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EFFECT OF WASTE FOUNDRY SAND (WFS) ON STRENGTH AND DURABILITY OF PRESSED FIRED CLAY BRICKS

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Abstract- Bricks are significant construction material due to their cost and excellent properties such as durability and compressive strength. With the increasing demand in construction, scarcity of natural material is nowadays a major problem. To counter this, waste foundry sand has been utilized in fired clay pressed bricks in different proportions by replacing clay. Compressive strength and durability were studied as main properties. It was observed that replacing clay with 10% waste foundry sand increases compressive strength. Incorporation of 10% waste foundry sand in bricks resists acid attack and minimum weight loss was observed. Scanning electron microscope analysis suggested the crystallization of bricks by incorporation of waste foundry sand. It is recommended that waste foundry sand can be effectively used in bricks to enhance its properties.

Keywords- acid attack, Brick, durability, foundry sand, Scanning Electron Microscope (SEM)

1 INTRODUCTION

Soil has been used in different forms as the construction material for centuries. In developing countries, with the least demand for natural resources, earth construction is considered as the most efficient and economic. However, with increasing demand in construction material as well challenges with waste disposal, both developed and developing countries are on a mission to impede scarcity of natural resources [1].

Construction industry is one of the major industries to use waste in construction material promising to alter and enhance material properties. Investors, builders and stack holders are grueling to use alternates materials that provide the same or enhanced properties with low cost and ecofriendly. To counter this problem, researchers around the globe are using waste products in engineering materials with promising cost and superior properties than existing. For instance, concrete has been incorporated with fly ash, ground granulated blast furnace slag (GGBS), glass powder, marble powder, bentonite, waste foundry sand with multiple goals to enhance the properties of concrete as well utilization of discarded materials [2-6].

Brick is the oldest, economic and commonly used material, was first used 6000 years ago [7]. Bricks are significant material in construction due to its cost and outstanding properties such as its compressive strength and great durability. According to a report, its worldwide production is about 1.3 trillion units per year and increasing [8]. Pakistan ranks third in contribution to the worldwide production of fired clay bricks which is about 59 billion units per year. With this huge consumption of bricks, the diminishing of natural resources is a major problem. In recent decades, mainly in developing countries, researchers have been using waste materials in bricks by replacing fully or part of clay. For instance, the use of granulated blast furnace slag, rubber, waste processed tea, cotton waste, rice husk ash, industrial wastewater, limestone dust, sawdust, fly ash, cigarette butts, plastics waste and waste papers. All these researches are evident for enhanced properties of brick which are mainly compressive strength, water absorption and durability. The brick properties along with material also depend upon the method of manufacturing, drying and firing [9-14].

Foundry sand is a byproduct in foundry and metal casting industries. Million tons of foundry sand is discarded from industries each year. According to a report, 104.12 million tons of both ferrous and nonferrous casting is carried out each year. Casting done with cast iron and steel are called ferrous industries while casting with aluminum, brass and bronze are termed as non-ferrous. Silica is the main constituent of foundry sand which is 80-95%. Other constituents such as iron oxide, alumina, calcium are also present but in very little amount. After casting, the foundry sand is discarded and dumped which creates landfilling and environmental pollution. Foundry sand has been used before in construction material such as concrete which may enhance the properties at low cost [6,15].The foundry sand has been also utilized in making fired clay bricks which resulted in significant properties compared to commercial bricks [16].

In this research, an attempt has been made to incorporate Waste Foundry Sand (WFS) in fired clay bricks by replacing clay in different proportions. The machine pressing method was used for manufacturing brick and firing in a traditional tunnel oven. Compressive strength and durability tests were conducted. Scanning Electron Microscope (SEM) was used to study the microstructure of bricks.

2 EXPERIMENTAL PROCEDURES

In this research, bricks were manufactured from the mixture of fired clay and Waste Foundry Sand (WFS). The WFS was collected from Heavy Mechanical Complex (HMC) Taxila, Pakistan at their dumping site. The large lumps of sand (bounded by chemicals) were separated at the site and clean sand was taken into bags. The sand was then taken into the lab for initial testing such as sieving, water absorption, and specific gravity. The physical properties of WFS is given in Table 1. The sieve analysis of foundry sand is given in figure 2, indicating more fine particles than natural sand. The elemental composition of the WFS has been analyzed through Energy Dispersive X-ray (EDX) technique in Central Resource Laboratories (CRL), University of Peshawar, Pakistan. The peaks generated by the corresponding elements are shown in Figure 1.

