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Green Cement For Sustainable Concrete Using Marble Dust

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Abstract: Utilization of waste industrial sludge as a raw material to reduce their adverse effect on environment and make it eco-friendly. Marble sludge powder can be used as filler and helps to reduce the total voids content in concrete. This paper presents the feasibility of the usage of marble sludge dust hundred percent substitutes for natural sand in concrete. The compressive strength and microstructure of blended cement was investigated in this study. The hydration products of cements were identified by means of scanning electron microscopy. Compressive strength discussed as a function of several parameters: curing time, binder composition and (Binder/aggregate) ratio. It was observed that the blended cements developed higher strength, at 28 days compared to 7 days. The strength increase was higher, the higher the marble dust content. So, concrete prepared by marble dust which helpful to reduce consumption of natural resources and energy and pollution of the environment.
Key words*:* marble dust; cement; blended; environment.

1. Introduction

In India the extractive activity of decorative sedimentary carbonate rocks, commercially indicated as Marbles and “Granites”, is one of the most thriving industry. Marble sludge powder is an industrial waste containing heavy metals in its constitutes. Stone slurry generated during processing corresponds to around 40% of the dimension stone industry final product. This is relevant because dimension stone industry presents an annual output of 68 million tons of processed product. Satisfactory strength has obtained by prepared concrete with quarry rock dust along with fly ash[1]. The addition of marble particles, makes the water unfit for reuse and thus the slurry is dumped out of the factory. The disposal of millions of tons of slurry is the biggest environmental catastrophe facing India especially Rajasthan, Tamil Nadu and other states. According to our survey, on an average about 45-50 Metric tonne of marble is cut in a day in a medium scale unit. The slurry generated is about 12- Metric tonne per day, containing about 50% water after treatment in sedimentation tanks, which is transported out of the factory to be thrown at roadside dumps. The slurry has the following composition: Fine marble dust 20%, Water 80%. The rapid industrialization has resulted in generation of large quantities of wastes. Most of the wastes do not find any effective use and create environmental and ecological problems apart from occupying large tracts of valuable cultivable land. It has been observed that some of these wastes have high potential and can be gainfully utilized as raw mix/blending component in cement manufacturing. The utilization of the industrial solid wastes in cement manufacture will not only help in solving the environmental pollution problems associated with the disposal of these wastes but also help in conservation of natural resources (such as limestone) which are fast depleting. The other benefits to cement industry include lower cost of cement production and lower green house gas emission per tonne of cement production. This may also enable cement industries to take benefits of carbon trading. The present study deals with utilization of industrial wastes such as fly ash (from thermal power plants), marble sludge (from marble industry), blast furnace slag and steel slag (from iron & steel industries), phospho gypsum (from fertilizer plants), red mud (from aluminum industries), lime sludges[2] (from sugar, paper, calcium carbide industries), lead-zinc slag (from zinc industries) and kimberlite (from mining) for manufacture of cement and related building materials. Production of cement clinkers from municipal solid waste incineration fly ash. From the results it is observed that all of the major components of ordinary portland cement clinkers are present in the produced clinkers[3] .Waste can be used to produce new products or can be used as admixtures so that natural sources are used more efficiency and the environment is protected from waste deposits[4]. The ordinary stone dust obtained from crushers does not comply with IS: 383-1979. The presence of flaky, badly graded and rough textured particles result in hash concrete for given design parameters. Use of marble dust as a fine aggregate in concrete draws serious attention of researchers and investigators. Marble powder has a very high Blaine fineness value of about 1.5 m^2/g with 90% of particles passing 50 µm sieves and 50% under 7 µm. The maximum compressive and flexural strengths were observed for specimens containing a 6% waste sludge when compared with control and it was also found that waste sludge up to 9% could effectively be used as an additive material in cement. To avoid the pollution and reuse the waste material, the present study is carried out. As the properties are as good as the sand, the marble sludge powder and quarry dust is used as fine aggregate in the cement concrete.

