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Partial Replacement of Sand with Quarry Dust in Concrete

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Abstract--The reduction in the sources of natural sand and the requirement for reduction in the cost of concrete production has resulted in the increased need to identify substitute material to sand as fine aggregates in the production of concretes especially in Concrete. Quarry dust, a by-product from the crushing process during quarrying activities is one of such materials. Granite fines or rock dust is a by-product obtained during crushing of granite rocks and is also called quarry dust. In recent days there were also been many attempts to use Fly Ash, an industrial by product as partial replacement for cement to have higher workability, long term strength and to make the concrete more economically available. This present work is an attempt to use Quarry Dust as partial replacement for Sand in concrete. Attempts have been made to study the properties of concrete and to investigate some properties of Quarry Dust the suitability of those properties to enable them to be used as partial replacement materials for sand in concrete.

Key Words: Quarry Dust, Fly ash, Workability, Compressive strength.

I. INTRODUCTION

Concrete is the most popular building material in the world. However, the production of cement has diminished the limestone reserves in the world and requires a great consumption of energy. River sand has been the most popular choice for the fine aggregate component of concrete in the past, but overuse of the material has led to environmental concerns, the depleting of securable river sand deposits and a concomitant price increase in the material. Therefore, it is desirable to obtain cheap, environmentally friendly substitutes for cement and river sand that are preferably byproducts. Fly ash (pulverized fuel ash) is used extensively as a partial replacement of cement [1]. However, though the inclusion of fly ash in concrete gives many benefits, such inclusion causes a significant reduction in early strength due to the relatively slow hydration of fly ash. Nevertheless, fly ash causes an increase in workability of concrete [2]. 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 [3]. When examining the above qualities of fly ash and quarry dust it becomes apparent that if both are used together, the loss in early strength due to one may be alleviated by the gain in strength due to the other, and the loss of workability due to the one may be partially negated by the improvement in workability caused by the inclusion of the other [4].

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The use of Fly Ash in concrete is desirable because of benefits such as useful disposal of a byproduct, increased workability, reduction of cement consumption, increased sulfate resistance, increased resistance to alkali-silica reaction and decreased permeability[5]. However, the use of fly ash leads to a reduction in early strength of concrete. Therefore, the concurrent use of quarry dust and fly ash in concrete will lead to the benefits of using such materials being added and some of the undesirable effects being negated[1]. The decrease in early strength by the addition of fly ash is ameliorated by the addition of quarry dust[4]. The decrease in workability by the addition of quarry dust is reduced by the addition of fly ash. The concurrent use of the two byproducts will lead to a range of economic and environmental benefits. This present work is aimed to determine whether such benefits could be obtained by the use of these two materials together to produce Self Compacting Concrete and to quantify such benefits [6].

II. NEED FOR THE REPLACEMENT OF SAND

Large scale efforts are required for reducing the usage of the raw material that are present, so that large replacement is done using the various by-product materials that are available in the present day [2]. Materials like fly ash [7] especially Class F fly ash is very useful as the fine aggregates [8]. The fly ash is obtained from the thermal power plants which is a by-product formed during the burning of the coal [1]. The other material that can be used is quarry dust which is made while in the processing of the Granite stone into aggregates [9], this is formed as a fine dust in the crushers that process the coarse aggregates, which is used a earthwork filling material in the road formations majorly [9]. Many studies are made with several other materials which gave the concrete to be a material made of recycled material but the parameters that are primary for the material was not satisfied [2].

The properties of concrete in fresh and hardened state are studied in the various papers that are used as a reference for this. Some of the properties are workability, compressive strength are the major one that are considered[4].

III. QUARRY DUST

A. Origin of Quarry Dust:

The quarry dust is the by-product which is formed in the processing of the granite stones which broken downs into the coarse aggregates of different sizes.