Table 1- Physical Properties of WFS and fired clay

Material	Specific Gravity	Absorption (%)	Fineness Modulus	Moisture content (%)	OMC	Plastic Limit
WFS	2.68	0.89	2.11	2.67	_	Non plastic
Fired clay	2.64	-	-	-	8.62	34

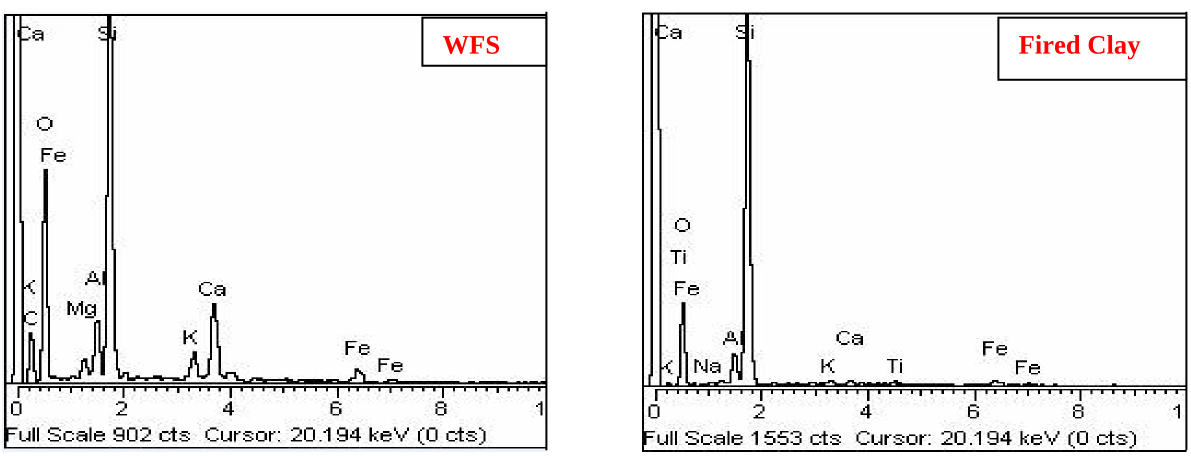


Figure 1: EDX analysis of WFS and fired clay

The fired clay was collected from Standard Ceramics, Hattar, Pakistan. The clay was subjected to some initial physical tests. The physical properties of clay are given in Table 1. The elemental composition of the clay was found through Energy Dispersive X-ray (EDX) technique in Central Resource Laboratories (CRL), University of Peshawar, Pakistan indicating less silica then WFS as shown in Figure 2.

The mixing, casting, drying and firing of bricks were done in the industry named Standard Ceramics, Hattar Pakistan. Total of six mixes of bricks were prepared by replacing clay with WFS. The replacement level of WFS was 10%, 20%, 30%, 40%, 50% and 60% for each set of bricks. Each brick was designated by the level of replacement of clay with WFS. For instance, FB1 brick shows "Fired Clay Brick with 10% incorporation of WFS".

