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Performance of Concrete Mixes Using Marble Waste and ISF Slag

Sudarshan D Kore *

Department of Civil Engineering, Al Imam Mohammed Ibn Saud Islamic University, Kingdom of Saudi Arabia

***Corresponding author:** Dr. Sudarshan D Kore, Imam Mohammed Ibn Saud Islamic University, Riyadh- Kingdom of Saudi Arabia, Tel: +966562672443; Email: sudarshankore123@gmail.com/ SDKORE@imamu.edu.sa

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Abstract

A high volume of marble production generate a considerable amount of waste in the form of odd sizes of stones and slurry during the mining, processing and polishing stages that has a serious impact on the environment. Imperial Smelting Furnace (ISF) slag is a waste generated in the primary extraction of zinc by a pyro metallurgical process with a granular texture. The main goal of this study is utilization of marble mining waste as a partial replacement for conventional coarse aggregate and ISF slag as a partial replacement for sand in concrete mixes. The concrete mixes were designed by using particle packing density approach with a constant water/cement ratio 0.5. In this study the natural coarse aggregate was replaced by 75% marble aggregate and natural sand was replaced by 40% ISF slag by weight. The results of the study show that, the mechanical and durability properties of concrete mixes using these wastes did not have significant adverse impact on properties of concrete.

Keywords: Concrete; Marble Waste; ISF Slag; Durability

Introduction

Concrete is extensively used throughout in the infrastructure works. India produces about more than 170 million cubic meters of concrete annually [1]. Rajasthan's Marble production accounts for 90% of the country's production [2]. A huge amount of waste is generated during mining, processing and polishing stages. During quarrying operation around 30% of marble is wasted in the form of odd sizes of stones and during processing and polishing operation 15% of material is wasted in the form of slurry. These waste materials are dumped into open lands that create environmental issues, such as air pollution, water pollution etc.

Metal extraction is a major industrial process resulting in large quantities of waste in the form of slag. Imperial Smelting Furnace (ISF) slag is a waste generated in the primary extraction of zinc by the pyrometallurgical process. It is a hydraulically quenched slag with a granular texture. It contains traces of heavy metals like zinc and lead. The quantity of ISF slag generated is approximately same as that of the quantity of refined metal extracted. The accumulating ISF slag needs large stretches of land for dumping. The concentration of lead present in ISF slag exceeds the limits set under schedule II of Hazardous Waste (Management & Control) Rule [1989], Ministry of environment & forest, the government of India. Therefore, ISF slag has been classified as Schedule II hazardous material by Central pollution control board (CPCB) India [3,4]. There is a need for proper disposal of this waste. One such study carried out by Patil, et al. [5] reported that, the particle size distribution of ISF slag and fine aggregate river sand are very close and it is possible to use it as replacement for fine aggregate in concrete mixes. It was also reported that, up to 60% replacement of sand by ISF slag satisfies strength and environmental acceptability. The leaching of heavy metals was observed but these were within the prescribed limits as per USEPA.

Shashidhara and Vyas [4] reported that, concrete prepared with complete replacement of sand by ISF slag showed approximately 60% reduction in weight and compressive strength of concrete mix. It was also reported that, the acid neutralization capacity of ISF slag concrete increased by 70% as compared to that of conventional concrete mix. Tripathi and Chaudhary [3], in their study reported that, replacement of convention fine aggregate by ISF slag improve the resistance to carbonation, shrinkage, sorptivity and chloride penetration. The results ensured that it is possible to produce durable concrete using ISF slag as partial substitute of natural sand.

Bhattacharjee, et al. [6] obtained optimum bulk density of mix and co-relation curves were plotted between compressive strength vs. waster-cement ratio and compressive strength vs. paste content. Theses curves were used to decide the water-cement ratio and paste content for specified grade of concrete in packing density method. From the test results, it was observed that compressive strength of concrete by packing density and IS code method was nearly same.

Past researchers have demonstrated advantages of Packing Density method. But replacement of coarse aggregate and fine aggregate by industrial wastes like marble waste and ISF slag in view of conservation of natural resources and properties of mixes have not yet been attempted. In the present study, the concrete mix was designed by packing density method and IS code method. The marble waste was used as a partial replacement for conventional coarse aggregate and ISF slag as a partial replacement for natural sand in cement concrete mixes. The mechanical and durability properties of concrete were investigated and compared with control mixes.

