Strength Behavoir Evaluation of Cement Mortar using Waste Fly Ash and Marble Dust

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Abstract

Pakistan being one of the most urbanized countries of the region having a large number of industries which have been known to produce large quantities of byproducts and wastes. For economic and environmental aspect the industrial waste reuse is appreciable because environmental contamination is the major issue associated with rapid increase in the byproduct and waste generated in the forms of fly ash and marble dust waste due to industrial activities. This study examines the mechanical properties of fresh and hardened cement mortar by using fly ash as partial replacement of cement and waste marble dust as partial replacement for fine aggregate in cement mortar at various percentages (0%, 5%, 10%, 15% and 20% by weight of the cement and fine aggregate) with water. An experimental investigation for the measurement of consistency, initial setting time and final setting time of cement with fly ash replacement were determined by using the Vicat apparatus. Consistency of cement mortar (Workability) with fly ash and waste marble dust replacement was determined by using flow table test. Cubes of the samples with fly ash and waste marble dust replacement as cement and fine aggregate were used to determine the compressive strength of hardened cement mortar. The test results showed that addition of fly ash and waste marble dust into cement mortar mixture significantly increased its compressive strength, initial setting time, final setting time and consistency of cement mortar, while consistency of cement was decreased as compared to conventional cement mortar. This study ensures that reusing of fly ash and waste marble dust as substitutes in cement mortar gives a good approach to solve industrial waste disposal problems.

Keywords: Industrial Waste; Fly Ash; Marble Dust; Cement Mortar; Compressive Strength

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INTRODUCTION

In the construction industry, cement mortar plays an imperative role in plastering, block and brick masonry. Cement mortar is a composite material which is a mixture of cement, fine aggregates, and water. Among which the cement plays an important role in strength of cement mortar.

In construction world cement mortar is the mostly used as a binding material of bricks, concrete blocks and as a plaster for covering the walls, roofs etc. Various industries such as marble industry, steel mills etc. use materials that result in the production of various by-products and wastes such as marble dust, fly ash and many others. In some countries these materials are dumped in open fields as of no use without knowing about their cementitious properties. Thus by doing so they are polluting the environment and also reducing the natural resources by cutting mountains. Some of these by-products and wastes have cementitious properties, so they can be used as replacement with cement while some can be used as a replacement of sand (Baboo Rai et al., 2014).

Out of various cementing materials worldwide the mostly used material is fly ash. In thermal power plants when pulverized coal is combusted a byproduct is produced this byproduct is basically called fly ash. American Concrete Institute (ACI) defined the fly ash as "The finely divided residue transported from the combustion zone to the particle removal system by flue gases resulted from the combustion of powdered coal." Worldwide, in 1998 above than 390 million tons of coal ash annual production was estimated. The utilization rate of this fly ash was only 14 percent while remaining amount was dumped in landfills.

Marble Dust is a grounded marble fine particles also another byproduct during process of marble cutting and finishing in marble industry. In structure marble has been widely used since ancient times. With the help

of marble most of the monuments and ancient sculptures were made. Nowadays its demand is increasing day by day because it is used for decoration purpose. With the increase in production of marbles it increases the waste that obtained from it. Many of marble industries in world generate several thousand tons of marble dust annually. As marble powder is the waste product this marble dust is considered to be solid waste material which is obtained in the process of shaping and sawing of marble by parent marble rock, water is unfit for use due to heavy meatal involvement. Environmental problems are also created by marble powder generation, Due to this nature and human health is also deteriorated (Nitisha Sharma et al., 2015).

MATERIALS AND METHODS

Ordinary portland cement was purchased from local cement distributor. River sand was used as fine aggregate for preparing cement mortar, classifying was verified through sieve analysis. ASTM class F fly ash was brought from Karachi. The fly ash was used as a partial replacement in cement and marble dust was used as a partial replacement of fine aggregate for preparing the mortar sample for compressive strength, initial setting, final setting time and consistency tests. In this work, portable water suitable for human consumption was used in the experimental procedures. Cement mortar of 1:2 was prepared by replacing fly ash by weight of cement and marble dust waste by weight of fine aggregate with percentages of 0%, 5%, 10%, 15% and 20%. All the materials were mixed thoroughly in pan with water cement ratio of 0.5 by trowel. Once the mortar ingredients were mixed thoroughly it was placed in a large rigid pan where the quality of cement mortar was observed and consistency test for fresh mortar was conducted and then it was poured in the Moulds of 2x2 inch cubes. After curing period of 7, 14 and 28 days, and the specimens were allowed to dry the surface for about one to two hours. Then they were tested in UTM for studying the compressive strength.

