An Innovative Method of Replacing River Sand by Quarry Dust Waste in Concrete for Sustainability

Dr. P.B.Sakthivel, C.Ramya, M.Raja

Abstract— In the construction industry, there is a high demand for natural river sand, especially in the production of concrete, which creates major sustainablility issues. The best way to deal with these environmental concerns is to use waste or recycled material, as substitute for natural river sand. This paper deals with replacement of sand used in concrete as fine aggregates by the waste generated by the stone quarry industry. This study has made an attempt to partially replace quarry dust in place of sand in M35 grade concrete. On experimentation, it was found that the partial replacement of sand with 10% of quarry dust has given the optimum results. Therefore, this study recommends that if partial replacement of sand with quarry dust upto 10% in M35 grade of concrete is done, the effective waste management can contribute towards saving of our environment. Similar studies may be done with other concrete mix ratios and also cement mortar mixes which is used for ceiling and wall plastering and tile-laying purposes.

Index Terms— Global Warming, Green Concrete, Replacement, Strength, Sustainability, Quarry Dust, Waste Material

1 Introduction

SUSTAINABILITY is a global concern and hence the goal of human kind should be to create a sustainable world. In order to achieve sustainability, methods that are to be employed are effective utilization of currently available resources for a prolonged period of time, minimization of wastage of material/ energy and controlling overuse, and ensuring that there are reserves kept for future generations without complete exhaustion. But the man's greed has influenced his ownself to over-utilize, pollute and destroy the natural resources around him without giving a thought for future generations or for the existence of other species. By 2050, humanity could consume an estimated 140 billion tons of minerals, ores, fossil fuels and biomass per year (three times its current amount) [1]. Urban sprawl and building construction industry are the main causes of environmental pollution leading to severe sustainable issues. This environmental imbalance has created a situation for the people to focus on adoption of newer technologies and environmentally preferable materials, which will not only preserve the natural resources but also create a productive environment in which human and nature can exist in harmony. To reach this endeavor, one way is to go green, i.e., produce green building materials for construction [1] from the wastes that are generated by manufacturing industries, as waste is certainly a good potential resource and lot of energy can be recovered from it; and the terminology 'green' in the present context refers to use of sustainable materials like stone dust or recycled stone, recycled blue metal/ gravel and other products that are non-toxic, reusable, renewable, and/or recyclable [2].

In the construction industry, river sand is used as an important building material, and the world consumption of sand in concrete generation alone is around 1000 million tonnes per year, making it scarce and limited [3]. The excessive and non-scientific methods of mining sand from the river beds has led to lowering of water table and sinking of bridge piers [4]. Further, it has caused environmental degradation like removal of minerals from top-soil due to erosion and change in vegetative properties leading to soil infertility problems thereby affecting agricultural productivity, change in river-courses leading to floods, and alteration of river eco-system affecting flora and fauna. Hence, the current focus of construction industry should be to partially or completely replace natural sand in concrete by waste material or a material that is obtained through recycling, without compromising the quality of the end product [5]. In the recent years, the construction industries have identified some waste materials like flyash, slag, limestone powder and siliceous stone powder [6] and quarry dust [7] for use in traditional concrete.

Quarry dust is a kind of waste material that is generated from the stone crushing industry which is abundantly available to the extent of 200 million tonnes per annum [7] which has landfill disposal problems and health and environmental hazards [8]. The present study is an attempt to experiment on use of quarry dust to replace sand in concrete.

2 Review of Literature

The choice of quarry dust as replacement for sand has been supported in the previous study (Manassa, 2010) [5] showing that up to 20% of sand has been effectively replaced by quarry dust in traditional concrete. Ilangovan et al. (2008) [9] reported that the strength of quarry rock dust concrete was comparably 10-12% more than that of similar mix of conventional concrete. Hameed and Sekar (2009) [10] studied the effect of crushed stone dust as fine dust and found that flexural strength increases than the concrete with natural sand but the values decreases as the percentage of crusher dust increases.