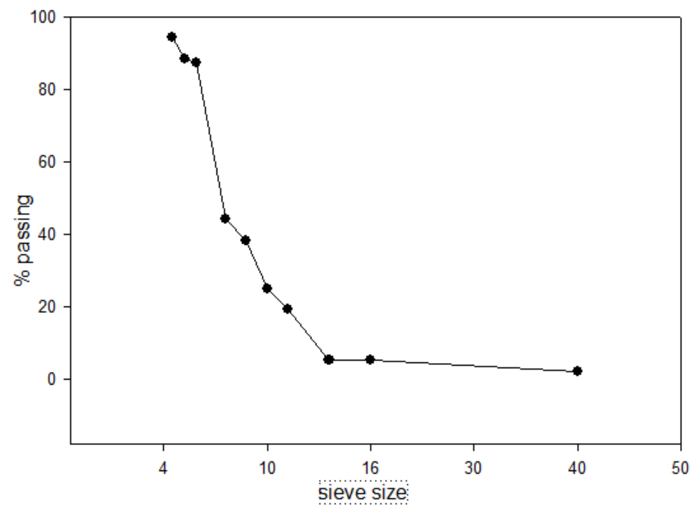


Figure 2: Sieve analysis of WFS

After mixing of raw materials, 15% water by the weight of material is added to each mix. it may be worth noting that machine pressed bricks to require less water than traditional hand mix bricks. After that, the mixture was taken to a hydraulic pressing machine. The pressing machine is electric driven which presses the raw material with 20.6 MPa force and mold the raw material into standard brick size (9" x 4.5"x 3"). After removing from the pressing, the bricks were carefully stacked for drying in sun. After 6-8 days, the unfired bricks were loaded into conveyer for firing. The firing was carried out in a traditional tunnel oven which operates on natural gas. The length of the oven was measured 262 feet and its diameter was about 5 feet. The firing process is subdivided into three steps. In the first step, the bricks are loaded on an auto electric conveyer belt which moves with certain fixed speed into the oven. In this step, the further drying of the bricks occurs which eliminates the free water present in bricks. The temperature in this step ranges from 100 ^{O}C to 450 ^{O}C. In the second step, the crystallization process takes place and the highest temperature noted in this step was 1200±10 ^{O}C. In this step, the bricks are burnt completely and moved to third step.

The third step is linked with exit side of the tunnel in which cooling of the bricks process initiates. At the exit, the temperature of the brick was noted 60±5 ^{O}C. The firing process is completed in five days. After removal from tunnel; the bricks are left for cooling for few hours. After complete cooling, the bricks were collected and taken into a laboratory for compressive strength test, water absorption and durability. The whole process is demonstrate in Figure 3.

Before the compressive strength test, the bricks were made leveled from both sides so that the force applied may remain constant throughout testing. The compressive strength values were noted for three set of bricks for each mix. For durability test, the bricks were immersed in 10% sulphuric acid (H2SO4) concentrated water for 28 days. Before immersing, the bricks were carefully weighed and noted. After 28 days, the bricks were weighed again and then taken into compression testing machine. The method of sampling, stacking and testing was in accordance with ASTM C67 / C67M-20 [17].

