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Strength Properties of Concrete with Partial Replacement of Cement by Granite Quarry Dust

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***Abstract*- Granite quarry sludge is the waste from rock processing in quarries and crusher units. The fines are at present disposed by filling in barren land causing serious environmental issues. If this material is possible to be used for partial cement replacement it is of benefit both economically and environmentally. The effect on strength properties of concrete in replacing some portion of cement by quarry sludge obtained from a local crusher unit is analyzed.**

The research work carried out included an experimental investigation on strength properties of concrete made with 2.5% to 20% replacement of cement by quarry dust of less than 75 micron particle size. The tests were carried out to find the compressive strength, splitting tensile strength and flexural strength on specimens.

Results showed that up to 7.5 % replacement of cement by quarry dust there was no reduction in compressive strength, splitting tensile strength and flexural strength.

The experimental work was carried out with M sand confirming to zone II as fine aggregate in concrete. Test is also carried out using another fine aggregate, namely bottom ash obtained from the furnace of an industry combined with manufactured sand. The study showed that the trend is same whatever be the fine aggregate used.

Keywords—quarry sludge; concrete; waste; strength.

I. INTRODUCTION

Concrete is the most popular building material in the world. After aggregate, cement is the majour component of concrete. The yearly production of cement is nearly 3 billion tons. Emissions from industries adversely affect earth's climate pattern. Nearly 7 % of the total global CO_2 emission is contributed by cement industries. Reducing the consumption of cement in concrete will thus reduce the emission. Using of supplementary cementing materials such as fly ash and granulated slag offers reduction in consumption of cement. If an adequate industrial or agricultural by-product which is a waste material can replace cement partially it will reduce the emission. It will also be an environment friendly method of disposal of large quantities of materials that would otherwise pollute land, water and air. Rock dust/sludge which is an abundant waste from granite rock quarries and crusher units is such a material. Disposal of the sludge by land filling is causing serious environmental concern. If this waste can be used as a partial cement replacement material in concrete it will be a valuable resource.

T. Ramos et al studied the effect of granitic sludge from a quarry as a partial cement replacement material in mortar in terms of strength and durability, so as to envisage its use in concrete. [1] The granite rock sludge was analyzed as cement replacement for strength and durability testing, for alkali-silica reaction expansion (ASR) and chloride attack. From the analysis it is found that there is marginal workability and strength loss for up to 10% cement replacement. It is also found that there is improvement of reduction in ASR expansion and improvement in chloride resistance. Scanning electron microscopy (SEM) after ASR attack showed deeper surface grooving and thicker gel layers corresponding to higher measured expansion. SEM on mortar after chloride ingress showed that aluminates led to formation of chloro aluminates explaining good results.

Quarry granitic sludge waste studied is mainly composed of silica and alumna and therefore in accordance with chemical requirements regarding pozzolanic materials.

Ho DWS et al studied the use of quarry dust for self compacting concrete application.[2] [It is observed that the introduction of quarry dust to mixes is limited due to its high fineness. Its addition to fresh concrete would increase the water demand and consequently the cement content for given workability and strength requirements. Strength results for coarser and finer mortars at 28 days were lower than control mix, where flexural and compressive strength decreased with increase of replacement dosage. Nevertheless strength loss is marginal when using finer.

Abukersh.S et al studied on 'Recycled aggregate concrete produced with red granite dust as a partial fine aggregate replacement.'[3] The experimental test results showed that the use of granite dust at 20 to 50% level reduces significantly the concrete compressive strength and had little negative effects on concrete tensile strength.

The effect of using granite dust on producing concrete bricks was also studied by Hamza et al. [4] The test results showed that the use of granite dust had a positive effect and the optimum granite content was 10 %.

Johan DA et al in 'Concrete Petrography' a handbook of investigative technique[5] explained that the presence of chloro aluminates suggests that alumna present in granite sludge may react with chlorides and thus retard chloride ingress. This may help to explain lower apparent chloride diffusion coefficients when there is sufficient fineness of granite sludge as a partial cement replacement material.