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International Journal of Scientific & Engineering Research Volume 4, Issue 5, May-2013
ISSN 2229-5518

Divakar et al. (2012) [8] have experimented on the behaviour of M20 grade concrete with the use of granite fines as a partial replacement for sand in 5%, 15%, 25%, 35% and 50%; and based on the results obtained for compressive, split-tensile and flexural tests, it was recommended that 35% of sand can be replaced by granite fines. Mahzuz et al. (2011) [11] have investigated on the use of stone powder in concrete as an alternative of sand using three concrete mix proportions, 1:1.5:3, 1:2:4 and 1:2.5:5. When the results of compressive strength were compared for these mixes between use of sand and stone powder, it was found that stone powder gives higher value than sand by about 14.76%, 4% and 10.44% respectively. In another study conducted by Wakchaure et al, (2012) [12] using artificial sand in place of river sand, it was found that for M30 mix using artificial sand, the compressive strength increased by 3.98%, flexural strength by 2.81% and split tensile strength by a marginal value than concrete which used river sand. Seeni et al. (2012) [13] have made an attempt to partially replace fine aggregates with waste material obtained from China Clay industries. Out of the replacement percentages of 10% to 50%, the highest strength was achieved at 30% in compressive, split and flexural strength.

As there are very limited studies on partial replacement of sand with quarry dust, the objective of this study is to conduct an experimental on partial replacement of sand with quarry dust in M35 concrete, and find out the optimum results.

3 Experimentation

3.1 Control and Test Specimens

In this study, M35 concrete mix has been used with Ordinary Portland Cement (OPC 53 Grade) with specific gravity of 3.14, conforming to IS 12269: 1987 [14]. The natural river sand of specific gravity of 2.74, conforming to Zone II of IS 383:1970 [15], and quarry dust of specific gravity 2.69 have been used for this study. The maximum nominal size of coarse aggregates (blue metal) was 20 mm, and the sieve specifications conform to Table 2 of IS 383:1970 [15].

3.2 Control and Test Specimens

The partial replacement of sand ('S') with quarry dust ('D') in M35 concrete has been experimentally studied, and the replacement steps have been shown in Fig.1. The consumption of cement and the coarse aggregates are maintained the same for both the controlled concrete and the test specimens.

Based on the design mix for M35 in line with IS 456:2000 [16] and IS 10262:2009 [17], the mix ratio has been arrived at 1:1.68:2.8 (cement:sand:blue metal jelley) with a water-cement ratio of 0.45. In this paper, the terminologies 'S' and 'D' have been used for 'Sand' and 'Quarry Dust' respectively. Adopting the above design-mix ratio, the control specimens (S100 D0, i.e., Sand 100% and no Quarry Dust) have been cast. Then the sand was replaced by 10%, 20%, 30% and 40% with quarry dust, and accordingly, the terminologies 'S90 D10', 'S80 D20', 'S70 D30', 'S60 D40' (respectively) have been used. The mix proportions were determined by conducting slump and flow table tests and using the mix ratio derived. Three tests for hardened concrete, namely, the compressive strength, split-tensile strength and flexural strength were carried out at 28 days as per IS 456:2000; and the cube moulds of 150 mm size, cylinders of 150 X 300 mm (height), and beam moulds of 100 X 100 X 500 mm were used respectively.

First, the ingredients, namely the sand (Fig.1a) and quarry dust (Fig.1b) are mixed together (Fig.1c). Then cement is added to the ingredients (sand and quarry dust) as shown in Fig.1d. The mortar which consists of cement, sand and quarry dust is now added to the blue metal jelley (coarse aggregate) and thoroughly mixed, and then subsequently, the required amount of water is added, as shown in the Fig. 1e. This mix is casted into required moulds and after 24 hours of setting, it is demoulded (Fig. 1f) and cured for 28 days in the curing tank. Slump cone tests were done to determine the consistency and workability of control and test specimens, and there was enough workability and consistency for both the control specimens, as well as the test specimens (which used 10% and 20% replacement of sand with quarry dust). But the test specimens which used 30% and 40% of quarry dust (replacing sand) had some workability and consistency issues.