RESULTS AND DISCUSSION

Cement consistency test was conducted on Vicat apparatus (ASTM International, 2016a) to evaluate the consistency of cement containing various fly ash percentages of 0, 5, 10, 15 & 20 respectively, Result are shown in Fig.1 and Table 1. From the obtained results, it was observed that the consistency of cement decreased with the increase of fly ash continents due to which the water quantity required was 6% percent more with 20% of fly ash replacement in cement as compared to normal cement.

Table 1: Results of Cement Consistency Tests

Weight of Cement (Grams)	Percentage of Fly Ash	Weight of Fly Ash (Grams)	% Age of Water For consistency
400	0	0	27
380	5	20	28.5
360	10	40	30
340	15	60	31.5
320	20	80	33

From the obtained results, it was observed that the initial and final setting time of cement (ASTM International, 2016c) increased with the increase of fly ash as compare to normal cement with zero percent of fly ash content. This was due to the reduction of heat of hydration produced when cement is mixed with water as shown in Fig 2, Fig 3 and Table 2.

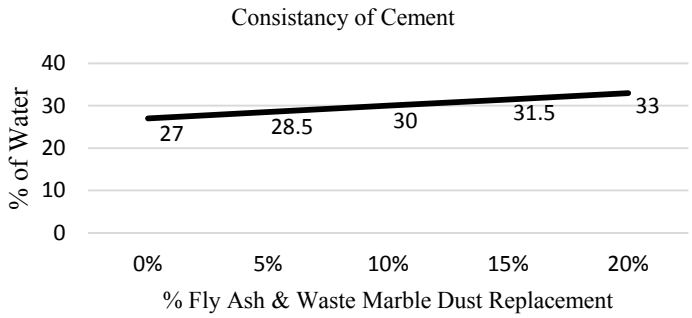


Figure 1: Consistency of Tested Specimens

Table 2: Results of Cement Consistency Tests

Weight of Cement (Grams)	Percentage of Fly Ash	Weight of Fly Ash (Grams)	% Age of Water for Consistency	Initial Setting Time (minutes)	Final Setting Time (minutes)
400	0	0	27	33	255
380	5	20	28.5	35	270
360	10	40	30	38	293
340	15	60	31.5	41	316
320	20	80	33	44	340

