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Experimental Study on the Properties of Concrete with Replacement of Cement by Quarry Sludge

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***Abstract*--Quarry sludge is a residue which shows certain chemical properties similar to cement that is obtained from rock crushing units. Like every industrial waste, quarry sludge also causes environmental hazards which urges to think of an outcome of utilizing it in an efficient manner. Currently, there are many researches to use supplementary cementing materials as cement replacement partially to accomplish more strength. This experimental program encompasses 0%, 5%, 10%, 15% and 20% of cement replaced by quarry sludge for M30 grade concrete for studying the strength properties and durability properties. This study also includes Scanning Electron Microscopy and X-Ray Diffraction. Results showed up 20% of partial replacement of quarry sludge improves strength properties of concrete.**

Keywords : Quarry Sludge, Compressive Strength, Split Tensile Strength, Durability Tests, XRD, SEM.

INTRODUCTION

Currently, the construction industry today is in a rapid requirement of concrete. Naturally cement is the supremacy constituent of the concrete. This results in the production of cement in a large quantum which has consequences such as the emission of carbon dioxide. Amount of carbon dioxide emitted by the cement industry is nearly 900 kg for every 1000 kg of cement produced which affects earth largely. For this reason, there is an essential urgency for discovering an alternative supplementary cementing material. This study involves quarry sludge being partially replaced by cement to achieve high performance and also to reduce the disposal of large quantities of abundant waste materials which paves way for pollution making the attempt environmental friendly.

Soman K, et al studied the strength properties of concrete with partial replacement of cement by granite quarry dust.[1] 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. The tests were carried out to find the compressive strength and flexural strength on specimens 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.

Venkata sairam kumar N, et al made experimental study on partial replacement of cement with quarry dust. [2]The percentages of quarry dust partial replacement of cement in concrete are 0%, 10%, 15%, 20%, 25%, 30%, 35% and 40%. M20, M30, M40 grade concrete cubes of 150x150x150mm size were cast for conducting compressive strength test. From the observations of test results, cement can be replaced with 25% of quarry dust in concrete. The physical and mechanical properties of materials used in concrete were investigated.
The effect of using granite dust on producing concrete bricks was also studied by Hamza et al.[3] The test results showed that the use of granite dust had a positive effect and the optimum granite content was 10%.

M.S. Jaafar et al made study on strength and durability characteristics of high strength autoclaved stone dust concrete.[4] 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.
Dr.T.Felix Kala et al reviewed on ‘effect of granite powder on properties of concrete’.[5] 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.

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% were used. The test results

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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.

MATERIALS

Quarry sludge

Quarry sludge which is of powder state has to be obtained from quarry dust that is collected from crusher units is subjected to sieving using IS 90 microns. Specific gravity of Quarry Sludge is 2.67.

Fine aggregate

River sand which is the natural fine aggregate is been used in this study. Sieve analysis is carried out. Specific gravity of fine aggregate is 2.59 and fineness modulus is 2.84.

Coarse aggregate

20mm size stones is used as coarse aggregate in this study. Specific gravity is 2.75.

Cement

Ordinary Portland cement of grade 53 is used for this study. Properties of cement are given in the table 1

Table 1: Properties of cement

S.No	Description	Results
1	Fineness of cement	3%
2	Specific gravity	3.056
3	Standard consistency of cement	30%
4	Initial setting time Final setting time	115 min 165 min

Water

Water used in the production of the concrete samples for this study was clean tap water from the laboratory.

Mix design for M30 grade concrete

The mix design was done as per IS 10262 : 2009

Table 2: Mix Design for M30 grade

Mix design proportion			
Cement	Fine aggregate	Coarse aggregate	Water
492.1	631.86	1094.61	197.16
1	1.282	2.221	0.4

MECHANICAL PROPERTIES

Compressive strength

Concrete has certain compressive strength. But this study is to increase the normal compressive strength values. Cubes of 150x150x150 mm size were used confirming to IS516. Totally 45 cubes were cast for different percentages and are kept for curing for 7 days, 14 days and 28 days.