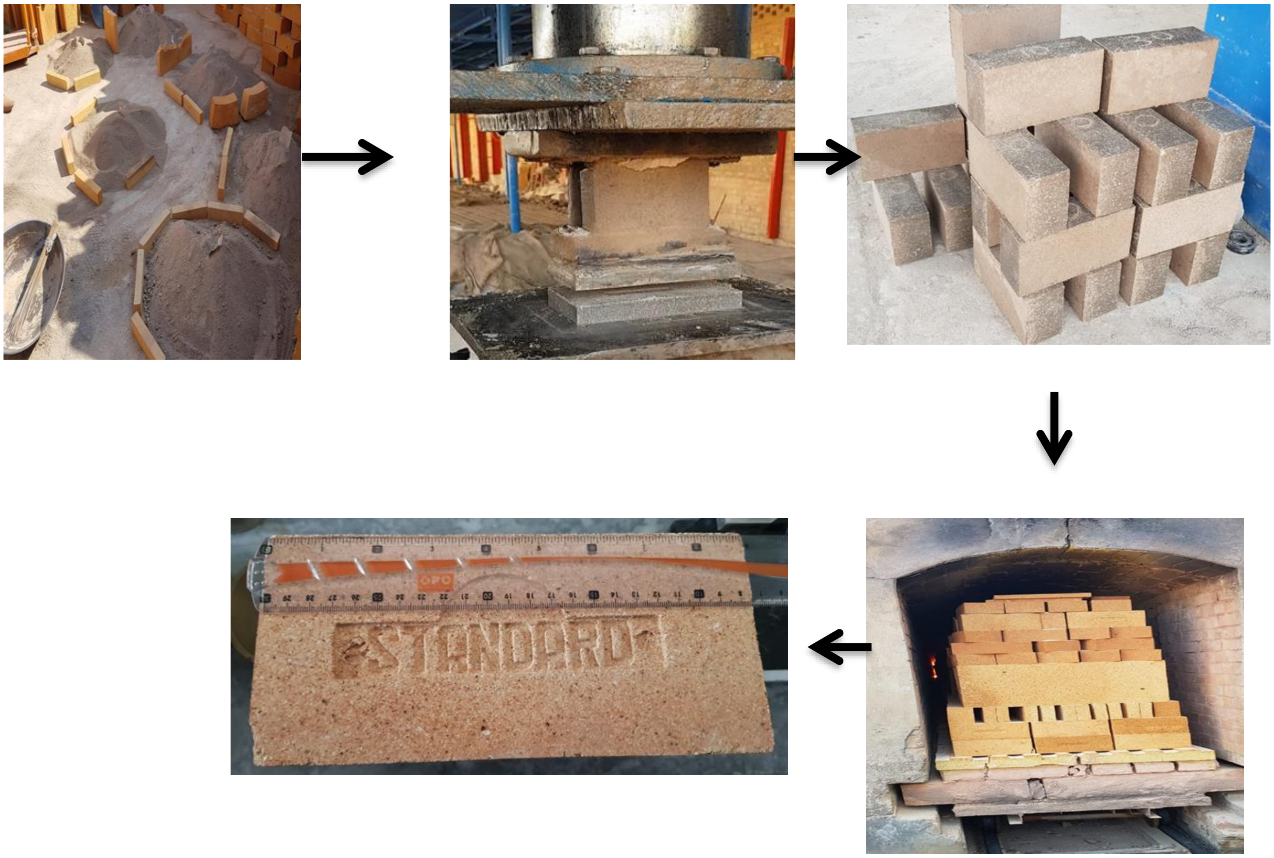


Figure 3: Process of brick making from mixing, pressing, drying, firing and final brick

3 RESULTS AND DISCUSSION

3.1 Compressive strength

All the bricks were tested in compression testing machine. For each mix, three sets of bricks were tested and values were noted. It was observed that the highest strength was noted for FB1 brick (incorporated with 10% WFS), which was 18.97 MPa. The control specimen having designated as FB0 (having no WFS) shows the strength of 18.20 MPa, which was lower than FB1 by 4.24%. The lowest strength was noted for FB6 brick (incorporated with 60% WFS), which was 10.81 MPa lower than control mix by 41.70%. The bricks FB2 and FB3 showed almost similar strength to control mix as shown in the figure.

The increase in strength is attributed to the fine size of WFS which fills the pore of the mixes. As a result, a compact dense structure is formed which completely crystallizes during sintering process at 1200 OC in oven. The slow and steady firing also takes a share in high strength. It may be noted that due to the high content of silica in WFS, the bricks were showing brittle behavior during testing i.e., sudden failure with large cracks. However, small cracks were observed for CM, FB1 specimens compared to other bricks. The lowest strength, as indicated was noted for FB6 specimens, which may be due to the abundance of WFS particles. All the particles were not able to fill the pores and as a result, non-crystallization of bricks occurred which results in lower strength.

3.2 Durability

The bricks were immersed in 10% H2SO4 concentrated water for 28 days. After removal, the brick was weighed and tested for compression test. It was observed that no significant weight loss was observed for mixes except FB5 and FB6. The weight loss for control mix was 3.31%. Mixes incorporated with WFS showed higher weight loss than control mix. For instance, FB1 specimen showed weight loss of 4.71% greater than control mix. The highest weight loss was found for specimens FB5 and FB6 which was 10.5% and 10.9% respectively as shown in Figure 5.