B. Physical and chemical Properties:

The physical and chemical properties of quarry dust obtained by testing the sample as per the Indian Standards are listed in the below table

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Table 1 showing the Physical properties of quarry dust and natural sand [2]

Property	Quarry Dust	Natural Sand	Test method
Specific gravity	2.54 -2.60	2.60	IS2386(Part III)- 1963
Bulk density (kg/m3)	1720- 1810	1460	IS2386(Part III)- 1963
Absorption (%)	1.20- 1.50	Nil	IS2386(Part III)- 1963
Moisture Content (%)	Nil	1.50	IS2386(Part III)- 1963
Fine particles less than 0.075 mm (%)	12-15	6	IS2386(Part III)- 1963
Sieve analysis	Zone-II	Zone-II	IS 383- 1970

Table 2 showing the typical chemical properties of quarry dust and natural sand [2]

Constituents	Quarry Dust (%)	Natural Sand (%)	Test method
SiO2	62.48	80.78	IS 4032-1968
Al2O3	18.72	10.52	
Fe2O3	6.54	1.75	
CaO	4.83	3.21	
MgO	2.56	0.77	
Na2O	Nil	1.37	
K2O	3.18	1.23	
TiO2	1.21	Nil	
Loss of ignition	0.48	0.37	

C. Advantages of Quarry Dust:

The Specific gravity depends on the nature of the rock from which it is processed and the variation is less [3].

D. Disadvantages of Quarry Dust:

Shrinkage is more in when compared to that of the natural river sand [2]. Water absorption is present so that increase the water addition to the dry mix[5].

IV. FLY-ASH

A. Origin of the Fly-ash:

The fly ash is the by-product that is formed in the thermal power plants. This is used as a partial replacement of cement now-a-days in general cases.

B. Properties of Fly-ash:

The physical and chemical properties are tested according to the standard specifications.

Table 3 Showing the Physical properties [8]

Property		Result
Specific Gravity		2.227
Fineness	Retained on 45μ Sieve	9%
	Specific Surface, Blaine, m2/Kg	526

Table 4 Showing the chemical properties [8]

Chemical Compound	Percentage Present
SiO2	55.5
Al2O3	31.3
Fe2O3	6.4
CaO	1.02
MgO	0.21
Alkalis equivalent	Nil
TiO2	2.7
SO3	0.44
Loss on Ignition	0.74

C. Sub Classification of Fly-ash:

The fly-ash is classified on the basis of the chemical composition, Class F fly ash is used for the replacement of the sand

Table 5 showing the properties of Class F fly ash

Properties	Percentage of presence
SiO2	55.3
Al2O3	25.7
Fe2O3	5.3
SiO2+Al2O3+Fe2O3	85.9
CaO	5.6
MgO	2.1
TiO2	1.3
K2O	0.6
Na2O	0.4
SO3	1.4
Moisture	0.3

V. MATERIALS USED

A. Cement:

The cement that is used is of OPC 53 grade as per the Standard Specifications of the country [2, 4, and 5]. The cement according to the Indian specification must satisfy the IS code IS 12269- 1987 (reaffirmed 1999).

B. Fine Aggregates:

The natural fine aggregates are the river sand which is the most commonly used natural material for the fine aggregates that is used, but the recent social factor that created a shortage of the material created a great problem in the construction sector [7,8]. For the studies the river sand of Zone-II is used in all the references.

C. Coarse Aggregate:

Ordinary granite broken stone aggregates of size greater than 12mm are used for the study [3,4].

D. Quarry Dust:

The dust is selected from the nearest source as raw materials without any processing of the dust from the quarry.

E. Mixing of the Materials:

The normal grade of the concrete that is used is M20 for normal construction purposes in India[4]. The mix deign is done separately for the quarry dust using the minimum void ratio methods and maximum density method [8].

