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Case study

Impact of marble waste as coarse aggregate on properties of lean cement concrete

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ABSTRACT

Marble industry produces large amount of waste during mining and processing stages. This waste is dumped on to open land which creates a lot of environmental problems. The main objective of this study was utilization of marble waste as a replacement for conventional natural coarse aggregate in concrete. Experimental investigations were carried out to examine the feasibility of use of marble waste as a coarse aggregate in concrete. Conventional natural coarse aggregate was replaced by marble aggregate in different percentages 0–100% by weight. The concrete formulations were prepared with a constant water–cement ratio 0.60. It was observed that workability of concrete mixes containing marble aggregate was 14% more than that of control concrete. The average compressive strength of all the concrete mixes containing marble aggregate increased by 40% and 18% at 7 and 28 days, respectively.

1. Introduction

The stone has played significant role in human endeavors since earliest recorded history. Marble ranks the largest produced natural stone in the world and it accounts for 50% of the world's natural stone production. Approx 85% of production of marble in India is from Rajasthan state [11]. The marble mining industry has come up significantly in recent past. Rajasthan has around 4000 marble mines and about 1100 marble gang saws (processing plants).

The industry involves mines, processing plants, cutters for the production of tiles for walls and floors, household articles. The industries produce a lot of waste of marble in the form of powder/slurry and pieces of irregular size of stones. The waste generated during the quarrying operations is mainly in the form of rock fragments (called "Stones" in the common parlance). The stones obtained from the quarries are usually dumped in empty pits in the forest area; thereby creating huge amounts of waste. There is absolutely no method of systematic disposal of waste in the quarrying areas. The waste & overburden is dumped on forestland, Roads, riverbeds, pasture lands & agricultural fields leading to widespread environmental degradation. There is no segregation of the overburden from the stones thereby causing a loss of fertile top soil. The quarry operations express their inability in proper segregation and disposal of waste.

In a study by Binici et al. [3]. the marble waste was used as 100% replacement for natural coarse aggregates by weight in concrete with constant water–cement ratio 0.4. River sand and ground blast furnace slag (GBFS) were used as fine aggregate. It was reported that compressive strength, Flexural strength, Splitting tensile strength and young's modulus of elasticity of concrete prepared with GBFS as fine aggregate and marble waste as coarse aggregate was 3–6%, respectively higher than that

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of concrete with river sand as fine aggregate and marble waste as coarse aggregate. In a study by Hebhoub et al. [10] natural coarse aggregate was replaced by marble waste aggregate with constant water–cement ratio 0.5. The results showed that, workability decreased with increase in replacement level. Compressive and tensile strength of all concrete mixes containing marble aggregate was increased up to 75% replacement of conventional coarse aggregate. In a study by Andre et al. [1], it was reported that, workability of concrete mix decreased as the replacement level increased, the same trend was reported by Hebhoub et al. [10]. Compressive strength of all concrete mixes shows downward trend with increasing incorporation ratio but this decrease may be considered almost insignificant with variations up to 10.3%. In case of water absorption by immersion and depth of carbonation, the behavior of concrete containing marble aggregate shows similar results to that of control concrete. Part of this generated waste was used in preliminary studies by several researchers in medium strength concrete mixes in the past.

In the present study, the generated waste was used in lean cement concrete as a replacement of conventional coarse aggregate in different percentages 20–100% by weight. The idea of working on lean concrete mixes was maximum utilization of marble waste which saves the natural resources.

2. Experimental study

2.1. Characterization of materials

2.1.1. Cement

Portland Pozzolane cement used in this study fulfills the requirement of Bureau of Indian standards BIS: 8112-1989 [7]. The initial and final setting time, consistency and compressive strength of cement are shown in Table 1.

2.1.2. Fine aggregate

Sand was collected from Banas River, Rajasthan. The sand used in this study was conforming to grading zone II of BIS: 383-1960 [6]. The results of specific gravity and water absorption of sand are presented in Table 2.

2.1.3. Coarse aggregate

Crushed stone aggregate used in this study was used from a nearby quarry. Specific gravity and water absorption of coarse aggregate are presented in Table 2.The nominal maximum size of coarse aggregate used was 20 mm. The chemical compositions of natural aggregate are presented in Table 4.

2.1.4. Marble aggregate

Marble waste used in this study was nearby Rajnagar area and crushed in to crusher. Specific gravity and water absorption of marble aggregate are presented in Table 2. The chemical composition of marble waste are presented in Table 4.The nominal maximum size of marble aggregate used was 20 mm. The particle size distribution of marble aggregate and conventional coarse aggregate is given in Table 3.

It can be seen that water absorption of marble aggregate is about 10% of that of natural conventional aggregate. The particle size distribution shows that marble aggregate lacks finer fractions as compared to natural aggregate (Fig. 1).

2.2. Concrete mix proportion

The concrete mix M 10 was designed as per the procedure prescribed by BIS: 10262-2009 [8]. The natural coarse aggregate was replaced by marble aggregate by weight in concrete. The mixture proportions of control concrete and concrete containing marble aggregate are given in Table 5.The concrete was prepared by replacing the natural coarse aggregate by marble aggregate in different percentages 20%, 40%, 60%, 80% and 100% by weight. For all concrete mixes cement content of 310 kg/m^3 and water–cement ratio of 0.60 were kept constant. Before addition of water all the concrete mixes were blended for 5 min to achieve thorough mix in a 160 l capacity mixer.

Table 1
Physical properties of cement.

Initial setting time	47 min
Final setting time	120 min
Compressive strength	
3 days	20 MPa
7 days	24 MPa
28 days	39 MPa
Consistency	27%
Specific gravity	3.11