Abd Elmoaty et al studied on mechanical properties and corrosion resistance of concrete modified with granite dust [6]. The cement pastes modified with granite dust were examined using thermo gravimetric analysis (TGA), X-ray and SEM. Granite dust cement replacement or addition of 5.0%, 7.5%, 10.0% and 15.0% were used. The test results showed an improvement on concrete compressive strength at 5.0% granite dust as cement replacement and improvement on compressive strength at most levels of granite dust as cement addition. Finally, a reduction in water cement ratio around 0.03 was enough to cancel the reduction in concrete compressive strength as a result of granite dust up to 15.0% as cement replacement.

Dr.T. Felix Kala et al reviewed on 'effect of granite powder on properties of concrete.'[7] An experimental study on the high performance concrete made with granite powder as fine aggregate and partial replacement of cement with 7.5 % silica fume, 10% fly ash and 10% slag subjected to water curing is conducted for finding the mechanical properties such as compressive strength, split tensile strength, modulus of elasticity, flexural strength and water absorption characteristics of concrete mixtures. The test results show clearly that granite powder as a partial sand replacement has beneficial effects of the mechanical properties of high performance concrete. Of all the six mixtures considered, concrete with 25% of granite powder was found to be superior to other percentages of granite powder concrete as well as conventional concrete and no admixtures concrete for all operating conditions.

M.S. Jaafar et al made study on 'Strength and durability characteristics of high strength autoclaved stone dust concrete.'[8] The study focused on the effect of using fine stone dust as cement replacement on the mechanical properties as well as durability characteristics in high strength concrete. 30% of the OPC was replaced by fine stone dust having 95% purity of silica. The result of the study indicated that high strength concrete can be produced using fine stone dust with improved strength and durability.

Yogesh Aggarwal & Rafat Siddique in paper on 'microstructure and properties of concrete using bottom ash and waste foundry sand as partial replacement of fine aggregates'[9] has given the study report. This paper presents the experimental investigations carried out to study the effect of use of bottom ash as replacement of fine aggregates.

Compressive strength, Splitting tensile strength and Flexural strength of fine aggregates replaced bottom ash concrete specimens were lower than control concrete specimens at all the ages. Mix containing 30% and 40% bottom ash, at 90 days, attains the compressive strength almost equivalent to of compressive strength of normal concrete at 28 days. Furthermore, it was observed that the greatest increase in compressive, splitting tensile and flexural strength were achieved by substituting 30% of the natural fine aggregate with bottom ash as fine aggregate.

II SIGNIFICANCE OF THE PROJECT

Lot of research works are carried out on fines passing through 150 micron sieves used for replacing fine aggregates. Most of the construction specifications today limit the proportion of materials finer than 150 micron to 5% to 10% or less. The permissible limit of fines passing the 150 micron sieve is 20 % in the case of manufactured sand as per IS 383-1970. Detailed research works needs to be done in using quarry dust of fines less than 150 mm micron to replace a portion of cement.

Objectives of project work could be summarised as to

- Compare **t**he properties of conventional concrete mix M30 with **t**he properties of concrete with granite quarry dust partially replacing cement.
- Find the optimum percentage of quarry dust that can be replaced for cement.
- Study the effect of strength properties with the optimum % cement replacement with another fine aggregate namely bottom ash.

Scope of project work was to

- Make use of the locally available granite quarry dust as partial replacement of cement.

III EXPERIMENTAL WORK AND RSULTS

A Materials.

The cement used for the experimental work is ordinary Portland cement of grade 53. A single brand namely Ramco cement is used. Material tests for standard consistency, initial setting time, final setting time, specific gravity etc. were carried out and found as conforming to the requirement.

Granite quarry dust from a local crusher unit is collected for the study. The sludge obtained from washing the aggregates is collected and prepared by wet sieving through 75 micron sieve. The specific gravity is 3.01.

The type of fine aggregate used is manufactured sand from granite rock. Sieve analysis of M sand is carried out as per IS:2386 (Part I) and it is conformed to grade for Zone II. M sand was having a water content of 0.80% and water absorption of 1.20 %.

Sieve analysis of fine aggregate (bottom ash) is also carried out as per IS:2386 (Part I) and found to be in zone II. For bottom ash water absorption was 1.40 %, and moisture content 0.3 %.