Increase in the concentration of glass fiber reinforced plastic (GRP) waste decreased the compressive strength. [5]However, increase in curing duration (14–180 days) resulted in improving the compressive strength of concrete with 5% GRP application to 45.75 N/mm^2. Rice husk ash (RHA), an agricultural waste, is classified as ‘‘a highly active pozzolan’’ because it possesses a very high amount of amorphous SiO_2 and a large surface area. The sample incorporating the ternary blend of cement with 10% RHA and 10% SF showed better compressive strength than that of the control sample without RHA or silica fume (SF) (Siddique, 2011). The feasibility of partial replacement of siliceous raw material for cement production with water purification sludge (WPS) was investigated by various test. It is found that WPS has no negative effects on the consumption of free lime and the formation of clinker minerals[6]. The following advantage with blended cement:

Admixtures lower the cost of production of Self Compacting Concrete. Admixtures reduce the heat of hydration. The incorporation of mineral admixtures also eliminates the need for viscosity-enhancing chemical admixtures. The lower water content of the concrete leads to higher durability, in addition to better mechanical strength of the structure. The admixtures may improve rheological properties and reduce thermally-induced cracking of concrete due to the reduction in the overall heat of hydration and increase the workability and long-term properties of concrete. To make recommendations to promote utilization of industrial waste and help in solving the environment pollution problems and conserve natural resources. This study deals with compatibility of industrial solid waste as raw material/ blending material/ admixture.

2. Materials And Methods

Marble sludge powder was obtained in wet form directly taken from deposits of marble factories, Northern India. Wet marble sludge powder must be dried before the sample preparation. Marble dust was sieved from 1mm sieve. The high content of various minerals confirmed that the original stones were Marble and limestone. The dust was also tested to identify the absence of organic matter, thus confirming that it could be used in concrete mixtures. IS 456 STANDARD for M20 Concrete 7 days cube compressive strength. IS 456 STANDARD for M20 Concrete 28 days cube compressive strength. With the help of compressing machine the compressive strength of block are determined. Ordinary Portland Cement (43 Grade) with 28 percent normal consistency with specific surface 2100 cm^2/g conforming to IS: 8112-1989 was used. Proportion of various mixture ingredient (Sand, cement, aggregate, water and marble powder) using hydrometer analysis is shown in Figs. 1-2. The chemical compositions of various low cost materials are listed in Table 1. Physical characteristics of marble sludge powder, quarry rock dust and river sand. Moisture content (%): Wet-21.22, Dry-1.43; Bulk density-1007 kg/m^3; fineness modulus-2.01; Effective size-0.12 mm; Coefficient of uniformity-1.34; Coefficient of gradation-1.21.

The WMD used as partial replacement of PC clinker in the amount of 0%, 2.5%, 5.0%, 7.5% and 10% by weight and grounded together with PC clinker and gypsum in order to produce composed cement with additive. Amount of gypsum was fixed as 5% by weight in the cement manufacturing in this study. Amount of WMD was substituted with the same amount of Portland cement clinker. The mixture proportions of constituents used for production of composed cement with WMD are given in the previous Table 2. Portland cement clinker, WMD and gypsum should be separately grounded at specified proportions by means of ball milling. Grinding period was fixed as 1 h in the experiments. The cement pastes are to be prepared by using laboratory type mixer. Initial and final setting times and standard consistency of cement pastes were determined. Soundness of cement pastes was determined by Le Chatelier method. Prepared cement mortars were placed into the steel moulds and after 24 h, samples were removed from moulds. Dimensions of mortar sample were 160 x 40 x 40 mm. Prepared cement mortars were placed into the steel moulds and after 24 h, samples were removed from moulds. They were cured at 20 ± 2^0C temperatures in water until the test day. Samples cured for 7 and 28 days were tested for tensile strength and compressive strength.

Blending Procedure: Cube dimensions are 15cm×15cm×15cm. Cement, sand and aggregates are mixed in the ratio of 1:1.5:3. Water to cement ratio taken is 0.46. Fine and solid aggregates are taken in ratio of 1:2. Sand, cement, aggregate, water and marble powder was mixed in the amount as given below in Table 2. The blended concrete with different composition is allowed to set in moulds for one day. On the next day concrete blocks are taken out from the moulds. For initial setting blocks are allowed to remain in water for the duration of 7 days. For final setting blocks are allowed to remain in water for the duration of 28 days. A hydraulic cement produced by inter-grinding Portland cement clinker with other materials, or by blending Portland cement with other materials, or by a combination of inter-grinding and blending.

Development of compressive strength:
Compressive strength tests were carried out on above specimens. In the experiment, moist curing was applied to the specimens. The specimens were dried for 24 h prior to testing for every mix at the required age, and the average strength of three specimens was used as an index.

