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Effect of Marble Sludge Powder and Quarry Rock Dust as Partial Replacement for Fine Aggregates on Properties of Concrete

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Abstract-Concrete sustainability involves continuously choosing low impact building materials. Use of alternate aggregate materials has greater potential because 75% of concrete is composed of aggregates. The experimental study has been carried out to investigate the suitability of marble sludge powder and quarry rock dust as partial replacements for fine aggregates. This paper reports the properties of concrete mixtures where in a portion of sand is replaced by marble sludge powder and quarry rock dust and mixtures of both. During this experiment, the properties of concrete were studied for eight series of concrete mixtures by replacing the portion of fine aggregates by marble sludge and quarry rock dust and mixtures of both. The chemical composition and some of the mechanical properties of marble sludge powder and quarry rock dust are reported with that of sand. The effect of quarry rock dust and marble sludge powder on the compressive strength and split tensile strength were recorded at the curing age of 7 and 28 days. All the data are tabulated and compared. It was observed that particular proportions of marble sludge powder and quarry rock dust displayed enhancing effect on the compressive strength.

Keywords: marble sludge powder, quarry rock dust, workability, compressive strength, split strength.

I. INTRODUCTION

Concrete is the most vital material in modern day construction. It is known for versatile properties like high compressive strength and long lasting durability. Due to rapid growth in construction activity, the consumption of concrete is increasing every year. This results in excessive exploitation of natural resources. In some places either natural sand may not be of good quality or good quality sand has to be transported from long distances, which adds to the cost of construction. Therefore, it is becoming inevitable to replace natural sand in concrete by an alternative material either partially or completely without affecting the quality of concrete. Large scale efforts are required for reducing the usage of the raw materials that are currently available, so that large replacement is done using the various by-product materials that are easily accessible in present day (Ilangovan etal 2008).

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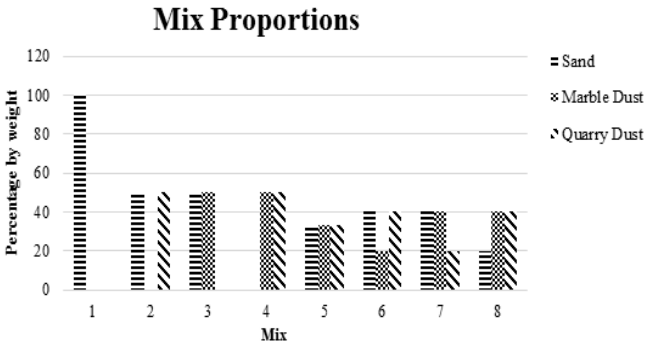
Use of steel industry waste by-products, marble sludge powder and quarry dust provides a great opportunity to be utilized as an alternative for natural sand. Marble is a metamorphic rock resulting from the transformation of pure lime stone. Marble sludge powder is an industrial waste containing heavy metals as constitutes. Chemically, marbles are crystalline rocks composed predominantly of calcite, dolomite or serpentine materials. The other mineral constituents vary from origin to origin. As Indian marble industry has been growing at an annual rate of around 10% every year, India is one among the top world exporters of marble stone. It was reported that about 3,172 thousand tones of marble dust was produced in the year 2009-10. (Prof. Veena G. Pathan, Prof. Md. GulfamPathanetal 2014). The marble industry's waste disposal is one of the environmental problems around the world. Marble powder due to its fineness will easily mix with the aggregates for perfect bonding. Marble powder will fill the voids present in concrete and will give sufficient compressive strength when compared to ordinary concrete. The marble industry's waste disposal is one of the environmental problems around the world. (Corinaldesi et al 2010). Many theoretical studies have been conducted on performance of concrete containing marble dust as admixture (Wu et al 2001, Binici et al 2008 and Corinaldesi et al 2010). Crushed rock aggregate quarrying generates considerable volumes of fine particles less than 4.75 mm IS sieve often termed as "quarry rock dust". Quarry rock dust consists of a mixture of coarse, medium and fine sized particles, plus a clay/silt fraction. The utilization of quarry rock dust which can be called as manufactured sand has been accepted as a building material in the industrially advanced countries of the West (Nisnerichetal 2003).The use of manufactured sand in India is not much,when compared to some advanced countries (Hudson 1997) but recently appreciable number of labs have conducted work on quarry rock dust(Sahuetal 2003, Prakash&Ginidhar 2004, Ilangovan and Nagamani 2006). The consumption of cement content, workability, compressive strength and cost of concrete made with quarry rock dust were studied by researches (Babu et al 1997). The mix design was proposed by Nagrajetal shows the possibility of ensuring the workability by wise combination of rock dust and sand reported significant increase in compressive strength, modulus of rupture and split tensile strength when 40% of sand is replaced by quarry rock dust in concrete(M.C. Dhoka 2013). The advancement of concrete technology can reduce the consumption of natural resources which in turn will further lessen the burden of pollutants on the environment.