20 mm nominal size broken stone is used as coarse aggregate in the experiment. The distribution of grain size was found to be within the upper and lower limit of percentage finer on each sieve size and so conforms to the requirement as per IS specification for coarse aggregate. The specific gravity was 2.74.Water absorption was 0.80 % and there was no moisture content. The aggregate crushing value, aggregate impact value, flakiness index all are found to be within the specified requirement.

The superplasticiser used is master glenium SKY 8233 which is a high-performance super plasticizer based on polycarboxylic ether. The manufacturer is BASF chemical company and it is conforming to IS 9103:1999 and IS 2645 :2003. Specific gravity is 1.08 and recommended usage is between 0.4% and 1.50%.

B Test parameters

Slump test is carried out to study the workability of fresh concrete and to check the uniformity of concrete from batch to batch. Compaction factor test is also done to study the workability of concrete. The compacting factor obtained for elected control mix was 0.93 which tallies with a slump of 100.

M30 mix was considered for the test. Mix design, severe exposure condition, placing of concrete by pumping, using superplasticiser and a water cement ratio of 0.45 is considered. Based on trial with superplasticiser a free water content of 180 liters gave a slump of 100 mm.

The tests carried out were for compressive strength on 150 mm cubes, splitting tensile strength and flexural strength on standard specimens.

The mixes are designated with the % replacement suffixed with QD for quarry dust and BA for bottom ash. Testing was carried out on 2.5,5,7,5,10,15 and 20% replacement of cement by quarry dust (QD). Testing was carried out on conventional mix (control mix) without any replacement and on mixes with 10, 20, 30 and 50% M sand replaced by bottom ash. Testing was also carried out on mixes with 10, 20, 30 and 50% M sand replaced by bottom ash along with the optimum replacement of cement with quarry dust. The mix proportions used are given in table 1.

Mix	W/C ratio	Cement	Granite Dust	water	Coarse aggregate	M Sand	Bottom ash	Super plasticizer
Control	0.45	400	0	180	1072	819	0	0.40
2.5 QD	0.45	390	10	180	1072	819	0	0.40
5.0 QD	0.45	380	20	180	1072	819	0	0.40
7.5 QD	0.45	370	30	180	1072	819	0	0.40
10 QD	0.45	360	40	180	1072	819	0	0.40
15 QD	0.45	340	60	180	1072	819	0	0.40
20 QD	0.45	320	80	180	1072	819	0	0.40
10 BA	0.45	400	0	180	1072	737	71	0.45
20 BA	0.45	400	0	180	1072	655	142	0.50
30 BA	0.45	400	0	180	1071	573	213	0.60
50 BA	0.45	400	0	180	1071	409	355	0.70
7.5 QD &10BA	0.45	370	30	180	1072	736	71	0.45
7.5 QD &20BA	0.45	370	30	180	1071	654	142	0.50
7.5 QD &30BA	0.45	370	30	180	1071	572	213	0.60
7.5 QD &50BA	0.45	370	30	180	1070	409	355	0.70

C Test results and discussion.

The most common of all tests on hardened concrete is the compressive strength as many of the desirable characteristics of concrete are qualitatively related to it and mainly because of the intrinsic importance of it in structural design. For each mix nine specimens are cast and three cubes each are tested after 3, 7 and 28 days curing in compression testing machine.

The compressive strength of control mix and for mixes with 2.5, 5, 7.5, 10, 15 and 20% of cement replaced by granite quarry dust are found from the test. The result on compressive strength of concrete is graphically represented in fig.1. From

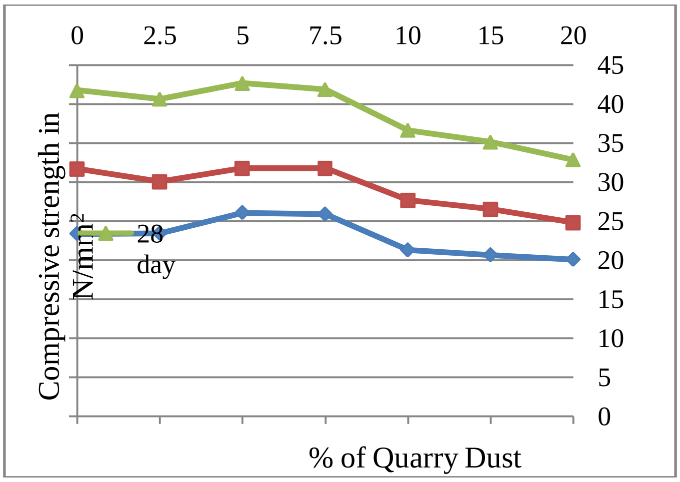

Fig.1 Compressive strength of concrete with different % replacement of cement by quarry dust.