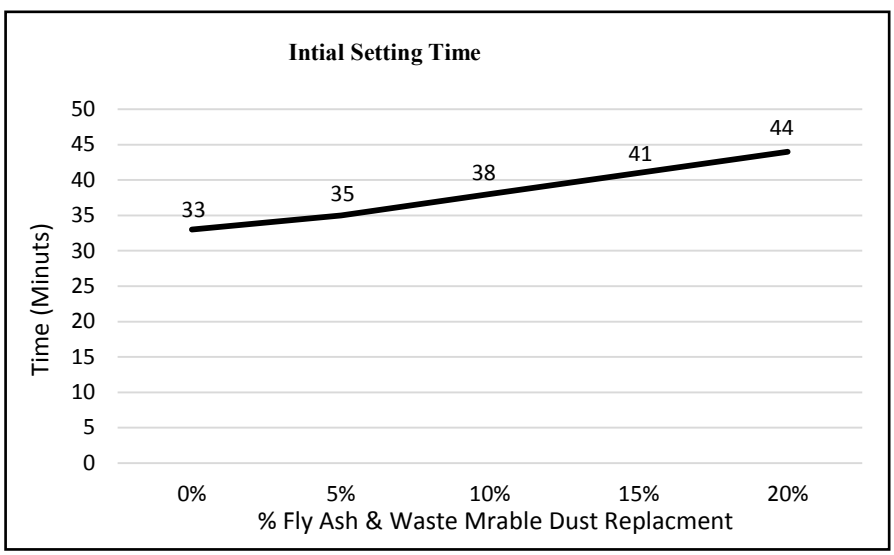


Figure 2: Initial Setting Time of Tested Specimens

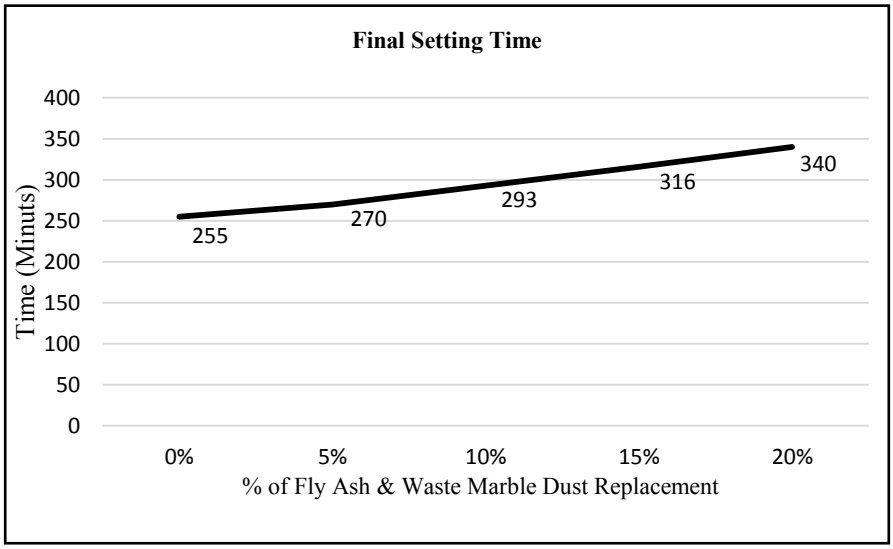


Figure 3: Final Setting Time of Tested Specimens

From the obtained results, it was observed that the consistency of cement mortar (ASTM International, 2014) with fly ash and waste marble dust had increased with the increase of fly ash and waste marble dust continents due to which the water quantity required was 8% percent less with 20% of fly ash and waste marble dust replacement in cement mortar as compared to normal cement mortar as shown in Fig 4 and Table 3.

Table 3: Results of Mortar Consistency Tests

% FA & MD	Weight of Cement (Grams)	Weight of Fly Ash by Weight of Cement (Grams)	Weight of Fine Aggregate (Grams)	Weight of Marble Dust by Weight of Fine Aggregate (Grams)	Total Weight of Sample (Grams)	% Age of Water for Consistency
0	200	0	400	0	600	28
5	190	10	380	20	600	26
10	180	20	360	40	600	24
15	170	30	340	60	600	22
20	160	40	320	80	600	20

To evaluate the strength development of cement mortar containing various fly ash and waste marble dust contents at the age of 7,14 & 28 days (ASTM International, 2016b), as shown in Fig 5 and Table 4. From the obtained results, it was observed that the compressive strength of all mortar samples were increased significantly with adding the percentages of fly ash and waste marble dust. After 28 days compressive strength of cement mortar with fly ash and waste marble dust increased 10% as compared to normal cement mortar with 20% replacements of fly ash in cement and waste marble dust in fine aggregate in the mortar mix with a constant water- cement ratio of 0.30. The reason for this was due to the cementitious properties of fly ash and waste marble dust. The bond b/w fly ash, waste marble dust, cement and fine aggregate were incredible and acted much more effectively due to which there was a decrease in voids.

The increase in compressive strength of cement mortar with fly ash and waste marble was attributed to the capability of the characteristics of fly ash and waste marble dust. The fly ash and waste marble dust resist the initial propagation of micro cracks due to which there was a delay in unstable development of micro

cracks. The reason was that the waste marble dust acted as a filler material and increased the bonding effect with cement which significantly influenced the cracking behavior and ultimate strength.