The effective utilization of the marble sludge powder and quarry rock dust in construction is desirably an option which would result in sustainable concrete technology. The present study is aimed at utilizing marble powder and quarry rock dust as fine aggregate in cement concrete, replacing natural sand. The study attempts to check the feasibility of these two waste materials to produce self-compacting concrete and to quantify their benefits. This study indicates that marble powder and quarry rock dust can partially replace the fine aggregates without compromising on the properties of the cement.

Composition	Sand	marble powder	quarry dust
Silica	98.66	98.89	98.25
Iron	1.29	0.19	1.63
Manganese	0.033	0.028	0.022

II. MATERIALS

A total of 8 mix series of concrete specimen including the control specimens were prepared in order to examine the effect of substituting marble powder and quarry rock dust (0,20,33 and 50% by weight) for the fine material on the mechanical properties of the mixtures. The compositions of these 8 mix series are depicted in Graph 1.



Graph 1: 8 Mix series showing the percentage of Sand, Marble sludge powder& Quarry dust

Cement:

Commercial grade Ordinary Portland cement (43 grade) with 36 per cent normal consistency was used in order to prepare all concrete specimens. The specific gravity of ordinary Portland cement was 2.9.

Marble Sludge Powder:

Marble sludge powder is obtained in dry form as an industrial by-product directly from deposits of marble factories.The composition of the marble sludge powder was recorded using the instrument(Thermo Scientific Into XL2 Series XRF Analyzer)and the readings are tabulated as shown in Table 1. The specific gravity depends on the nature of the rock it is processed. Marble sludge powder has a specific gravity of 2.57.The physical properties are tabulated as in Table 2. The sieve analysis is shown in Graph 2. The water absorption values were obtained by IS238686 (Part III-1963) test method and was found to be 2%.

Quarry Rock Dust

The quarry rock dust was obtained from local crushers and was used without any processing. The specific gravity of quarry rock dust was 2.56. The composition of quarry rock dust tabulated as in Table 1.Water absorption was 7% (Table 2). The sieve analysis is shown in Graph 2.

Aggregates:

Fine aggregate

The natural fine aggregates are the river sand. The medium sized sand with specific gravity 2.82 was used. The composition of fine aggregate tabulated as Table 1. The Physical Properties are tabulated in Table 2 and sieve analysis as Graph 2.

TABLE 1: Chemical composition of Sand, Quarry rock dust and Marble sludge powder
(percentageby volume).

TABLE 2: Physical Properties of Sand, Marble sludge powder and Quarry rock dust

Property	Marble sludge powder	Quarry rock dust	Natural sand	Test methods
Specific gravity	2.57	2.56	2.82	IS :2386 ,PART 3
Water absorption	2%	7%	3.4	IS:2386,PART3
Bulk density(kg/m3)	1135	1824	1385	Density Bottle

Graph 2: Sieve analysis of sand, quarry rock dust and marble sludge powder

Coarse aggregate

Crushed stone with a size 20mm was used for the study. The specific gravity of coarse aggregate was 2.66.

