on either side. Apply the loading without shock and increase at a constant stroke rate (0.02mm/min).

COMPRESSIVE STRENGTH OF CONCRETE

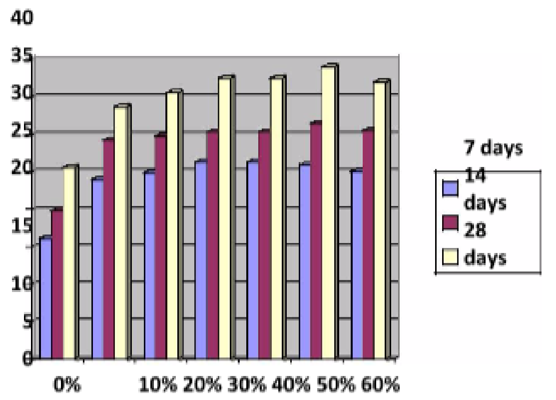

Fig 6. Graph for compressive strength

Table IV Compressive strength of concrete

% of quarry dust	Compressive strength in n/mm^2		
	7 days	14 days	28 days
0%	16.07	19.79	25.6
10%	24	29.19	33.70
20%	24.93	29.78	35.63

30%	26.31	30.37	37.48
40%	26.31	32	39.48
50%	25.93	31.5	39
60%	25.10	30.5	37

DISCUSSION:

From this research, the compressive strength increases up to 40 % quarry dust replacement and then 50% and 60% replacement of quarry dust results decrease in compressive strength but compare the conventional it was increased.

SPLIT TENSILE STRENGTH OF CONCRETE

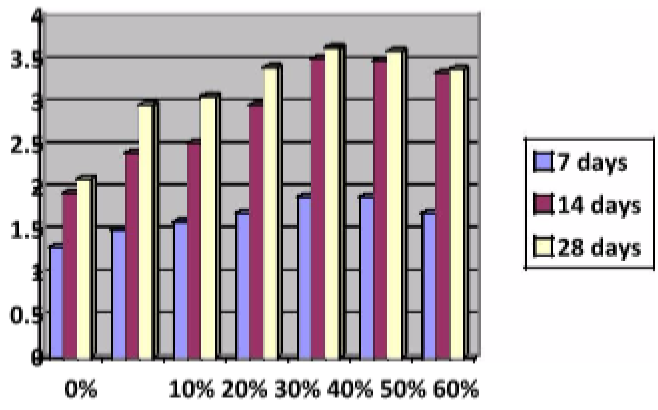

Fig 7.Graph for tensile strength

Table V Split tensile strength of concrete

% of quarry dust	Spilt tensile strength in N/mm^2		
	7 days	14 days	28 days
0%	1.3	1.94	2.1
10%	1.5	2.41	2.97
20%	1.6	2.53	3.08
30%	1.7	2.97	3.41
40%	1.9	3.52	3.65
50%	1.9	3.49	3.6
60%	1.7	3.35	3.4

FLEXURAL STRENGTH OF CONCRETE

Table VI Flexural strength of concrete

% of Quarry dust	0%	10%	20%	30%	40%	50%	60%
Flexural strength 28 days	3.37	3.5	4.6	5.8	6.2	5.4	4.2

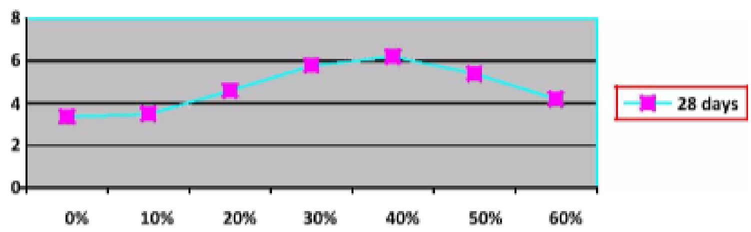

Fig 8. Graph for flexural strength

CONCLUSION

- Under certain conditions, replacement of fine aggregate by quarry dust and addition of steel powder appeared to increase the strength of concrete.
- The compressive strength is increased up to 40% replacement of quarry dust with 1% of steel powder. When 40 % replacement of quarry dust the value is increased over the conventional concrete, but decreased when increasing the percentage of replacement of quarry dust with steel powder.

- The split tensile strength is increased up to 40% replacement of quarry dust with 1% of steel powder and then increasing the percentage of replacement of quarry dust with steel powder results in decreasing the value of flexural strength.

- The flexural strength is increased up to 40% replacement of quarry dust with 1% of steel powder, and decreased when increasing the percentage of replacement of quarry dust with steel powder.

- Concrete made by fine aggregate with 40% replacement of quarry dust and steel powder gave more strength compared to conventional concrete.

- However the 50% replacement of fine aggregate by quarry dust decreased the value by comparing the 40% but it also increased the strength comparing the conventional concrete.

- Infact incorporation of quarry dust either in sand or in concrete not only fulfills the demand of sand but also made a role in production of durable concrete. The strength development of concrete produced with a particular level of quarry dust replacement with steel powder is more compared to the concrete made river sand.

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