Table 1. Compositions of Various Waste Samples

Composition (%)	Iron slag	DWTP Sludge	BOF sludge	Sewage sludge	Copper slag	Silica fume	Marble sludge (This study)
SiO_2	31.5	49.2	11.2	36.5	30.60	92.26	0.8
Al_2O_3	10.1	26.3	0.1	8.9	2.96	0.89	0.1
Fe_2O_3	56.1	6.6	60.7	3.9	59.08	1.97	0.2
CaO	4.2	0.8	6.9	1.0	0.66	0.49	58.1
MgO	2.0	1.0	1.7	0.6	0.92	1.31	0.1
Na_2O	0.2	0.6	0.4	0.4	0.01	0.42	ND
K_2O	0.1	3.2	0.1	0.9	0.48	ND	0.1
P_2O_5	ND	ND	ND	2.5	0.03	ND	ND
SO_3	1.4	0.1	0.2	4.8	1.01	0.33	0.1
TiO_2	-	-	-	-	0.13	-	-
ZnO	-	-	-	-	2.52	-	-
CuO	-	-	-	-	0.63	-	-
S	-	-	-	-	0.4	-	-
PbO	-	-	-	-	029	-	-
BaO	-	-	-	-	0.1	-	-

ND-not determined; - not available

Table 2. Concrete Composition

S.No	Marble (%)	Cement (Kg)	Sand (Kg)	Marble paste (Kg)	Fine aggregates(kg)	Solid aggregates(kg)	Water (l)
1	0	1.63	2.45	0	1.63	3.26	0.75
2	2.5	1.63	2.38	0.06	1.63	3.26	0.75
3	5	1.63	2.32	0.13	1.63	3.26	0.75
4	7.5	1.63	2.26	0.18	1.63	3.26	0.75
5	10	1.63	2.20	0.25	1.63	3.26	0.75

Figure 1. Photo view of blended raw materials.

Figure 2. Photo view of blended concrete.