Split tensile strength

Concrete normally is poor in split tensile strength. This study is to increase the split tensile strength. Cylinders of size 150mm diameter and 300mm height have been used. Totally 45 cylinders were cast for five percentages and are kept for curing for 7days, 14 days and 28 days respectively.

DURABILITY TESTS

Water absorption

Water absorption is an important index for durability of concrete. Cubes of 150mm are casted for the test. Cubes are kept for 7days, 14days and 28 days curing. Specimens are dried at a temperature of 100°c in an oven to constant mass and then immersed in water after cooling to room temperature. Tests are done by weighing the specimens.

Rapid Chloride Penetration Test

Evaluation of the electrical conductance of concrete is analyzed by RCPT test. Durability of concrete depends on the resistance to fluids that can lead to corrosion. RCPT identifies the ability of concrete allowing the fluids to pass through it. The specimens for this test is slice of 100mm diameter x 50mm thick were cut from 100 x 200mm cylinders. Cylinders were casted and are kept for curing for 28 days. Test was adopted by ASTM C-1202 by inducing in between two chambers of diffusion cell filled with sodium hydroxide (0.3N) in positive terminal and sodium chloride (3N) in negative.

MICRO STRUCTURAL ANALYSIS

X-Ray Diffraction

Density of the electrons of any structure is analyzed by X-Ray Diffraction. It identifies the composition of the molecules with a high degree of certainity on an atomic scale. XRD technique is used to evaluate each phase of cement to predict the performance of the concrete. Samples are taken from the optimum percentage of partial replacement obtained from the strength results are used.

Scanning Electron Microscopy

SEM is used to measure bulk phase abundance and surface area of phases. It gives high resolution of solid objects. The analysis of the microstructural characteristics are examined by the Scanning Electron Microscope. It employs to capture images from the cross sections of the concrete specimens. Samples from the optimum replacement are used for the test.

TEST RESULTS AND DISCUSSION

Compressive strength test results

Table 3: Compressive strength test results for 7 days

S.No	% of Quarry Sludge	Compressive Strength For 7 days
1	0	26.51
2	5	25.06
3	10	26.13
4	15	25.07
5	20	27.34

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Table 4: Compressive strength test results for 14 days]

S.No	% of Quarry Sludge	Compressive Strength For 14 days
1	0	26.61
2	5	25.51
3	10	26.27
4	15	29.471
5	20	28.57

Table 5: Compressive strength test results for 28 days

S.No	% of Quarry Sludge	Compressive Strength For 28 days
1	0	36.72
2	5	39.49
3	10	40.495
4	15	42.282
5	20	44.682