Materials and Methods

Characterization of Materials

Portland Pozzolana cement used in this study fulfills the requirement of BIS: 8112- (1991) [7]. The initial and final and setting time, consistency and compressive strength of cement are shown in Table 1.The fine aggregate used in this study conform to grading zone II of BIS: 383-(1997) [8]. Crushed stone aggregate used in this study was used from a nearby quarry conforming to IS: 383-1960 (1960). Marble waste obtained from mines used in this study was crushed into the crusher to obtain the desired gradation. The nominal maximum size of coarse aggregate used was 20 mm. ISF slag from the dump yard of zinc smelter was used to replace natural sand in cement concrete mixes. The ISF slag was granular in nature with some lumps formed due to a long period of dumping. To achieve the desired slump of 75 mm, Auramix 400 conforming to BIS: 9103-(1999a) [9] was used. Auramix 400 is a unique combination of the latest generation super plasticizers, based on a poly-carboxylic ether polymer with long lateral chains. The chemical compositions of conventional aggregate, marble waste and ISF slag are presented in Table

The physical properties of aggregate are shown in Table 2. The particle size distribution of aggregate used in this study is shown in Figure 1.

Initial setting time	47 min
Final setting time	483min
Compressive strength	
3 days	20 Mpa
7 days	24 Mpa
28 days	39 Mpa
Consistency	27%
Specific gravity	3.11

Table 1: Physical Properties of Cement.

Aggregate Type	Specific gravity	Water Absorption (%) by weight	Grading Zone
Natural coarse aggregate	2.61	0.54	As per Table 2 of IS 383
Natural Fine aggregate	2.66	2	Zone II As per Table 4 of IS
Marble Coarse aggregate	2.7	0.05	As per Table 2 of IS 383
ISF slag	3.62	0.35	Zone I As per Table 4 of IS 383

Table 2: Physical Properties of Aggregates.

Oxide Component	Natural aggregate	Marble waste	ISF slag
SiO_2	53.70%	3.75%	18.08%
CaO	4.83%	33.12%	17.91
MgO	2.01%	17.91%	1.93%
$Fe2O_3$	10.66%	0.13%	34.28%

$Al2O_3$	-	Traces	8.17%
Na_2O	-	-	0.68%
Mn_2O	-	-	1.33%
ZnO	-	-	9.21%
PbO	-	-	1.22%
Sulphide sulphur	-	-	1.41%
Insoluble residue	-	-	6.28%
LOI	5.08%	45.07%	5.68%

Table 3: Chemical Composition of Aggregate.

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

Methods

Concrete Mix Proportion

The concrete mix was designed by packing density method [10] with a constant water- cement ratio 0.5. The mixture proportions of control concrete and concrete containing marble aggregate and ISF slag are given in Table7. Before the addition of water, all the concrete mixes were blended for 5 min in the mixer. Table 4 shows the mix proportion of concrete mixes designed by packing density method.

Mix	Water (lit)	Cement (kg/m^3)	Sand (kg/m^3)	ISF Slag (kg/m^3)	Natural Aggregate (kg/m^3)	Marble Aggregate (kg/m^3)
C1	163	327	800	-	1200	-
C2	168	337	500	333	312	936

Table 4: Proportioning of Concrete Mixture.

Note: Mix designated by C1 shows control mix designed by Packing Density Method andC2 shows mix designed by packing density method in which natural coarse aggregate was replaced by 75% marble aggregate by weight and natural sand was replaced by 40% ISF Slag by weight. While designing the concrete mixes C1 and C2 by packing density method cement paste 10% in excess of void content was taken in order to ensure adequate workability [1,11,12].

Preparation and casting of Test Specimens

Concrete cubes of size 150mm were cast to determine the compressive strength test. For ultrasonic pulse velocity UPV test 100 mm size cube specimens were cast. The molds were filled with concrete in three layers, and each layer was compacted with the help of vibrating table as per procedure defined in Indian standard BIS: 516-(2002) [13]. After casting all specimens were de-molded after 24 ± 1hr and cured in water at room temperature until their testing dates.