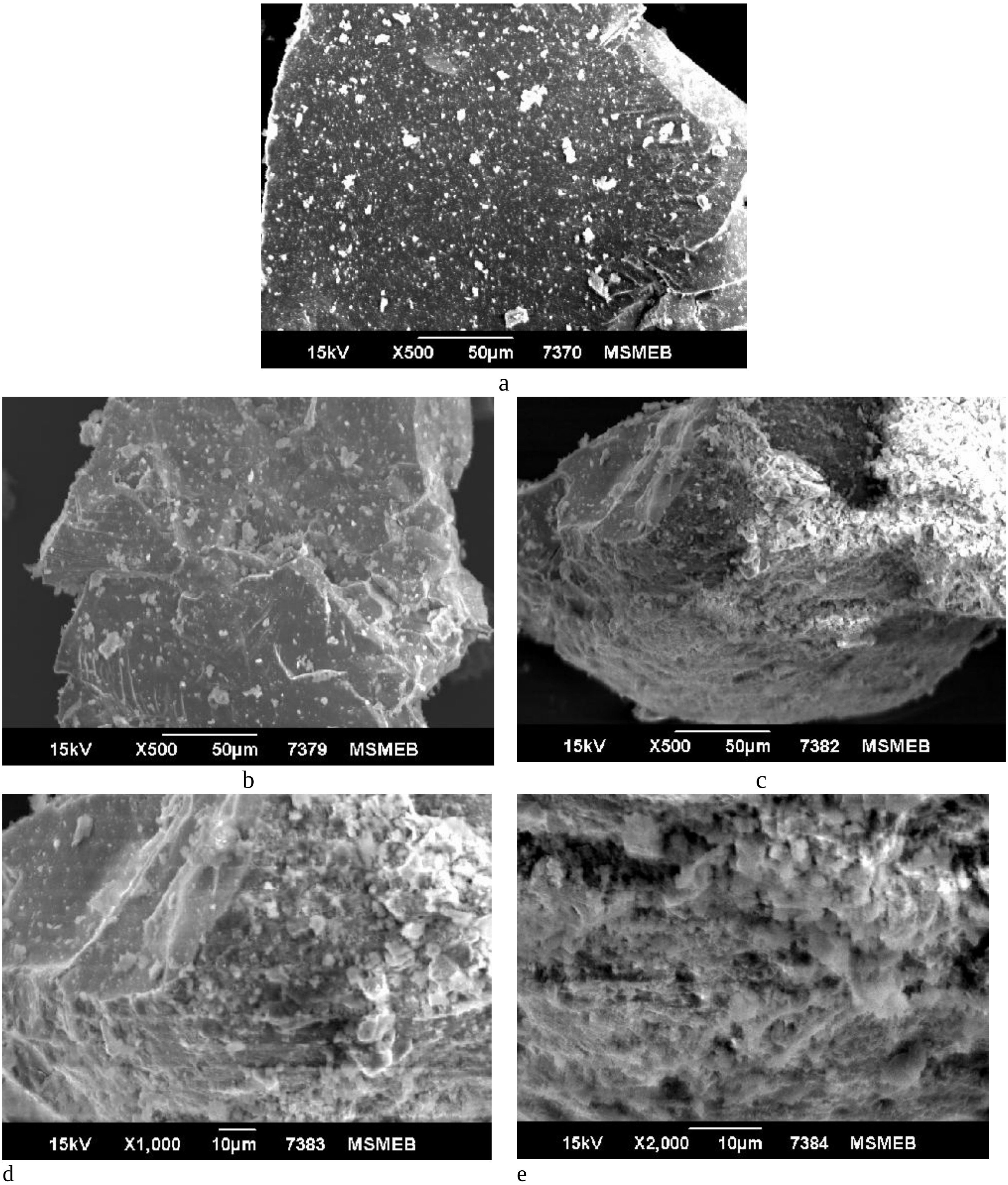

Figure 3. SEM image of blended cement for 28 days curing: sand, cement, aggregate, water and various percent of marble dust a) 0% b) 2.5% (c) 5% d) 7.5% e) 10%.

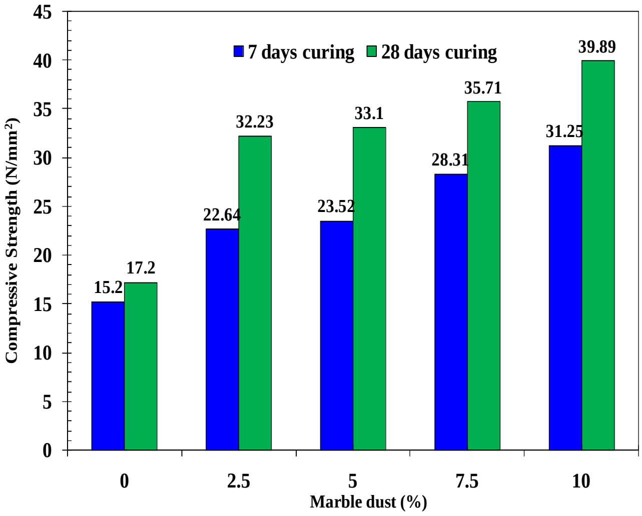

Figure 4. Compressive strength with different marble dust (%).

3. Results And Discussions

In this work, the blended products were identified by means of a SEM (SEM, JEOL JSM-6390 model, Japan). SEM photos were taken at the end of the 7 and 28 days testing period for the development of the hydration process. Some selected images in Fig. 3 are samples that have been curing for 24 days, with the exception of the blended cement paste. Some hydration particles are surrounded by rims of hydration products. It is seen from Fig. 3 that the microstructure of without marble dust addition is very compact and a great deal of plate-shaped calcium hydroxide is also present[7]. The microstructures of blended cements are also very compact however, needle shaped ettringite and plate-shaped were observed[7]. The 150 mm size concrete cubes, concrete cylinder of size 150 mm dia and 150 mm height were used as test specimens to determine the compressive strength. Compressive strength was obtained as per Indian standard method IS: 516-1959. The 7 days and 28 days compressive strength of green concrete is 16.05% and 18.69% higher than controlled concrete respectively.The strength (the ratio of the blended cement to the strength of ordinary cement) of the blended cements in relation to curing age is given in Fig.4. The development of the relative strength of the blended cements in relation to the curing ages is observed to be different. Hence, it can be said that blended cement can achieve adequate early compressive strength[7]. Result shows that blended cement exhibits excellent compressive strength characteristics. Though blended cement has a high long-term strength for 7 and 28days curing period. It is well known that for a given replacement level with mineral admixtures, properties of high-strength concrete are influenced by the reactivity of the mineral admixtures. From Fig. 2, we can see that the combination of marble dust and other ingredients has a modulus/compressive strength higher than alone for 7 and 28 days curing respectively. Therefore, the hydration rate of cementitious materials in admixture is faster than that in alone, which will give rise to higher strength. It can also be seen from the SEM images that there are numerous un-hydrated marble dust particles in blended cement at the 7 and 24 days curing respectively (Fig. 1). The poor compressive strength of ordinary cement is due to the presence of large pores and free few minerals in the concrete (see Fig. 3). The use of high proportions of marble dust increases the strength of the cement paste. The blended cement seems to be the real challenge for the future of cement technology. An increase in fineness of the blended cements induces development of uniform pore spaces and products of hydration as seen in Fig 3. Other workers also support these observations[7,8].

Conclusions

Microscopic investigations of the various cement samples show that there are obvious differences in free CaO, silica, aluminate and ferrite compositions, sizes and distribution between the blended cement and ordinary cement. Increase in fineness of blended cement induces development of uniform pore spaces and products of hydration. Also, all blended cement mortars fulfill the compressive strength requirements of standards. Therefore, blended cement can achieve adequate early compressive strength.

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