Fig 1: 7 days compressive strength

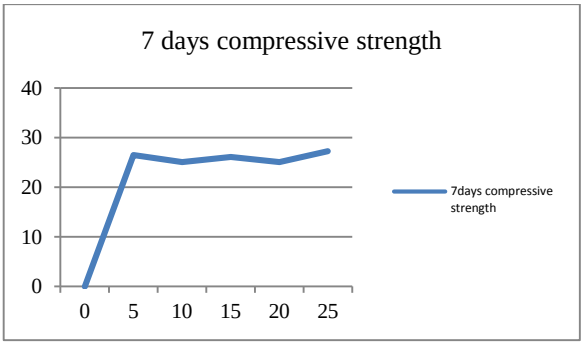


Fig 2: 14 days compressive strength

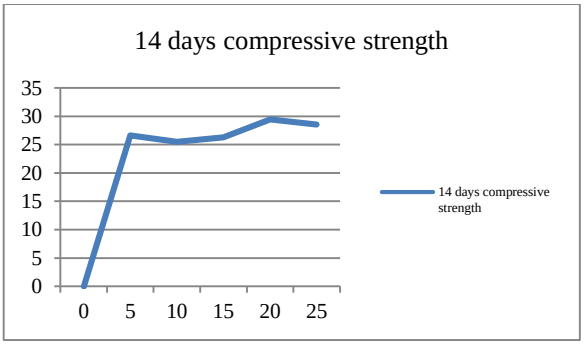
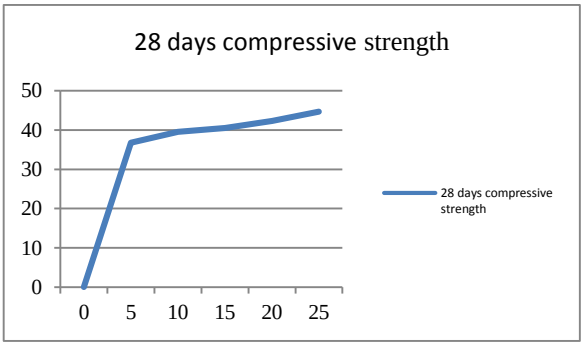


Fig 3: 28 days compressive strength



The results show that there is an increase in the compressive strength of concrete as 3.13% for the 7th day testing, 7.37% increase for the 14th day testing and an optimum value of increase of 21.68% for the 28th day testing.

This shows that Quarry Sludge partial replacement shows desirable increase in compressive strength.

Split tensile test result

Table 6: Split tensile strength test results for 7 days

S.No	% of Quarry Sludge	Split tensile Strength For 7 days
1	0	2.5
2	5	2.8
3	10	2.9
4	15	2.8
5	20	2.6

Table 7: Split tensile strength test results for 14 days

S.No	% of Quarry Sludge	Split tensile Strength For 14 days
1	0	2.6
2	5	2.3
3	10	2.9
4	15	2.5
5	20	2.9

Table 8: Split tensile strength test results for 28 days

S.No	% of Quarry Sludge	Split tensile Strength For 28 days
1	0	2.8
2	5	2.6
3	10	3.0
4	15	2.9
5	20	3.1

Fig 4: 7 days split tensile stength

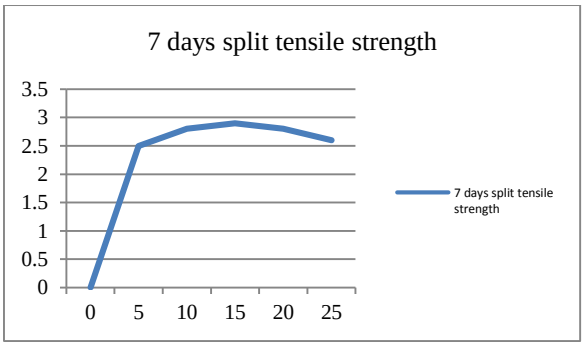


Fig 5: 14 days split tensile strength

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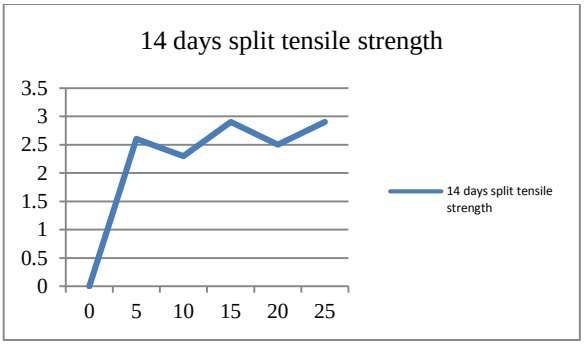
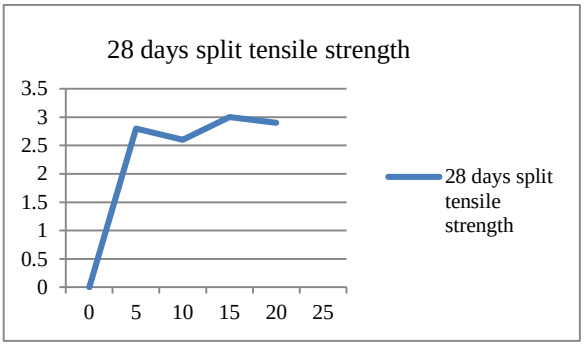


Fig 6: 28 days split tensile strength



The result shows that there is a slight increase in the split tensile strength test as the results are 4% increase for the 7th day, 12.69% increase for the 14th day and final value of 13.93% increase for the 28th day testing. This shows that Quarry Sludge partial replacement gradually increases split tensile strength to a certain amount.