Results and Discussion

Workability

The slump cone test as per BIS: 1199 - (1999b) [14], was carried out for measuring workability of concrete. It can be seen from the Table 5 that, all the concrete mixes achieved a target slump of 75 mm. Both the concrete mixes were designed for 10% excess cement paste content over the void content. Both the concrete mixes required same dose of super plasticizer but the slump achieved in mix C2 was more as compared to that of control mix. This is mainly due to presence of round shape marble aggregate in concrete mix C2.

Mix	slump (mm)	Dose of super plasticizer
C1	90	0.70%
C2	100	0.70%

Table 5: Workability of Concrete.

Compressive Strength

Compressive strength of concrete specimens was determined at 7 days and 28 days curing age as per BIS:

516 [13]. Digital compression testing machine of 1000 KN capacity was used, and the results are given in Figure 1.

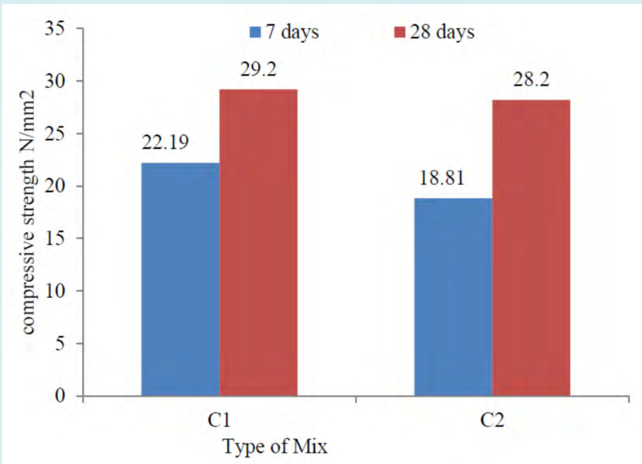

Figure 1: Compressive Strength.

From the test results it was observed that, compressive strength of mixC1and mix C2was 9.12% and 5.38% more than that of control concrete. This increase in strength was due to dense packing of the particle present in the concrete mixes C1 and C2 respectively. Another reason for increase in strength of Mix C2 was, marble aggregate having higher carbonate content than the natural aggregate, which improves the aggregate-cement paste bond [15-19]. The excess paste content used in this study was to disperse the aggregate particles to produce a thin coating of paste around each aggregate particle for lubricating the concrete mix and excess paste strengthens the bond between the aggregate particles and cement paste.

Ultrasonic Pulse Velocity

To assess the homogeneity and Quality of concrete, the UPV test was conducted by IS 13311(Part 1): 1992. The pulse velocity (V) is calculated by dividing the length of the specimen (L) by transit time (T). The underlying principle of assessing the quality of concrete is that comparatively higher velocities were obtained when the quality of concrete in terms of density, homogeneity and uniformity is good. In case of poor quality, lower velocities are obtained. The results of the UPV tests are presented in Table 6.

Mix	Obtained Pulse Velocity	Concrete Quality grading as per BIS 13311-92 Part-1:1992	
		Pulse velocity	Concrete Quality grading
C1	6.777	Above 4.5	Excellent
		3.5- 4.5	good
C2	6.07	3.0 -3.5	Medium
		less than 3	Doubtfull

Table 6: Ultrasonic Pulse Velocity through Concrete Mixtures.

From the above Table it was observed that, the pulse velocities passing through all the concrete mixes defined concrete of excellent quality. Higher values of pulse velocities obtained in this study indicate the quality of all concrete mixes in terms of density, homogeneity and uniformity was good. Both the concrete mixes were almost same values of pulse velocity. Again it shows that the concrete mixes C1 and C2were good in homogeneity because of the higher particle packing density. The above results show that presence of waste marble aggregate and ISF slag does not have any impact on the quality, homogeneity and uniformity of concrete mix.

Conclusion

- In this paper the attempt has been made to investigate the mechanical and durability properties of concrete using marble waste as coarse aggregate and ISF slag as fine aggregate. From this study it was concluded that,
- All the concrete mixes achieved desired workability, incorporation of marble waste and ISF slag does not affect the workability of concrete mixes.
- The compressive strength of concrete mix prepared with use of Marble waste and ISF slag are nearly equal to that of control mix.
- The results of the Ultra sonic Pulse velocity showed that all the concrete mixes fall within the excellent category.
- Overall the concrete prepared with use of this industrial waste in concrete mixes showed improved mechanical performance. The durability properties of concrete are under observation.

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