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An Effort in Developing a Sustainable Concrete using Marble Powder as Partial Cement Replacement and Quarry Rock Dust as Fine Aggregrate with an Emphasis on Cost of Production

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Abstract—*Concrete is well known as a heterogeneous mixture of cement, water and aggregates. In our project we have studied the difference between compressive strength of concrete when they are mixed with additives like stone dust, marble dust and normal concrete. The detailed experimental investigation is done to study the effect of partial replacement of cement with marble dust and 100% replacement of sand with stone dust on concrete. In this project starting with proportion from 5% replacement of marble dust, 10% replacement of marble dust, 15% replacement of marble dust and 20% replacement of marble dust for cement and 100% replacement of quarry rock dust for sand in all the above case, a study has been done for checking the compressive strength of concrete with an emphasis on cost effective nature. It is observed that the strength of concrete goes on increasing with the increase in the percentage of marble dust and 100% replacement of stone dust when they are used upto a fraction in place of cement and sand respectively in concrete.*

Keywords*: Concrete, marble powder, stone dust*

1. INTRODUCTION

Concrete is a building material made from a mixture of broken stone or gravel, sand, cement and water, which can be spread or poured into moulds and forms a stone-like mass on hardening. It is a composite construction material composed of cement (limestone, alumina-silicate, and calcium sulphate), and other cementation materials such as fly-ash, aggregate, water and chemical admixtures. Concrete is well known as a heterogeneous mixture of cement, water and aggregates. The admixtures may be added in concrete in order to enhance some of the properties desired specially. In its simplest form, concrete is a mixture of paste and aggregates. Various materials are added such as marble dust, stone dust, other admixtures etc. to obtain concrete of desired property. The character of the concrete is determined by the quality of the paste. The key to achieve a strong, durable concrete rests in the careful proportioning, mixing and placing of the concrete. Numerous tests are performed on wet concrete such as slump test to measure the workability of concrete. In actual practice, test on workability of wet concrete are carried out to ensure uniform quality concrete only. Strength is not measurable at that stage with the available technology. Therefore the concrete samples are to be cured for 28 days in normal method to arrive at the compressive strength and for necessary follow up action. It is not only difficult to dismantle the suspected portion of concrete at such a stage but also expensive in terms of time and money. Predicting the strength at the manufacturing stage, however, is yet to receive due attention of engineers. Hence, any new approach that is capable of predicting reliably the compressive strength of hardened concrete based on the properties of the ingredients and the wet concrete will be helpful to practicing engineers. Besides, such tests could be performed with the same ease as the workability tests. 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. 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. Gulfam Pathanetal 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. 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 researchers (Babu et al 1997). 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 as a partial cement replacement and quarry rock dust as full replacement with the fine aggregates can give an effective result without compromising on the properties of the cement.

2. WORKABILITY OF CONCRETE

The behavior of fresh concrete from mixing up to compaction depends mainly on the property called “workability of concrete”. According to **IS:6461 (PartVII) - 1973**, workability is that property of freshly prepared concrete mix which determines the ease and homogeneity with which it can be mixed, placed, compacted and finished. Thus workability of concrete is a term which consists of the following four partial properties of concrete mainly Mix ability, Transportability, Mould ability and Compatibility. In general terms, workability represents the amount of work which is to be done to compact the concrete in a given mould. The desired workability for a particular mix depends upon the type of compaction adopted and the complicated nature of reinforcement used in reinforced concrete. A workable mix should not segregate.

3. SIEVE ANALYSIS

We performed the sieve analysis on a sample of aggregate in a laboratory. The typical sieve analysis involved a nested column (25mm, 20mm and 10mm) of sieve with wire mesh cloth (screen).

1. A representative weighed sample is poured into the top sieve which has the screen openings of 25mm. 60% of the total aggregates used in our project were passed through 25mm and retained to 20mm and 40% of the aggregates were passed through 20mm sieve and retained to 10mm sieve.
2. The sieves were shaked manually, usually for some amount of time. The entire nest was agitated.
3. After the shaking was complete the material retained on sieve was weighed.

4. WORKABILITY OF CONCRETE BY SLUMP TEST

Slump test is used to determine the workability of fresh concrete. Slump test as per IS: 1199-1959 was followed. The apparatus used for doing slump test are tamping rod, weights and weighing device, tools and containers for mixing, or concrete mixer, ruler and slump cone which has the shape of a frustum of a cone with the following dimensions: base diameter 20cm,top diameter 10cm and height 30cm.

Fig. 1: Slump mould

5. COMPRESSIVE STRENGTH TEST

150mm x 150mm x 150mm concrete cubes are cast by using M20 grade concrete. Specimens with ordinary Portland Cement (OPC) and OPC replaced with marble dust at 5%, 10%, 15% and 20% levels with sand being fully replaced with quarry dust were casted. During casting the cubes were manually compacted by tamping rod. After 24 hours the specimen is removed from the mould and subjected to water curing for 7, 14 and 28 days. After curing, the specimens tested for compressive strength using a calibrated compression testing machine of 2,000 KN capacities. The apparatus used are weights and weighing device, tools and containers for mixing, tamper (square in cross section), testing machine and three cubes (150 mm side).