Fig.1 (a) Sand

Fig.1 (b) Quarry dust

Fig.1(c) Sand + Quarry Dust

Fig.1 (d) Cement + Sand+ Quarry Dust

Fig.1 (e) Cement + Sand + Quarrydust + Blue Metal Jellay + Water

Fig.1(f) Test specimens

Fig 1 Replacement of Sand by Quarry Dust

4 Results And Discussion

4.1 Compressive Strength

The cube-compressive strength for controlled concrete specimens and test specimens (with 10%, 20%, 30% and 40% replacement of 'S' with 'D') have been ascertained at 28 days, and the results are shown in Table 1 and Fig. 1. From Table 1, it was found that the cube-compressive strength of M35 controlled concrete is 42.22 N/mm^2. On 10% replacement of 'S' with 'D', it was found that the cube-compressive strength has

International Journal of Scientific & Engineering Research Volume 4, Issue 5, May-2013
ISSN 2229-5518

increased by about 8% (i.e., from 42.22 N/mm^2 for controlled concrete specimens to 45.55 N/mm^2). On 20% replacement of 'S' with 'D', the compressive strength has decreased by 22.4% (i.e., from 42.22 N/mm2 for control specimens to 32.78 N/mm^2). Further replacement of 'S' with 'D' of 30% and 40%, there is a drastic reduction of about 30% and about 37% in the compressive strength of the specimens (i.e., from 42.22 N/mm^2 for controlled specimens to 29.33 N/mm^2 and 42.22 N/mm^2 to 26.33 N/mm^2) respectively.

TABLE 1
COMPRESSIVE STRENGTH OF CONCRETE @ 28 DAYS

Identification of Specimens	Sand (%)	Quarry Dust (%)	Cube-compressive Strength @ 28 days (N/mm^2)
S100 D0	100	0	42.22
S90 D10	90	10	45.55
S80 D20	80	20	32.78
S70 D30	70	30	29.33
S60 D40	60	40	26.33

S – Sand; D – Quarry Dust

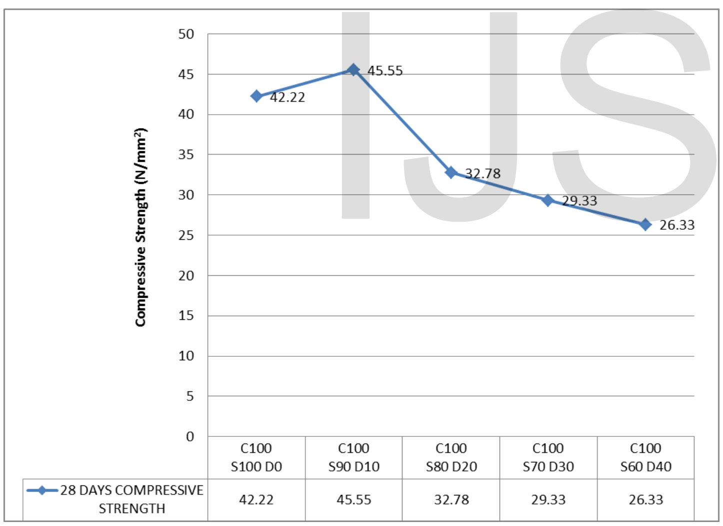

Fig. 2. Compressive strength Vs. % Replacement

4.2 Split Tensile Strength

Split-tensile strength for controlled concrete and all the test replacements replacing sand with quarry dust were determined at 28 days, and the ratios of cement and coarse aggregates are not modified between controlled and test specimens. From the results shown in Table 2 and Fig.3, it can be seen that the split-tensile strength obtained for control specimen is 3.53 N/mm^2, and for replacement of 10%, 20%, 30%, 40% of 'S' with 'D', the values have increased by about 23%, 19%, 16% and 10% (i.e., from 3.53 N/mm^2 to 4.338 N/mm^2, 3.53 N/mm^2 to 4.196 N/mm^2, 3.53 N/mm^2 to 4.102 N/mm^2 and 3.53 N/mm^2 to 3.89 N/mm^2). According to the values obtained, the highest value is 4.196 N/mm^2 which indicates that 10% addition of quarry dust gives higher strength, when compared to the control specimens.