Water

Tap water available in concrete laboratory was used.

III. METHODS

In Fresh State:

Slump Test: The slump cone test was conducted according to Indian standard IS1199-1959. The strength and durability for the appearance of the finished surfaces are directly affected by the physical parameter of the concrete, more so by the workability.

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The workability of concrete depends on the water cement ratio and the water absorption capacity of aggregate. A standard slump cone of 100 mm diameter at the top and 200 mm diameter at the bottom was used. Difference in height of the fall of the cone of concrete was measured as slump value. The same procedure was done for all the concrete mixtures and the slump values were recorded. Table 3 shows the slump values for different mix proportions.

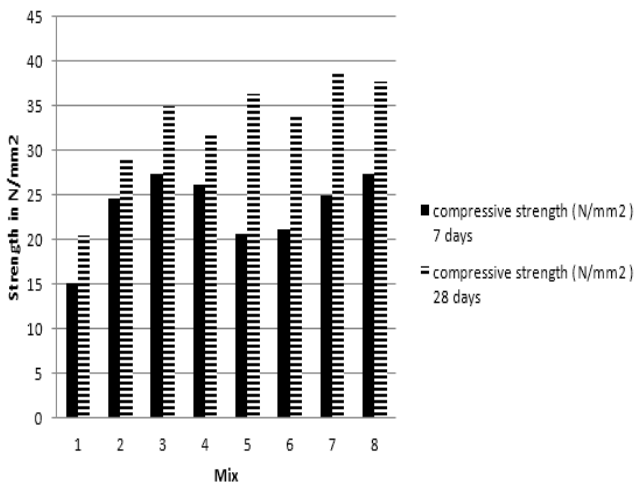
TABLE 3: Slump values showing workability of different mix proportions

Mix id	Slump Value (mm)
Mix 1	27.5
Mix 2	17
Mix 3	8
Mix 4	11
Mix 5	14
Mix 6	19
Mix 7	8
Mix 8	8

In hardened state:

a. Compressive strength test:

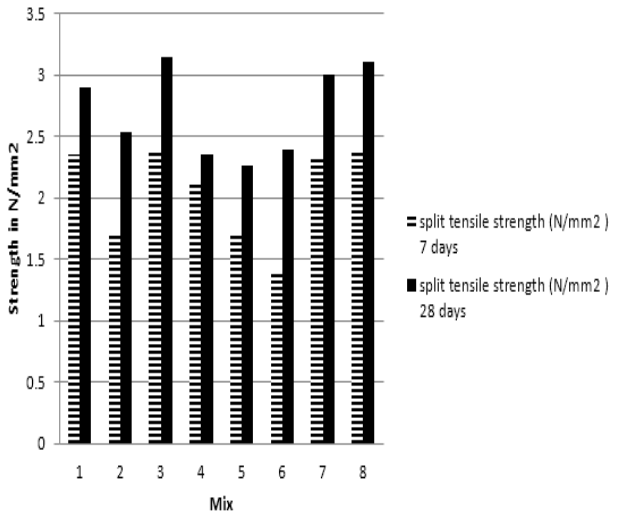
The strength attained by the mixture was tested by the compression test method. The 150 mm size concrete cubes were used as test specimens to determine the compressive strength of concrete. The respective amount of sand, quarry rock dust and marble sludge powder were used to prepare the cubes. The ingredients of the concrete were thoroughly mixed in mixing machine till uniform consistency was achieved; using tamping rod, cubes were compacted.The tests were conducted on universal testing machine on 7th and 28th day respectively. The results are tabulated as shown in Graph.2



Graph 2: Compressive strength for different mixproportion

b. Split tensile strength :

The concrete cylinders of size 150 mm diameter and 300 mm height were used as test specimens to determine the split tensile strength of concrete. The tests wereconducted on universal testing machine on 7th and 28th day respectively. The results are tabulated as shown in Graph 3