Fig. 2: Mould after curing

6. RESULTS AND DISCUSSIONS

WORKABILITY OF FRESH CONCRETE BY SLUMP TESTS

Table 1: Slump tests results

Sl. No.	Particular	Slump (mm)	w/c ratio
1.	Normal M20 concrete	100	0.50
2.	M20 concrete with 5% of cement replaced by marble dust and 100% of sand replaced by stone dust	80	0.50
3.	M20 concrete with 10% of cement replaced by marble dust and 100% of sand replaced by stone dust	75	0.50
4.	M20 concrete with 15% of cement replaced by marble dust and 100% of sand replaced by stone dust	62	0.50
5.	M20 concrete with 20% of cement replaced by marble dust and 100% of sand replaced by stone dust	60	0.50

COMPRESSIVE STRENGTH TEST RESULTS

COMPRESSIVE STRENGTH OF NORMAL CONCRETE

Table 2: Compressive strength results for normal concrete.

Sl. No.	Particular	7 days strength (N/mm^2)	14 days strength (N/mm^2)	28 days strength (N/mm^2)
1.	Normal Concrete	19.42	26.115	29.875

COMPRESSIVE STRENGTH OF CONCRETE CONTAINING MARBLE DUST AND STONE DUST

Table 3: Compressive strength results for concrete with 100% replacement of sand with stone dust and partial replacement of cement with marble dust

Sl. No.	Particular	7 days strength (N/mm^2)	14 days strength (N/mm^2)	28 days strength (N/mm^2)
1.	5% replacement of cement with marble ust	20.295	27.85	32.935
2.	10% replacement of cement with marble dust	21.345	28.865	34.95
3.	15% replacement of cement with marble dust	22.3	30.25	35.715
4.	20%replacement of cement with marble dust	23.005	31.6	38.895

HISTOGRAM SHOWING COMPRESSIVE STRENGTH VERSUS NUMBER OF DAYS

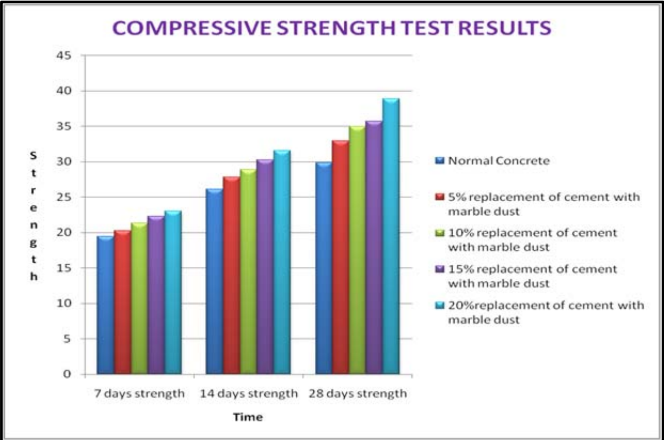

Fig. 3: Histogram

7. COST COMPARISON

Absolute volume of concrete for 50kg of cement

= V_c = [{(w/c ratio /1000) + (mass of cement/ (1000 x sp.gravity of cement)) + (mass of FA/(1000 x sp.gravity of FA)) + (mass of CA/(1000 x sp.gravity of CA)) } x 50]

For normal concrete, V_c= 0.1283 cum. (1:1.63:2.82 for 0.50 w/c)

For full replacement of sand by quarry rock dust and 20% replacement of cement with marble dust, V_c= 0.1320 cu.m. (1:2.07:3.32 for 0.50 w/c)

Considering 2% of entrained air, actual volume of concrete for 1 cu.m. of compacted concrete construction will be = 1- 0.02 = 0.98 cu.m.

Therefore, quantity of cement required for 1 cum. of:

(a) Normal concrete = 0.98/0.1283 = 7.64 bags

(b) Replaced concrete = 0.98/0.1320 = 7.4 bags

Quantity of material for 1cum. of concrete production can be calculated as:

Weight (kg)	Normal concrete	Replaced concrete
Cement	7.64x50 = 382	7.4x50 = 370
FA	1.5x382 = 573	1.5x370 = 555
CA	3x382 = 1146	3x370 = 1110

If 50 kg cement costs Rs.450, 382kg will cost Rs.3438 and if 1 cu.m FA costs Rs.1900, 0.375 cum. will cost Rs.713 in case of normal concrete. Whereas, if 50kg marble dust costs Rs.300 then 74kg (20% of 370kg) will cost Rs. 444 and remaining 296kg (370-74kg) of cement will cost Rs. 2664. The sum of marble dust and cement is Rs. 3108 and if 1cum of quarry dust costs Rs.700, then 0.363 cu.m of FA will cost around Rs. 254.

Hence we can conclude that the use of replaced concrete is also cost effective in nature by providing adequate amount of compressive strength.

8. CONCLUSION

Based on limited experimental investigations concerning the compressive strength of concrete, the following observations are made regarding the resistance of partially replaced marble dust and fully replaced quarry dust:

(a) The value of slump decreases when replacement of marble dust percentage increases and stone dust is fully replaced.
(b) The value of compressive strength of normal concrete is less than the value of replaced concrete, i.e., stone dust is fully replaced in place of sand and partial replacement of marble dust with cement.
(c) As the percentage of replacement of marble dust increases and stone dust is fully replaced, the value of compressive strength gradually increases. This trend can be attributed to the fact that marble dust possess cementing properties and has a lower fineness modulus whereas the physical and chemical properties of stone dust satisfies the requirements of fine aggregate.
(d) Waste utilization makes Green Concrete more environmental friendly.
(e) Green concrete is cost effective in nature

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