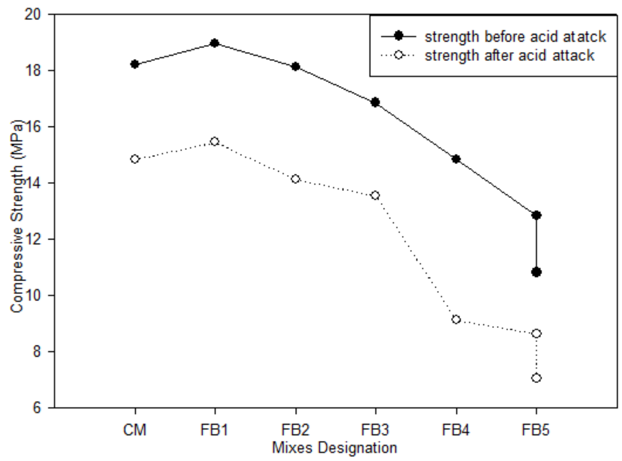


Figure 4: Compressive strength Vs Bricks Specimens

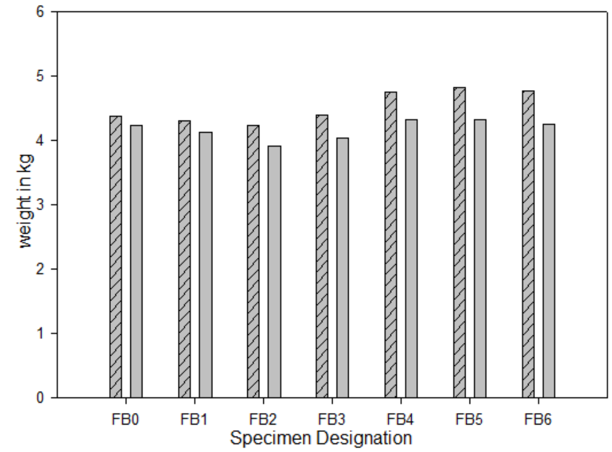


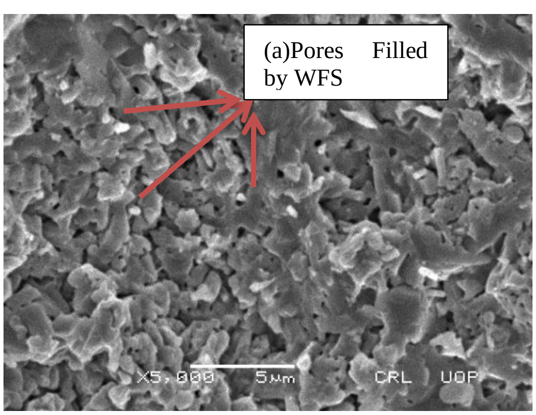
Figure 5: Weight loss variations after acid attack

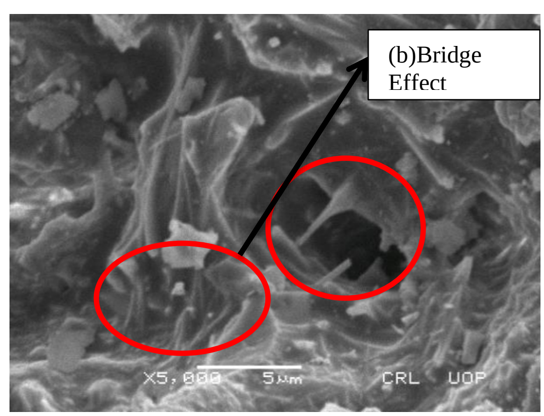
The bricks were also tested for compression strength after immersion in acid concentrated water. It was observed that the same trend was followed in strength after removal from acid. The strength of control specimen, FB1 and FB2 showed almost same strength. For instance, FB1 showed a little higher strength than control by 4.08% whereas FB2 showed little lower strength than control specimen by 4.8%. it was observed that FB5 and FB6 specimens affected more due to the acid attack. The reason for strength reduction is the more permeability of FB2 bricks. The strength of FB5 and FB6 specimen was lower than control specimen by 41.9% and 50.4% respectively as shown in Figure 4.

3.3 Scanning Electron Microscope (SEM)

This test is used to study the topography of the material as well composition at various intensity and magnification. The statement of compressive strength for FB1 specimens can be verified through SEM. It was observed that the pores are filled well by WFS particles, which makes it firm and dense structure. The bridging effect is quite visible, which offers tremendous resistance against loads as shown in Figure 5.

On the other hand, control specimen shows quite same micro properties as for FB1 specimen except that few pores are still left unfilled. It was observed from compressive strength test and durability that FB6 specimen affected more as compared to other specimens. Cracks are visible in FB6 specimen in SEM images. Moreover, there are unfilled pores present in greater density compared to other samples which make it a week and unable to sustain loads as shown in Figure 5.