the graph it is seen that there is no reduction in compressive strength when 5% and 7.5 % of cement is replaced by quarry dust. There is progressive reduction in strength for replacement of 10% and above. The reduction in concrete compressive strength as a result of using 10% and above granite dust as cement replacement may be due to the reduction in cement content. Also the present test results show that the reduction in concrete compressive strength decreases with the increase of curing time.

The fine aggregate used for the concrete is M sand which contains 17 % particles finer than 150 microns. The code allows usage up to 20% particles finer than 150 microns.

Hence the provision allows only a further 3 % addition of rock dust in the concrete. From test it is found that if further fines are added replacing cement there is no reduction in compressive strength.

Compressive strength of concrete mixes made with and without bottom ash is given Figure 2.

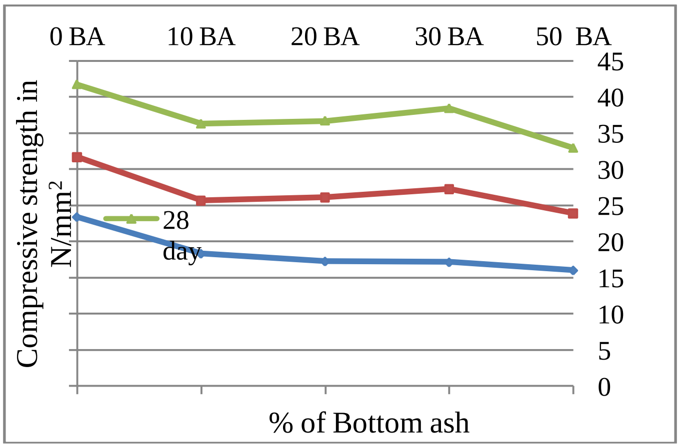

Fig.2. Compressive strength of concrete with replacement of M sand by bottom ash.

The bottom ash concrete gains strength at a slower rate in the initial period and acquires strength at faster rate by 28 days. Earlier studies have reported that due to pozzolanic action of bottom ash strength is comparable at 90 days. This study shows that the strength for 30% replacement is the most adequate and at this level the targeted mean strength is obtained even though there is slight reduction in compressive strength compared to that of control mix.
From the study of replacement of cement by quarry dust it is identified that up to 7.5% replacement of cement there is no reduction in compressive strength. So the effect of replacement of this 7.5% cement when another fine aggregate other than the M sand can also be studied if the combination of M Sand and bottom ash is selected as fine aggregate Cubes with varying percentage of bottom ash as fine aggregate and with the optimum 7. 5% replacement level of cement with quarry dust are cast and tested and the test results are plotted in fig. 3.

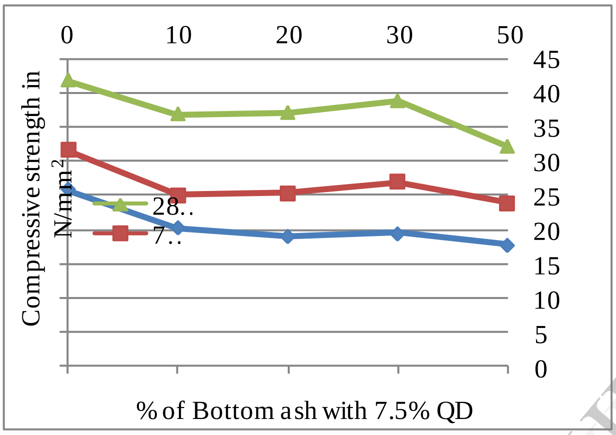

Fig 3. Strength of concrete with replacement of M sand by bottom ash and 7.5% of cement by quarry dust.

