Effect of Brick Dust on Strength and Workability of Concrete

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Abstract. The aim of this research is to utilize the waste generated in concrete. Brick dust is lavish material which on dumping not only occupy land but also it has environmental problems which is hazardous to livings. This waste is generated in brick kilns, brick masonry construction sites and during transportation. By recycling brick dust the problem could be solved up to some extent. In this research, brick dust was used in plain cement concrete to check its fresh and hardened properties. Brick dust was used to check the workability and strength of concrete, using the water-cement ratio of 0.55 which was kept constant during research. Three samples were cast for each 3, 7, 14, 28 and 56 days with 0%, 5%, 10% 15% and 20% incorporation of brick dust. The test results reveals that replacing cement with brick dust shows higher workability than control sample for 5%, 10% and 15%, of which 15% was greater of all. However, strength results were quite competitive, replacing cement with 15% brick dust shows higher compressive strength. The split tensile test were also conducted, which shows high tensile strength by replacing cement with 15% brick dust. This research shows that cement can be replaced with brick dust.

Keywords: brick dust, compressive strength, workability, split tensile

1. Introduction:
Brick dust is lavish material which generates as waste in brick kilns and construction sites. This material goes into dumping and used as landfills which concerns our environment. Researchers around the globe use many innovative and waste materials in concrete to overcome the environmental and economic problems. These waste materials give higher or almost same concrete properties.

A report [1] stated that brick kilns generates most of the brick dust wastes where largest brick producing country is China and India lies second in list. The report further state that there are more than 2, 20,000 number of bricks unit in both countries with 80,000 brick units alone in China. Ahmed [2] concluded that in Pakistan, there are approximately 10,000 brick units which contributes about 1.5% GDP to country. These brick Kilns generates brick wastes in form of brick dust which not occupy lands but also hazardous to health and environment. Cement is most costly material in concrete, so its economical use should be adopted. In this way, many innovative and waste materials has been used by researchers to overcome the cost of concrete. These materials include fly ash, silica fume, marble dust, stone dust, and many others.

Researchers are using different materials as a replacement of cement to check the properties of concrete. The world is experiencing great expansion in concrete construction especially in developing countries. This leads to emission of carbon di oxide in atmosphere. The Cement Sustainability Initiative report [3] state that approximately 1 Ton of CO₂ is produced in preparation of 1 Ton of cement. Sayem et al [4] used waste plastic and stone dust in concrete. Properties like compressive strength, split tensile and unit weight were enhanced by using these wastes. Aliabdo et al [5] used crushed clay bricks in concrete and tested against non-traditional tests like XRD, thermo-gravimetric analysis (TGA) and microstructural analysis. Based on experimental observation they concluded that
strength is reduced while thermal resistance, cost effects, and environmental aspects may be considered. Heidari and Hasanpour [6] reported that brick dust contain pozzolanic properties which can be used in concrete to replace cement. They further concluded that using brick dust has minor effects on strength loss. Khan et al [7] analyzed brick dust and marble powder as cement replacement. Results shows that workability is increased by using both ingredients in certain proportion, compressive strength is reduced by increasing brick dust content beyond 10% replacement. Duby and Porwal [8] reported that fly ash and brick dust mixed in concrete as admixture can save cost of cement up to 20% by providing the same strength. Bharti and Patel [9] reported that replacing cement with 15% silica fume and 10% brick kiln dust shows maximum compressive and tensile strength using 0.50 w/c ratio.

2. Brick Dust:
Brick dust occurs from loading or unloading, construction sites and brick kilns. This dust is used in dumping and filling. There are thousands Ton of brick waste generated each year around the world which goes in unplanned way. Pozzolanic materials such as brick dust and other ceramics powder has been used in concrete since ancient times. In ancient times the brick dust was used according to experiences and experiments as they were unaware of the properties of brick dust.

Bricks are made up of different types of clays and other materials like sand. Clay composed up of 20-30% Alumina, 50-60% Silica and other carbonates and oxides. Clay is responsible for the pozzolanic behavior of brick. Clay itself has no pozzolanic properties but when fired together with lime during brick making process it gains pozzolanic nature. [9]

2.1. Chemical Reaction of Brick Dust in Concrete:
Brick dust as pozzolana reacts with lime in presence of water to form hydraulic compounds. Calcium carbonate and water is produced when carbon dioxide reacts with calcium hydroxide. The chemical reactions are following:

\[ \text{Portland cement} + \text{Water} \rightarrow \text{Calcium Silicate Hydrate} \]
\[ \text{Ca(OH)}_2 + \text{CO}_2 \rightarrow \text{CaCO}_3 + \text{H}_2\text{O} \]

Extra amount of hydraulic cement is formed when reacts with lime. The reaction is following:

\[ \text{Pozzolana} + \text{Ca(OH)}_2 + \text{water} \rightarrow \text{C-H-S (Glue)} \]

The former reaction of Portland cement with water is fast reaction which provides early strength to concrete where the later reaction of pozzolana with liberated lime in presence of water is slow reaction which effect early age strength. But after some time, the brick dust provides extra amount of C-H-S which contribute to strength of concrete. [10]

3. Materials Used in Research
3.1. Portland cement
Portland cement of Bestway Cement was used which was according to ASTM type 1. Cement was clean, free from slumps and impurities.