VI. METHODOLOGY

A. Test on materials:

1. Specific Gravity:

The Specific gravity of the aggregates that are used is tested by following the Indian Standards specification by following IS 2386 (Part III) – 1963. The specific gravity is one of the important factor that everything depends on the design mix also depends on the specific gravity of the materials that we use. As the particle size is less we will use pycnometer for sand. The empty weight of the pycnometer is measured and then it is filled with sand up to a mark and the weight is measured. Then water is filled with water and the weight is measured.

Then weight of the pycnometer only with water is measured and the specific gravity of the fine aggregates used is calculated.
The same method is used for determining the specific gravity of the raw quarry dust.

Picture showing the pycnometer with quarry dust, water

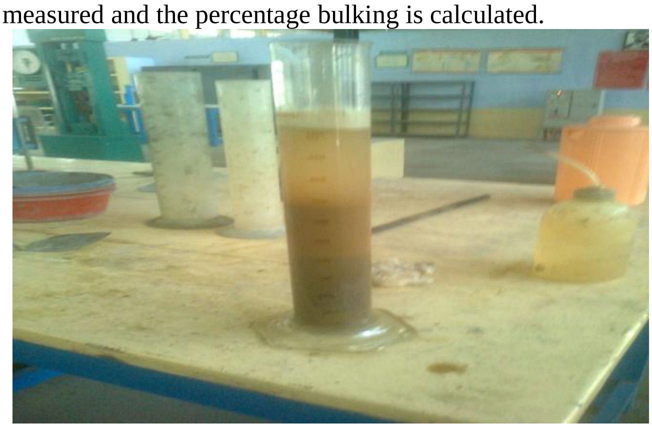
2. Particle Size analysis:

The Particle size analysis is done by following the procedure given in IS 2386 (Part I)-1963, the gradation of the aggregate material is important for determining the size and shape of the material The gradation is used to determine the fineness modulus of the plastic material that is used for casting of the cubes. In the first step the IS sieves are arranged in order(i.e. 4.75mm, 2.36mm,1.18mm, 600µ, 300µ,150µ) . take about 2kgs of fine aggregate and place them on the top most sieve and start sieving them for fifteen minutes and then note down the weight retained on each IS sieve and the values of fineness modulus is calculated. A graph is plotted between the particle size and the percentage fineness on a semi log graph sheet.

The graph that is plotted is called gradation curve / particle size distribution curve(PSD) this is use full to know whether the sample of the aggregates is well graded or poorly graded. If the coarse aggregates is poorly graded it is not used in the construction.

3. Bulking:

The bulking test is done by following the procedure given in IS 2386 (partIII) – 1963, the bulking is the property of change of volume when water is added to the material. Bulking is a major problem while mixing the concrete. A measuring jar is taken and sad is filled up-to a mark in the measuring jar. Then water is added up to the highest mark in the vessel and left it for settling and the settled height is measured and the percentage bulking is calculated.



Picture showing the test for the bulking of quarry dust

4. Workability:

The workability is one of the physical parameters of concrete which affects the strength and durability and the appearance of the finished surface. The workability of concrete depends on the water cement ratio and the water absorption capacity if the aggregates. If the water added is more which will lead to bleeding or segregation of aggregates. The test for the workability of concrete is given by the Indian Standard IS 1199-1959 which gives the test procedure using various equipments. In our case we have used slump cone test for measuring the workability of concrete. We have measured the height of the fall of the cone of concrete for various water-cement ratios and recorded the values for ordinary concrete. Then the same procedure is done with the concrete having the partial replacement of sand with raw quarry dust at various percentages.

Picture showing the cone of the workability test

5. Compressive strength:

Concrete has relatively higher compressive strength, nut very poor in tensile strength. The different mix of concrete gives various strength, according to the IS 10262: 1982 gives the characteristic and design strength values for various grades of concrete. The strength attained by the mix must be tested by its compressive strength of the samples which are made in the standard mould of size 150mm X 150mm X 150mm and then the cubes are kept for curing and the compressive strength test was done according to IS 516: 1959 for 7days, 14days, 21 days and 27days for ordinary mix and for the partial replaced samples.

