Study on performance of concrete with over-burnt bricks aggregates and micro-silica admixture

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Abstract: Concrete is made by mixing cement, sand, aggregates and water in required proportion, where aggregates occupy the major volume. Addition of aggregates in concrete improves properties of concrete. With the natural resources depleting rapidly, limiting the use of natural resources and enhancing the use of waste materials is very important for sustainable development. Over-burnt bricks are a waste material which cannot be used in construction directly because of their irregular shape and dark colour. Use of over-burnt bricks helps to preserve natural aggregate source. The present study focuses on the effects of micro-silica at various percentages as a partial cement replacement in concrete with over-burnt bricks as coarse aggregates. The mechanical properties of hardened concrete such as splitting tensile strength, flexural strength and compressive strength are studied and analyzed.

1. Introduction

Concrete is the most popular building material used and the cost and quality of construction depends on the quality of concrete. Aggregates constitute more than 70% of volume of concrete [1]. At present, gravel is the widely used course aggregate. There is an urgent need to preserve natural resources for sustainable development and save the resources for future generations. This compels the use of other coarse aggregates which are locally available and also cheap. Class IV bricks or over-burnt bricks are formed by uneven heating of bricks in kilns. Use of over-burnt bricks helps to preserve natural aggregates as well as reduces the waste storage. Bricks are a versatile building material with considerable load bearing capacity. The changes and deterioration of concrete limits the life-time of structures. Addition of mineral admixtures like micro-silica makes the concrete more durable and also improves the mechanical properties of hardened concrete. Cement replacement with upto 20% micro-silica is done for a mix design of M30 and various strength parameters are studied and analysed. If over-burnt bricks are used as an alternative for coarse aggregate in concrete, several quality control measures have to be done to ensure that the bricks satisfies the minimum requirement according to IS standards.

Rashid Et Al [2] studied the concrete properties with over-burnt bricks as aggregates and inferred that compressive strength of concrete with over-burnt bricks as aggregates can be increased by decreasing the W/C ratio. Cachim [3] studied the concrete properties with crushed bricks as partial substitute for gravel as coarse aggregate and found the mechanical properties of concrete and inferred that, for upto 15% replacement of aggregates with burnt bricks, the mechanical properties of concrete is almost similar to that of normal concrete. Ozyildirim,C., and Halstead [4] reported that the durability and mechanical properties of concrete can be increased by adding micro-silica as partial replacement of cement at low water-cement ratio. Khaloo [5] studied the properties of brick aggregates and compares the properties of concrete with brick aggregates and the concrete with stone aggregates and inferred that there is no
reduction in strength of concrete for up to 20% replacement of stone aggregates with brick aggregates. Khalaf and DeVenny [6] studied the thermal properties of brick aggregates and inferred that the brick aggregates performed better than gravel at elevated temperature. Mohamed S.Morsy [7] studied the thermal properties of concrete with micro-silica as replacement and inferred that the addition of micro-silica increases the thermal resistance of concrete. Various studies have proved that micro-silica addition improves the mechanical properties of concrete [8-12].

Lack of knowledge about properties of concrete with over-burnt bricks as aggregates is a major setback for the use of over-burnt bricks in concretes. The present paper reports study on using over-burnt bricks as coarse aggregate. To overcome the reduction in strength due to the inclusion of brick aggregate, micro-silica is added as a replacement to cement. The optimum percentage of micro-silica to be added to get the prominent increase in mechanical properties is arrived at.

2. Materials and methodology

Ordinary Portland cement of grade 53 in accordance with IS 12269-1987 was used in present study. The properties of cement were found in accordance with IS 4031-1996. The results are shown in Table 1. Micro-silica of average size 150 nm and specific gravity 2.63 was used in the study. Physical and chemical properties of microsilica is given in the Table 2.

Table 1: Properties of cement

| S.No | Property               | Result  |
|------|------------------------|---------|
| 1.   | Consistency            | 32.25%  |
| 2.   | Initial setting time   | 60 min  |
| 3.   | Final setting time     | 480 min |
| 4.   | Fineness of cement     | 6%      |
| 5.   | Specific gravity of cement | 3.15   |

Table 2: Physical and chemical properties of microsilica

| S.No | Physical and chemical properties | Result   |
|------|---------------------------------|----------|
| 1    | Bulk density (gm/cc)            | 0.76     |
| 2    | Specific gravity                | 2.63     |
| 3    | Loss on ignition                | 0.015%   |
| 4    | Ph                              | 6.9      |
| 5    | Moisture                        | 0.058%   |
| 6    | Melting point                   | 1600°C   |
| 7    | Silica Content                  | 99.886   |
| 8    | Ferric oxide                    | 0.04     |
| 9    | Alumina                         | 0.043    |
| 10   | Titanium dioxide                | 0.001    |
| 11   | Calcium oxide                   | 0.001    |
| 12   | Magnesium oxide                 | 0.0      |
| 13   | Sodium oxide                    | 0.003    |
| 14   | Potash                          | 0.001    |

Natural sand as per IS 383-1987[16] was used and the properties of sand were found in accordance with IS 2386[15]
Crushed over burnt bricks of size passing through 20 mm and retaining 12.5 mm was used and reported in Table 4.