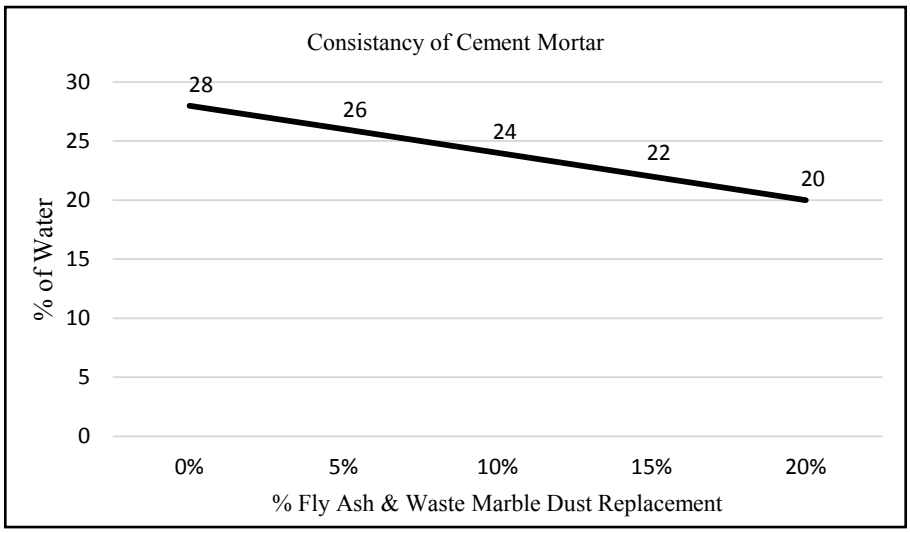
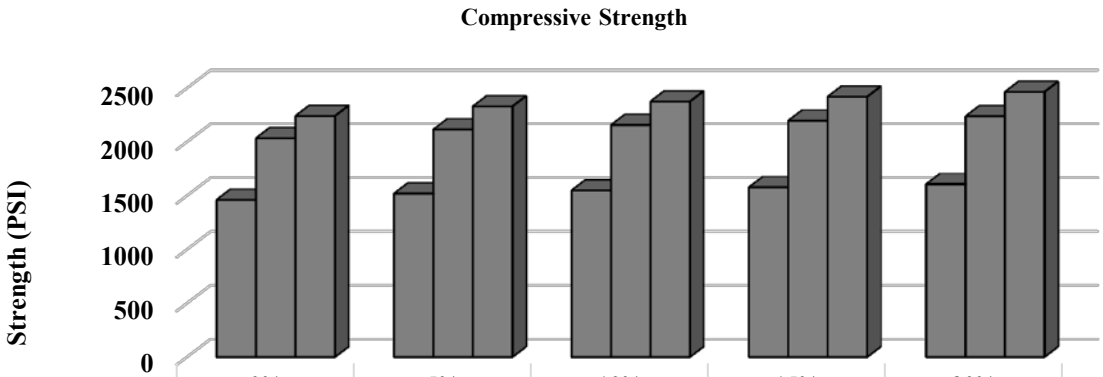


Figure 4: Mortar Consistency of Tested Specimens

Table 4: Results of Compressive Strength Tests

Days	Sample No.	0 % Fly Ash & Marble Dust	5% Fly Ash & Marble Dust	10 % Fly Ash & Marble Dust	15 % Fly Ash & Marble Dust	20 % Fly Ash & Marble Dust
		Strength (Psi)	Strength (Psi)	Strength (Psi)	Strength (Psi)	Strength (Psi
7	1	1458.318	1516.65	1545.817	1574.983	1604.149
	2	1488.085	1547.608	1577.370	1607.131	1636.893
	3	1435.994	1493.433	1522.153	1550.873	1579.593
	Average	1460.799	1519.230	1548.446	1577.662	1606.878
14	1	2030.749	2111.978	2152.593	2193.208	2233.823
	2	2071.964	2154.842	2196.281	2237.721	2279.160
	3	1999.837	2079.830	2119.827	2159.823	2199.820
	Average	2034.183	2115.550	2156.233	2196.917	2237.601
28	1	2236.824	2326.296	2371.033	2415.769	2460.506
	2	2282.16	2373.446	2419.08	2464.732	2510.376
	3	2202.821	2290.933	2334.990	2379.046	2423.103
	Average	2240.602	2330.226	2375.038	2419.850	2464.662



	0%	5%	10%	15%	20%
7 Days	1460.799	1519.23	1548.446	1577.662	1606.878
14 Days	2034.183	2115.55	2156.233	2196.917	2237.601
28 Days	2240.602	2330.226	2375.038	2419.85	2464.662

Figure 5: Compressive Strength of Tested Specimens

CONCLUSION

The following key findings and conclusions are drawn from this study:
Based on this experimental investigation, it is feasible to use fly ash as a cement replacement and waste marble dust as a fine aggregates replacement material to produce cement mortar with acceptable performance. The percentage mass of water absorbed by the cement mortar samples decreased with the use of fly ash and waste marble dust. Moreover using openly dumped waste of marble dust in cement mortar as fine aggregates results in reduction of waste. The initial and final setting time of cement was increased by using fly ash. Positive effect was observed by using fly ash as a replacement in cement and waste marble dust as a replacement in fine aggregate in cement mortar. Compressive strength and workability of cement mortar were increased by increasing the quantity of fly ash and waste marble dust. This research work is the basis for further experiments to establish the effect of fly ash and waste marble dust on the durability of cement mortar and on long term compressive strength after 28 days.

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