3.2. Fine Aggregates
Sand was obtained from Lawrencepur, Punjab. The sand was passed through sieve no 4. The fineness modulus of fine aggregate was determined according to ASTM C 136-93, which was 2.589.

3.3. Course Aggregates
Margalla crush was used in this research. Coarse aggregate sieve analysis was determined according to ASTM C 136.
3.4. Brick Dust

Brick Dust was obtained from Ring Road Kiln Peshawar. To attain the approximate fineness of cement, brick dust was further crushed in PCSIR Laboratories, Peshawar in grinding mill with 26 Nos cylindrical rods of length 3 feet each. Rotation of drum was set on 32 revolutions per minute. Brick dust retained about 2.6% on 90µm sieve. The physical properties of brick dust are presented in Table 1.

| Properties                | Brick Dust |
|---------------------------|------------|
| Moisture Content (%)      | 4.7        |
| Specific Gravity (unit)   | 2.54       |
| Fineness modulus          | 2.08       |

EDX Test was conducted in University of Peshawar Physics department to determine the chemical composition of brick dust which is presented in Figure 1. Brick dust is golden in colour as shown in Figure 2.

![Figure 1. Chemical Composition of Brick Dust](image1)

![Figure 2. Brick Dust](image2)

4. Experimental Investigation

Various experiments have been conducted to study the properties of brick dust and concrete.

4.1. Preparation of concrete samples and testing

Total of five concrete mixes with brick dust were prepared designated as M₀, M₅, M₁₀, M₁₅ and M₂₀ which represents 0%, 5%, 10%, 15% and 20% replacement of cement with brick dust respectively. Water-cement ratio 0.55 was used in this research. The details of mixes are shown below in Figure 3.

| S.No | Mix ID | Cement (g) | Brick Dust | Sand (g) | Course Aggregate | Water (mL) | w/c   |
|------|--------|------------|------------|----------|-----------------|------------|-------|
| 1    | M₀     | 2557       | 0          | 0        | 5960            | 6900       | 1406  | 0.55 |
| 2    | M₅     | 2430       | 127        | 5        | 5960            | 6900       | 1406  | 0.55 |
| 3    | M₁₀    | 2302       | 255        | 10       | 5960            | 6900       | 1406  | 0.55 |
| 4    | M₁₅    | 2174       | 383        | 15       | 5960            | 6900       | 1406  | 0.55 |
| 5    | M₂₀    | 2045.6     | 511.4      | 20       | 5960            | 6900       | 1406  | 0.55 |
4.1.1. **Slump Test:**
Workability of the above mixes were measured with slump test according to ASTM C 143 [11] Standard slump cone with 12-inch diameter with 8 inches top opening diameter and 4 inches bottom opening diameter and base plate was used. Cone was filled with concrete in three layers by tamping 25 blows each layer. For each mix, three trials were prepared and values were noted.

![Figure 4. Slump Variation](image1)

![Figure 5. Sieve Analysis of Fine Aggregates](image2)

4.1.2. **Compressive Strength Test:**
Compressive strength test was conducted for 3 days, 7 days, 14 days, 28 days and 56 days according to ASTM C39 [12] Standard mold with 12 inches length and 6 inches diameter were properly oiled and filled with concrete in three layers. Each layers were propped with 25 blows for proper compaction. After initial curing molds were removed and cured in water tank for 3, 7, 14, 28 and 56 days. The load noted on UTM was load at which specimen were failed. Compressive strength value was taken as average of three samples value.

![Figure 6. Compressive Strength at All Ages](image3)

![Figure 7. Compressive Strength Test](image4)

4.1.3. **Split tensile**
Split tensile test was conducted for 28 days and 56 days according to ASTM C 496/C 496M – 04 [13] Total 30 specimens were cast for split tensile test, average of each 3.
5. Results and Discussion

5.1. Slump test
Slump values tend to increase by increasing brick dust content in concrete samples. This increase in slump value may be due to spherical particles of brick dust which lubricate the mix and gives ball bearing effect to mixes. Beyond 15% replacement of cement with brick dust absorb more water hence slump value decreases. The trend of slump is shown in figure 3.

5.2. Compressive strength
It was observed that compressive strength increases with increasing brick dust content at all ages as shown in figure 6. Replacing cement with brick dust beyond 15% replacement tends to decrease strength. Maximum strength value was noted at 15% replacement. As brick dust is natural pozzolan so it produces more C-S-H gel which gives more strength [14] Secondly, the finer particles of brick dust forms a compact mass which fills the pores of concrete and results in more strength than control sample. Compressive strength setup is shown in figure 7.

5.3. Split tensile test
Split tensile shows similar strength gain pattern that is increasing up to 15% replacement of cement with brick dust and then tends to decrease as shown in figure 8. The increase may be due to finer particles of brick dust which contributes compact matrix. The test setup is shown in figure 9.

6. Conclusion of Research
In this research brick dust was incorporated in concrete by partial replacing of cement. Based on the result, the following conclusions can be drawn.

- The maximum slump was noted at 15% replacement after that it goes on decreasing. The minimum value of slump was observed at 20% replacement.
- Compressive strength tends to increase by increasing brick dust content up to 15%. Beyond this replacement the compressive strength shows inferior behavior at 20% replacement.
- Split tensile strength increases by increasing brick dust content up to 15%, beyond this replacement the split tensile strength tends to decrease.
- Brick dust can be used as plasticizer as it decreases water demand because workability is increasing.
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