Table 4: Properties of crushed over-burnt bricks

| S.No | Property                        | Result  |
|------|---------------------------------|---------|
| 1.   | Specific gravity                | 2.15    |
| 2.   | Aggregate crushing value        | 24.5%   |
| 3.   | Aggregate impact value          | 28.2%   |
| 4.   | Aggregate water absorption      | 5.6%    |

2.1. Mix design
The proportioning of raw materials in concrete is very important as it ensures quality and durability of concrete. The basic mix design adopted for M 30 concrete in present study was in accordance with IS: 10262-2009 [13]. The porosity and water absorption of over-burnt bricks is more than that of the natural aggregates. Due to high porosity and water absorption, the bricks are used in saturated surface dry conditions. Micro-silica was added at various percentages of weight of cement as a partial cement replacement. Table 5 reports the mix proportion for attained target strength of 38 MPa and Table 6 presents the concrete mix designation.

Table 5: Mix proportions.

| W/C Ratio | Water (kg/m³) | Cement (kg/m³) | Fine Aggregate (kg/m³) | Coarse Aggregate (kg/m³) |
|-----------|---------------|----------------|------------------------|--------------------------|
| 0.40      | 180           | 450            | 590                    | 940                      |

Table 6: Concrete mix designations.

| Mix Designation | Description               |
|-----------------|---------------------------|
| S0              | Concrete of grade M30     |
| S5              | 5% Micro-silica + 95% cement |
| S10             | 10% Micro-silica + 90% cement |
| S15             | 15% Micro-silica + 85% cement |
| S20             | 20% Micro-silica + 80% cement |

2.2. Compressive strength
For each mix design, compressive strength test were carried out in accordance with IS 516-1959[17] on a cube specimen of 100 mm size at 7, 14 and 28 days curing. Table 7 presents the results of compressible strength of concrete with varying percentages of micro-silica and shown graphically in figure 1.
Table 7: Compressive strength of concrete

| Mix designation | W/C ratio | 7th day (MPa) | 14th day (MPa) | 28th day (MPa) |
|-----------------|-----------|---------------|---------------|---------------|
| S0              | 0.4       | 18.50         | 27.25         | 31.50         |
| S5              | 0.4       | 19.00         | 28.50         | 32.25         |
| S10             | 0.4       | 21.00         | 29.00         | 33.50         |
| S15             | 0.4       | 20.50         | 27.50         | 33.00         |
| S20             | 0.4       | 19.50         | 26.50         | 32.50         |

2.3. Splitting Tensile strength

The split tensile strength was carried out in a cylinder of dimensions diameter 150 mm and length 300 mm according to IS 5816-1999 [18] after 7 and 28 days of curing. Table 8 gives the results of split tensile strength with varying percentages of micro silica. The results are shown in the form of graph (figure 2).

Table 8: Splitting Tensile Strength of concrete

| Mix Designation | W/C ratio | 7th day (MPa) | 28th day (MPa) |
|-----------------|-----------|---------------|---------------|
| S0              | 0.4       | 0.84          | 1.67          |
| S5              | 0.4       | 0.87          | 1.75          |
| S10             | 0.4       | 0.91          | 1.80          |
| S15             | 0.4       | 0.79          | 1.59          |
| S20             | 0.4       | 0.78          | 1.54          |
2.4 Flexural strength

The test was done after 28 days of curing. The flexural test was carried out in 100×100×500 mm beams according to IS 516-1959[17]. Table 9 gives the results of flexural strength with various percentages of micro-silica. The results are shown in a graph (figure 3).

Table 9: Flexural strength of concrete.

| Mix Designation | W/C ratio | 28th day (MPa) |
|-----------------|-----------|----------------|
| S0              | 0.4       | 3.45           |
| S5              | 0.4       | 3.5            |
| S10             | 0.4       | 3.6            |
| S15             | 0.4       | 3.5            |
| S20             | 0.4       | 3.55           |

Figure 2: Splitting tensile strength of concrete

3. Results and Discussion

In the current study, the effect of micro-silica as a partial cement replacement on properties of concrete with over-burnt bricks as coarse aggregate is studied.

The compressive strength for concrete with 10% micro-silica as replacement for cement increases by 13%, 6.4% and 6.3% for 7 days, 14 days and 28 days respectively when compared to concrete without...
micro-silica as replacement. Beyond 10% replacement, compressive strength decreases. The maximum silica fume replacement is 10% to achieve maximum compressive strength.

The split tensile strength for concrete with 10% micro-silica as replacement for cement increases by 8.3% and 7.7% for a curing period of 7 days and 28 days respectively when compared to concrete without micro-silica replacement. Beyond 10% replacement, the splitting tensile strength decreases.

The flexural strength of concrete with 10% micro-silica as replacement for cement increases by 4.3% for a curing period of 28 days when compared to concrete without micro-silica. Beyond 10% replacement, there is a decrease in flexural strength.

There is a predominant increase in mechanical properties of concrete when pozzolanic materials like micro-silica is incorporated into concrete. This is attributed to the reason that, silica present in micro silica reacts with calcium hydroxide produced during hydration of cement and forms calcium silicate hydrate. The formation of calcium silicate hydrate improves overall mechanical properties of concrete. Also because of extreme fineness of micro-silica, it acts as a filler material resulting in reduction in porosity and helps in densifying the concrete mix.

4. Conclusion

From the study conducted it is observed that the quality of concrete can be improved by conducting proper quality check for brick aggregate. The optimum percentage of micro-silica as a replacement of cement is 10% for M30 concrete. There is an increase in mechanical properties of concrete when micro-silica is added because of its high pozzolanic nature to form calcium silicate hydrate. It can also act as a filler material which increases density of the concrete and improves the durability. Hence the use of waste overburnt bricks along with micro-silica promises a sustainable way of construction by reducing the excess use of naturally available coarse aggregate and cement.

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