Water absorption test

S.No	Description	Days of curing	Water absorption
1	Conventional Concrete	7 days 14 days 28 days	0.25 0.73 0.86
2	20% Quarry Sludge mix	7 days 14 days 28 days	1.39 1.61 1.35

Table 9: Water absorption test results

Water absorption generally causes problems in the concrete which affects the strength of the concrete. The table 9 shows the test results of the conventional concrete and Quarry Sludge partial replacement optimum value obtained from the strength results for 7, 14, 28 days are given. In the case of 20% of quarry sludge replacement of cement for 7 days, 14 days and 28 days showed higher absorption compared to the conventional concrete mixture was observed.

Rapid Chloride Penetrability Test

Chloride ion permeability test were conducted on cylinder specimens for concrete mixture at 7days, 14 days and 28 days for M30 grade of concrete. The results of chloride penetrability in coulombs for different days of curing are given in the table 10.

Table 10: Chloride permeability

S.No	Description	Charge passed in coulombs	Remarks
1	20% Quarry Sludge mix 7th day	4077	High
2	20% Quarry Sludge mix 14th day	3269	Medium
3	20% Quarry Sludge mix 28th day	2198	Medium

From the table 10, the results show that 20% Quarry Sludge mix shows high chloride permeability. Charge passed for 7th day was 4077, 3269 and 2198 for 14th and 28th day respectively. High value of chloride permeability is observed for the 7th day testing, medium values of chloride permeability for the 14th and 28th day testing. The results show that permeability is significantly reduced with concrete ages.

X-Ray Diffraction

Fig 7 and 8 shows the XRD peaks for the Quarry Sludge specimens.

Fig 7: X-Ray Diffraction pattern of sample 1

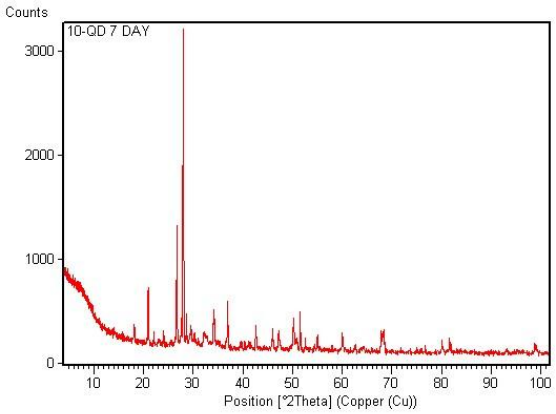
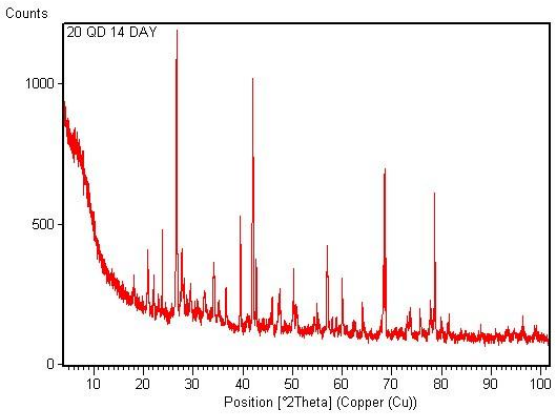


Fig 8: X-Ray Diffraction pattern of sample 2



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The results show that the mineral phases were mostly portlandite, Quartz and albite. The XRD patterns generates two forms of CH (portlandite/Calcium Hydroxide) which is crystalline CH and amorphous CH. Crystalline represents the major phase. The fig 7 represents the XRD pattern of cement replaced with 10% Quarry Sludge and shows that quartz with higher peak and varying Calcium Silicate Hydrate (C-S-H) and aluminium content with no portlandite peak. The formation of portlandite was lower in the sample and as a result makes the concrete dense.