VII. RESULTS

The results of the physical properties like specific gravity, Particle Size analysis and bulking are the most needed for determining the mix design of the concrete. The results are as follows

A. Specific gravity:

The average values of the specific gravity of natural river sand is 2.596, the average values of the specific gravity of quarry dust is 2.552

B. Particle Size analysis

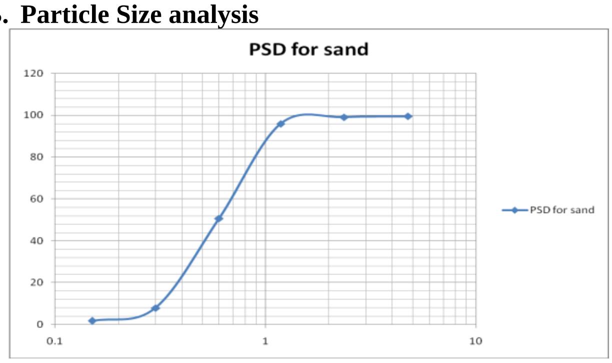


Chart showing the particle size distribution curve of sand

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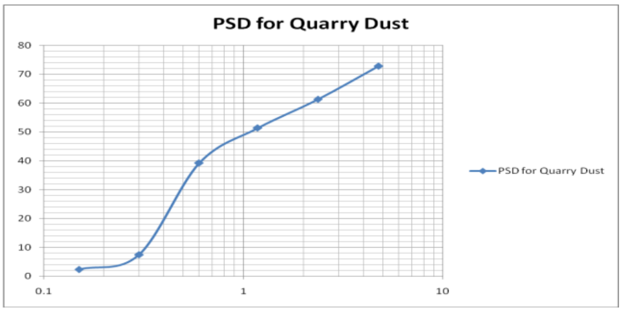

Chart showing the particle size distribution of quarry dust

C. Bulking of aggregates :

Average percentage of bulking of sand is 22.71%; Average percentage of bulking of quarry dust is 24.51%

D. Workability:

The workability test was conducted for various percentages of replacement of sand with quarry dust and at various water-cement ratios. The height of the cone after removing the mould is measured using the standard tamping rod and the values of the height of the cone is tabulated

Table showing the results of workability of ordinary mix

Water-cement ratio	Height of the cone (in cm)
0.5	30
0.55	28
0.60	26
0.7	23
0.8	Total collapse

Table showing the results of workability for mix having sand replacement percentage of 10%

Water-cement ratio	Height of the cone (in cm)
0.5	30
0.55	28
0.60	28
0.7	26
0.8	24
0.9	23

Table showing the results of workability for mix having sand replacement percentage of 20%

Water-cement ratio	Height of the cone (in cm)
0.5	30
0.55	29
0.60	27
0.7	26
0.8	24
0.9	24

Table showing the results of workability for mix having sand replacement percentage of 30%

Water-cement ratio	Height of the cone (in cm)
0.5	30
0.55	30
0.60	28
0.7	28
0.8	26
0.9	25

Table showing the results of workability for mix having sand replacement percentage of 40%

Water-cement ratio	Height of the cone (in cm)
0.5	30
0.55	30
0.60	30
0.7	30
0.8	28
0.9	26

Table showing the results of workability for mix having sand replacement percentage of 50%

Water-cement ratio	Height of the cone (in cm)
0.5	30
0.55	30
0.60	30
0.7	30
0.8	29
0.9	29

Picture showing the complete failure of the slump cone at maximum water-cement ratio

E. Compressive strength results:

The compressive strength results as tabulated

Compressive strength in N/ mm^2			
Days	Ordinary mix	10%	20%
7 days	23.12	22.86	22.65
14 days	24.45	23.87	23.50
21 days	30.52	31.45	31.69
27 days	33.00	34.46	35.21

The results show that there is an increase in the compressive strength of the concrete [4,5] which the increment is about 55% to 75% depending on the replacement if the sand with the quarry dust, for the 100% replacement of the sand the compressive strength is depending on the quarry dust location from where the quarry dust was taken. The workability of the concrete is decreasing when the replacement percentage of the quarry dust is increasing gradually, so as to increase the workability small quantity of the fly-ash is replaced in place of cement to increase the workability[4].