Graph 3: Split tensile strength for different mix proportions

IV. RESULTS AND DISCUSSIONS

There is very little variation in the specific gravity of sand, quarry rock dust and marble sludge powder (Table 2). The values on Table 3 denote that the slump values are comparatively less. As per IS code (IS: 1199-1959) it is desirable to have 25 - 50 mm of slump. The compressive strength of the different mix is reported in Graph 2. Surprisingly the control mix (mix1) had the least compressive strength compared to other mixes. It is observed that mix7 viz. 40% sand, 40% marble sludge powder, 20% quarry rock dust had the best compressive strength which means a total of 60% sand can be replaced by 40% marble sludge powder and 20% quarry rock dust. The compressive strength of mix 8 seems to be relatively good; Mix 8 had 20% sand, 40% quarry rock dust and 40% marble sludge powder which means around 80% of sand can be saved in the concrete; similarly mix5 also had better compressive strength viz. 33% quarry rock dust, 33% Sand and 33% marble sludge powder. Graph3 shows the Split tensile strength of concrete. There was not much of difference seen in split tensile strength of concrete compared with the normal concrete (Mix 1). Mix 1, 3, 7 and 8 had high values. Among this mix 3 viz. 50%quarry rock dust and 50%marble sludge powder and mix8 viz. 20% sand ,40%quarry rock dust and 40% marble sludge powder had the best values. The values of mix 1 and mix7 had good values; the values of remaining mix (mix4, 5 and 6) were comparatively less. The properties of the mix having the best values for slump, compressive strength and split strength are tabulated in Table 4. The concrete achieves more bonding (results not shown) with steel and it is observed that in normal concrete corrosion may occur at 28 days but this can be avoided by using marble sludge powder and quarry rock dust.

Table 4: Best Values

Slump	Mix 6	19 mm
Compressive strength	Mix 7	38.66 N /mm^2
Split tensile strength	Mix 3	3.15 N/mm^2

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Cost Saving:

Looking into the cost analysis, we summarize the following,

Cost of materials

$1m^3$ sand = Rs.1500/- , $1m^3$ quarry dust = Rs.700/- , $1m^3$ marble sludge powder =Rs.1280/-

$1m^3$ of concrete has $0.5m^3$ of fine aggregate (sand)

Therefore, the cost of normal concrete with only sand cost: 0.5 X 1500 = Rs.750 /-

Cost of Mix 7: (0.2 X 1500) + (0.2 X 1280) + (0.1 X 700) = Rs.626/-

Saving in sand: 750-626=Rs.124/-

It is well known that $1m^3$ of cement for M-20 concrete requires 8bags of cement. And $1m^3$ of cement for M-25 concrete requires 11bags of cement. Compressive Strength achieved by mix 7 is 38.66 N/mm^2 that is strength of M-25 concrete (which requires 11 bags of cement) so around Rs.900 can be saved (3 x 300). Therefore a total savings of Rs.1024/- per meter cube of concrete (900+124) would be achieved. Since the slump value is less admixture needs to be added, which might cost Rs.576/- (0.75% of weight of cement) Thus around Rs.448/- can be saved in mix7 and Rs.528/- in mix8.

V. CONCLUSIONS

River sand which is one of the constituents in conventional concrete has become expensive not just from economic point of view but also from environmental perspective too. There is an urgent need to seek an alternative. Marble sludge powder and quarry rock dust seems to be an excellent alternative. Marblesludge powder is a by-product of marble production factories and also creates large scale environmental pollution. Therefore, there is a need to ensure the prevention of the environmental pollution caused by marble sludge powder. The use of marble dust powder in construction might be cost effective since this is treated as a waste and is available cheaply in some regions. Concrete achieves more strength, durability and reduces environmental impact. The slump values are less for the mix where marble powder and quarry dust is used in appreciable mounts. This results in the reduced workability. This can be overcome by using admixtures. Addressing the cost benefits, this study provides a strong recommendation for the use of quarry rock dust and marble sludge powder as fine aggregate in concrete manufacturing.

VI. ACKNOWLEDGMENT

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