Fig 8 shows the increasing portlandite peak when compared to the previous fig and also shows the increasing peaks of quartz, silica rich C-S-H and aluminium contents. The second sample was cement replaced by 20% quarry sludge and which shows increasing portlandite which proves that increase in the percentage of quarry sludge as cement replacement gives more portlandite.

Scanning Electron Microscopy

SEM shows more complete picture of both bulk and surface phase composition.

Fig 9: Scanning Electron Microscope image of sample 1

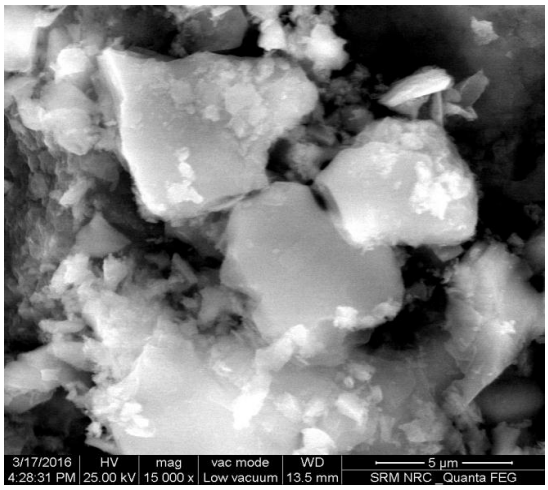
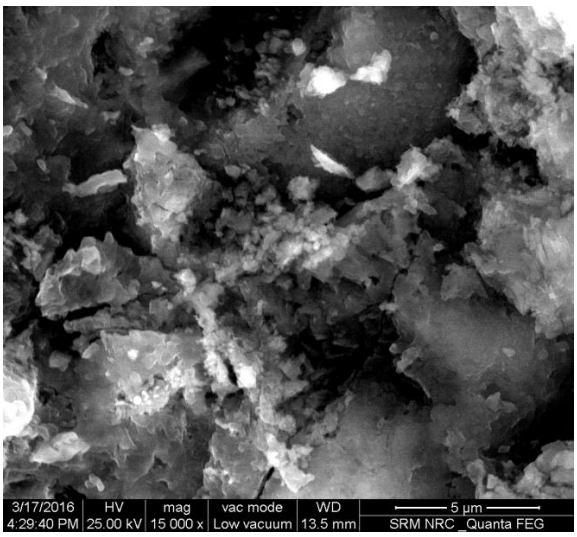


Fig 10: Scanning Electron Microscope image of sample 2



The results gives a complete picture of both bulk and surface phase composition. The fig 9 represents SEM image of cement replaced with 10% Quarry Sludge which shows similar results as of fig 10 which is the second sample of cement replaced by 20% Quarry Sludge and that is finer grained phases such as gypsum, ferrite and tricalcium aluminate shows much higher surface areas than the coarser grained phases such as alite and belite.

The results show that the sample is denser and hence inceases the strength.

CONCLUSIONS

1. Partial replacement of Quarry Sludge in cement shows 21.68% increased compressive strength if the cement is replaced with 20% quarry sludge compared to the conventional concrete.
2. There is enhanced improvement in the compressive strength of concrete without any addition of super plasticizers or other admixtures.
3. 20% of quarry sludge partial replacement shows 13.93% increase in the split tensile strength when compared to conventional concrete.
4. From the results, there is a gradual increase in both the mechanical properties for all the percentages of replacement without compromising workability.
5. The water absorption of the Quarry Sludge concrete is slightly higher than the conventional concrete.
6. XRD shows mostly portlandite, quartz and albite mainly when compared to other mineral phases. XRD, therefore indicates the formation of C-S-H and C-H which are responsible for strength development.
7. The study shows that increase in portlandite was observed with increase in the replacement of cement with quarry sludge.
8. The SEM analysis shows dense microstructure which increases the strength of the concrete.
9. From the results, the use of Quarry Sludge makes an efficient option of partial replacement of cement in every aspects including strength, durability and micro structural analysis.

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