This show that the fly ash and quarry dust replacement showed the desirable results which can suggest the usage of the quarry dust as replacement of sand [5].

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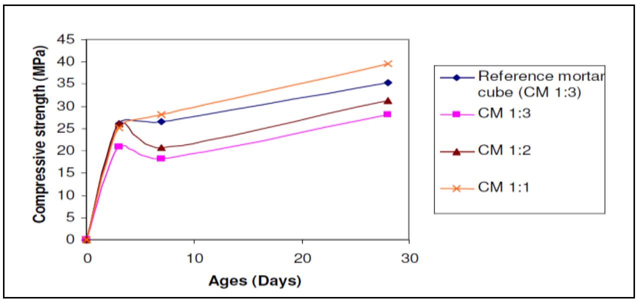
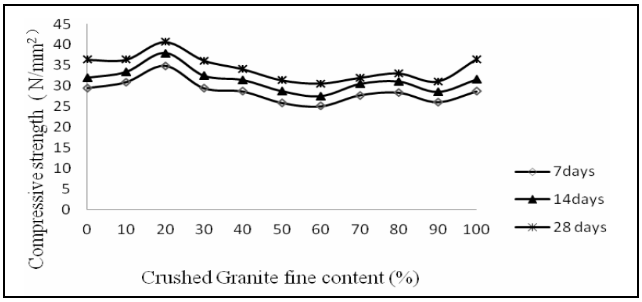
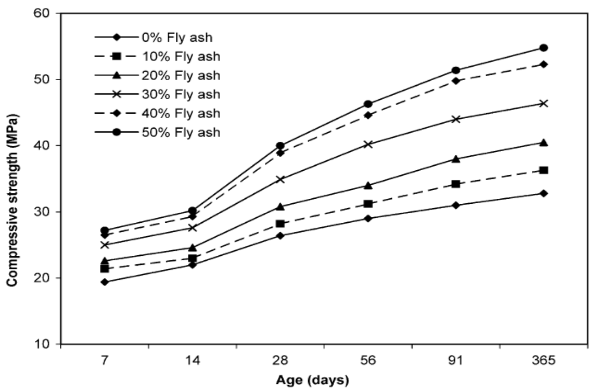


Above graph showing the Compressive Strength of the mortar cubes used with replacement of quarry dust [5]



Above graph showing the Compressive Strength with the replacement of the quarry dust [7]



Above graph showing the compressive strength with fly ash [6]

VIII. CONCLUSIONS

1. The Replacement of the sand with quarry dust shows an improved in the compressive strength of the concrete.
2. As the replacement of the sand with quarry dust increases the workability of the concrete is decreasing due to the absorption of the water by the quarry dust[5].
3. The specific gravity is almost same both for the natural river sand and quarry dust. The variation of the physical properties like particle size distribution and bulking is much varying parameter that which effect the mix design of the concrete.
4. The results from the table show the decrease in the workability of concrete when the percentage of the replacement is increasing. The workability is very less at the standard water-cement ratio and the water that is required for making the concrete to form a zero slump with a partial replacement requires more water. The test conducted at 50% replacement showed that the water-cement ratio increased to 1.6 at which the slump cone failed completely.
5. The ideal percentage of the replacement of sand with the quarry dust is 55% to 75% in case of compressive strength.
6. The further increasing the percentage of replacement can be made useful by adding the fly ash along with the quarry dust so that 100% replacement of sand can be achieved.

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