This shows that for 7.5% cement replacement the compressive strength is slightly more than the control mix when the fine aggregate is M sand as well as when fine aggregate contains different levels of bottom ash in it.
It also shows that 30% replacement of M sand by bottom ash is the most adequate whatever be the cementitious material.
The effect in splitting tensile strength in using quarry dust as cement replacement is shown in fig. 4.

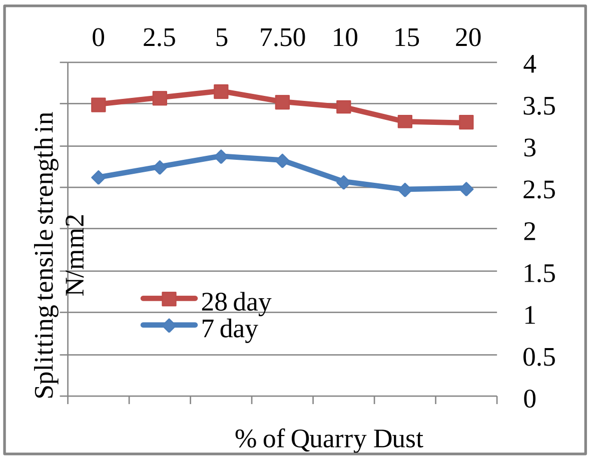

Fig 4 Splitting tensile strength of concrete with % replacement of cement by quarry dust

From this it is seen that use of 7.5% of quarry dust as cement slightly enhances the concrete tensile strength when compared to control mix. The trend is same for all ages of curing. For above 7.5 % replacement levels the decrease in tensile strength is only marginal at the ages of 7 as well as 28 days curing. These test result agree with test result of compressive strength for concrete modified with quarry dust as cement replacement.
Relation between concrete compressive strength F_c and concrete tensile strength F_t for concrete modified with granite dust as cement replacement shows that the concrete tensile strength is about 8 to 11% from concrete compressive strength. Also it is clear that the value of F_t/F_c is granite dust independent.
The result of splitting tensile strength of mixes with 7.5% quarry sludge and various percentages of replacement of M sand with bottom ash is shown in fig.5.

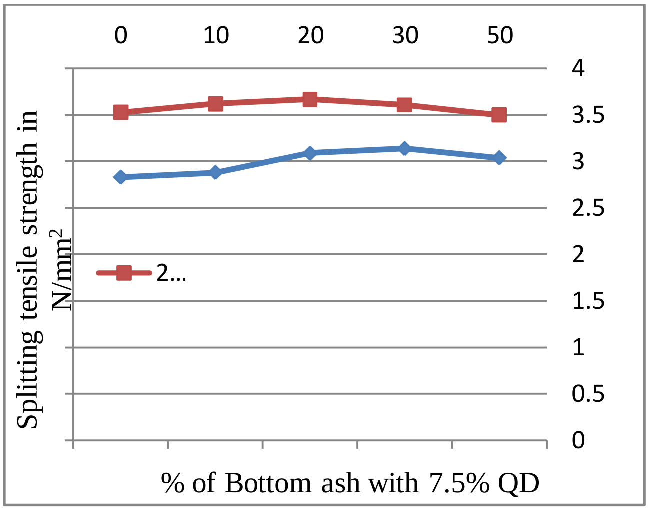

Fig.5. Splitting tensile strength of concrete with M sand and bottom ash and 7.5% replacement of Quarry Dust.

At 28 days curing there is increase in splitting tensile strength for 10%, 20% and 30% replacement and much less when replacement is 50%.