TABLE 2
SPLIT-TENSILE STRENGTH OF CONCRETE @ 28 DAYS

Identification of Specimens	Sand (%)	Quarry Dust (%)	Split Tensile Strength @ 28 days (N/mm^2)
S100 D0	100	0	3.53
S90 D10	90	10	4.338
S80 D20	80	20	4.196
S70 D30	70	30	4.102
S60 D40	60	40	3.89

S – Sand; D – Quarry Dust

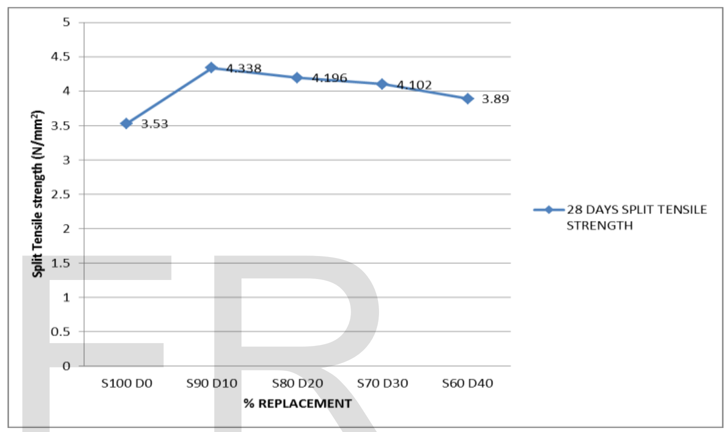

Fig.3. Split tensile strength Vs. % Replacement

4.3 Flexural Strength

Flexural Strength of concrete was obtained at 28 days for control and test specimens, and from the results that are shown in Table 3 and Fig.4, it can be found that at 10% and 20% replacement of 'S' with 'D', the flexural strength are 11.2 N/mm^2 and 10.6 N/mm^2, showing an increase in flexural strength of about 12% and 6% respectively, when compared to control specimens of 10 N/mm^2. For concrete with 30% and 40% replacement of 'S' with 'D', the flexural strength has reduced by 6.25% and 7.75% (showing values of 9.375 N/mm^2 and 9.225 N/mm^2) respectively.

TABLE 3
FLEXURAL STRENGTH OF CONCRETE @ 28DAYS

Identification	Sand (%)	Quarry Dust (%)	Flexure Strength at 28 days (N/mm^2)
S100 D0	100	0	10
S90 D10	90	10	11.2
S80 D20	80	20	10.6
S70 D30	70	30	9.375

International Journal of Scientific & Engineering Research Volume 4, Issue 5, May-2013
ISSN 2229-5518

S60 D40	60	40	9.225

S – Sand; D – Quarry Dust

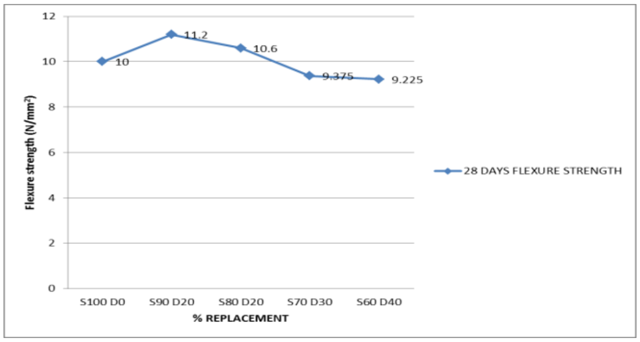

Fig. 4. Prismatic Flexural Strength Vs. % Replacement

5 Conclusion

One of the ways to improving sustainability is to reduce the human consumption of natural resources. In order to protect the natural resources such as river sand, this study has identified quarry dust, which is a waste product from stone crushing industry and available almost free-of-cost, as partial replacement for river sand. This study has brought out positive results that quarry dust can be effectively used as a partial replacing material upto 10% of natural river sand in M35 concrete. The present authors would like to highlight that this method of reducing the usage of river sand in concrete will not only cut down the cost of construction, but also reduce the level of illegal extraction of sand from the river beds but also will certainly help in preserving the natural resources and solve some sustainability issues. Also, reusing industrial wastes such as quarry dust will bring down the need for landfill disposal, and to a great extent, avoid the conversion of fertile lands into dumping yards. While recommending the application of quarry dust waste material in concrete, the present authors recommend that future studies may be taken up on this replacement technique in cement mortar for wider applications in ceiling and wall plastering and tiling work applications, and other concrete mix ratios.

Acknowledgment

The authors, Dr. P.B. Sakthivel, C. Ramya and M. Raja wish to thank the Management of Jerusalem College of Engineering, Chennai for providing all facilities for conducting this experiment on replacement of quarry dust in concrete.

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