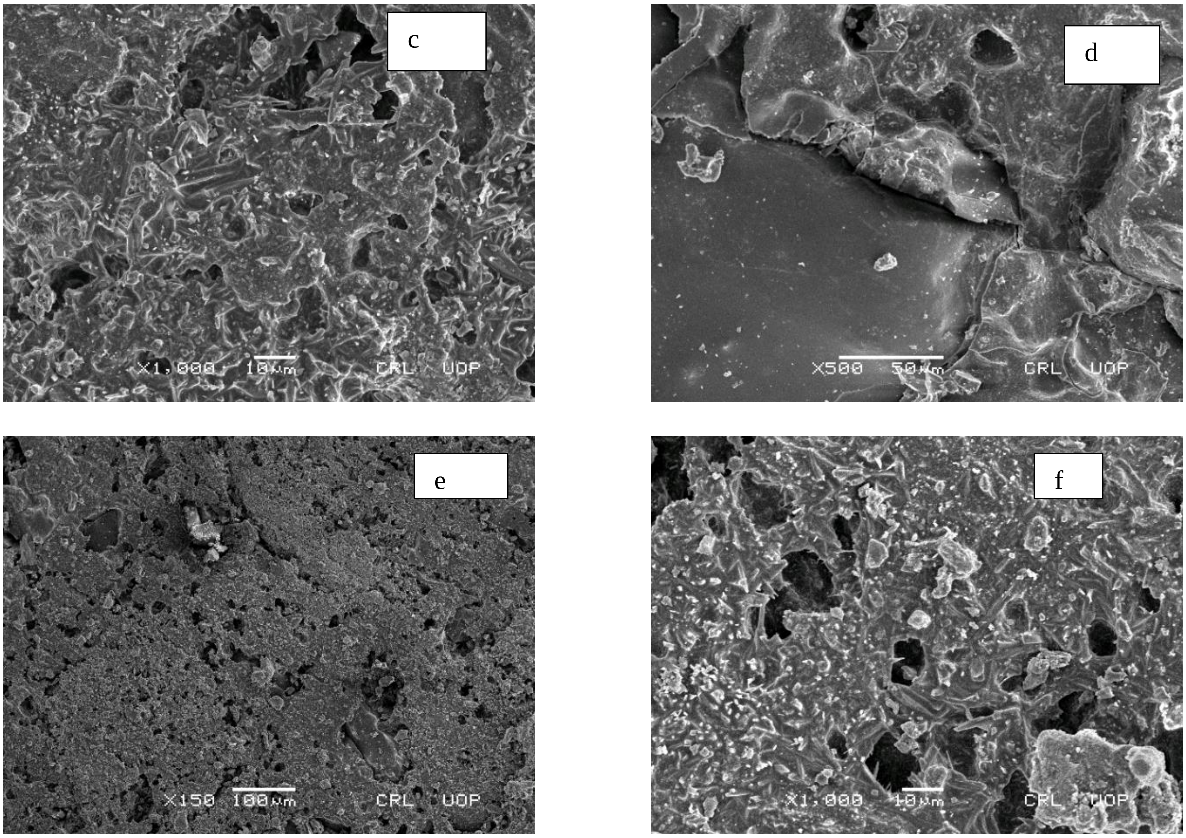


Figure 5: SEM FB1(a, b) ; CM (c, d); FB6 (e, f)

4 CONCLUSION

In this study, Waste Foundry Sand (WFS) has been utilized in bricks to study its properties. Following are the conclusion drawn from the study:

- The Energy Dispersive X-Ray technique shows that silica is the main and abundant element in WFS.
- Incorporation of 10% WFS in bricks gives maximum compressive strength. Beyond this replacement, the strength tends to decrease.
- Acid resistance was found maximum for brick specimens having 10% incorporation of WFS by replacing clay. Specimens having 60% WFS incorporated affected most against acid attack.
- It was observed that weight loss against acid is not significant in specimens except for bricks incorporated with 60% WFS.
- The scanning Electron Microscope analysis shows that bricks incorporated with 10% WFS crystallize completely during sintering temperature.

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