The flexural strength of control mix and for mixes with 2.5, 5, 7.5,10, 15 and 20% of cement replaced by granite quarry dust

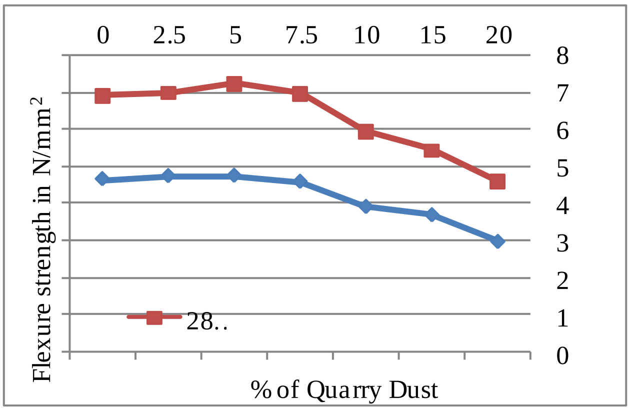

Fig.6. Flexural strength of concrete for % replacement of cement by quarry dust.

were also found from the test.The effect in flexural strength in using quarry dust as cement replacement is shown in fig.6. It is seen that use of up to 7.5% of quarry dust as cement slightly enhances the concrete flexural strength when compared to control mix. The trend is same for 7 days and 28 days curing. For above 7.5 % replacement levels there is decrease in tensile strength marginal for 10% and progressing further.

These test result agree with test result of compressive strength for concrete modified with quarry dust as cement replacement. Specimens with varying percentage of bottom ash as fine aggregate and with the optimum 7. 5% replacement level of cement with quarry dust are cast and tested and the test results are shown in Figure 7.

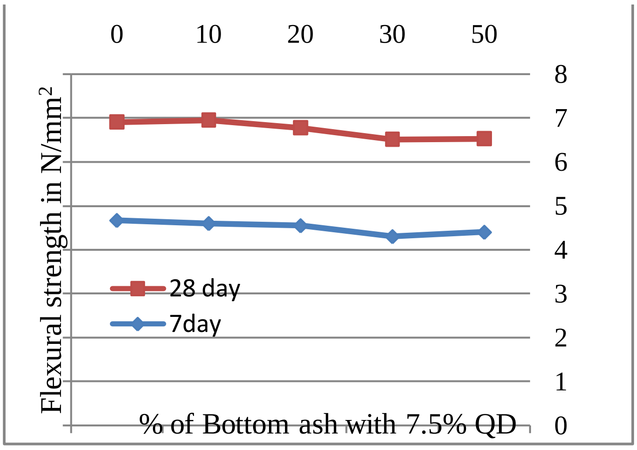

Fig.7. Flexural strength of concrete for7.5 % replacement of cement by quarry dust and bottom ash with M sand.

It is observed that when quarry sludge as 7.5% replacement of cement is used with different % of bottom ash as fine aggregate there is only slight fall in flexural strength. It is also observed that 30 % replacement of M sand with bottom ash gives comparable flexural strength at the age of 28 days. Bottom ash concrete gains flexural strength with the age that is comparable. The trend in result is independent of use of partial replacement of quarry dust for cement. Also whatever be the fine aggregate the trend is same for replacement of cement by quarry dust.

IV CONCLUSION

To investigate and identify supplementary by-product materials that can be used as substitutes for constituent materials in concrete is the need of the present.

Granitic dust is an abundant waste from granite rock processing, causing serious environmental concern. Studies so far done has revealed that quarry dust if used as a cement replacement material upto 5% and as cement addition upto 10% will increase durability study without compromising strength and workability.

Based on this experimental study, the following conclusions are drawn.

Granite sludge can be substituted for cement up to 7.5 %. The result obtained shows that there is no loss in compressive strength in replacing cement by quarry dust up to 7.50%. The tensile strength and flexural strength are also not affected for replacement of cement by quarry dust up to 7.5%

The study shows that 30% replacement of M Sand with bottom ash has given a 28 day compressive strength of 38.43 MPa (target mean strength is 38.25kN/m^2). The result shows that bottom ash can be used to substitute M sand and the optimum replacement level is 30%. The effect of using quarry dust to replace the identified optimum of 7.5% of cement along with bottom ash to partially replace M sand at 10% to 50% is studied and it shows that the result is almost of same pattern if the cement contains quarry dust or not.

There is no difference whatever be the fine aggregate used in the strength properties when cement is partially replaced by quarry dust.

The use of quarry dust in concrete will reduce carbon emission as a result of reduced cement consumption inhibiting the culture of green building and technology and reduction of landfill costs and ill effects of land filling using such waste products.

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