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# PERFORMANCE OF CEMENT MORTAR AND CONCRETE WITH PARTIAL REPLACEMENT OF CEMENT WITH CLAY BRICK POWDER- AN EXPERIMENTAL APPROACH

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***Abstract*: Cement is a good binding material and widely used in construction but the emission of $CO_2$ is increased day by day in manufacturing of cement. To mitigate the emission of $CO_2$, we have to depend on alternate binding material. But till now no other material fulfill the requirements of cement. So scientists, research scholars, institutions etc., are trying to find out alternate replacement materials in place of cement in construction industry. In this regard we investigate the feasibility of brick powder as a partial replacement material in place of cement in making of mortar and concrete. This experimental study shows the performance of brick powder in making of cement mortar and determination of workability and some of the mechanical properties of concrete as a partial replacement material**

*Keywords:* **Cement, $CO_2$, brickpowder, workability, mechanical properties.**

## I. INTRODUCTION

Cement is familiar of cheap, strong and durable material widely used in construction industry. Global cement production [9] was 2.3 billion tons in 2005 which is almost four times the number in 1970. In the production of cement the $CO_2$ and waste material like cement clinker dust released more and acts as a pollutant of environment. So the alternate materials for cement are necessary in this scenario to protect the environment.

### A. Objectives of Study

1. To check the suitability of brick powder as partial replacement material in place of cement for preparation of concrete by evaluating some mechanical properties.
2. To evaluate the soundness and compressive strength of brick powder in making of cement mortar as partial replacement material.
3. To analyze volume of voids % in cement mortar as a trail attempt using ASTM C 642 – 06

## II. REVIEW CRITERIA

A few reviews which helpful in this work are mentioned here.

**Muhammad Nasir AyazKhan *et.al.*,(2018)** explained brick dust as used in the 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 as constant during research. Three samples were cast for each 3,7,14, and 56 days with 0%, 5%, 10%, 15% and 20% incorporation of brick dust. The split tensile test was also conducted, which shows high tensile strength by replacing cement with 15% brick dust. This research shows that cement can be replaced.

**R. Veerakumar *et.al.*, (2018)** investigate the suitability of using brick debris in concrete in place of fine aggregate. Brick debris originated from demolished masonry walls crushed in the laboratory and added in partial fine aggregate replacement. Four replacement levels, 5%, 10%, 15%, and 20%, were compared with the control. The tests on concrete showed that the mechanical properties (compressive strength test) of concrete containing brick debris were well comparable to those of the concrete without ground brick.

**M.UshaRani *et.al.*, (2016)** explained on a comprehensive study on the use of brick powder produced from clay brick demolition wastes in concrete industry. The main focus of the research is to present additional information in the field of recycling clay masonry rubbles in order to explore the possible uses of these recyclable materials in structural applications.

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## III. METHODOLOGY

The aim of this experimental work is to assess the properties of cement mortar and concrete made with crushed brick powder. The replacement of cement by brick powder is 10%, 15%, and 20% in each case then performed required laboratory test. Materials were collected locally and the laboratory tests conducted on cement fine aggregate and coarse aggregate. After completion of laboratory tests on the materials the mix design was prepared for M30 grade concrete with referential codes of IS 10262-2009 and IS 456-2000.Based on the mix design the cube and cylindrical specimens were prepared for 7 and 28 days of curing period with and without using brick powder. The sizes of cube specimens and the cylinder specimens are 150mmX150mmX150mm and 150mmX300mm respectively. The measurement of workability carried out by slump test and compaction factor test. Compression and split tensile strengths were conducted after 7and 28days of curing period using CTM. The average strength of three cube specimen results was taken in each mix for strength evaluation. At the same time the compressive strength performed on cement cubes as well as cubes made with both cement and B.P of size 70.6 mm X 70.6 mm X 70.6 mm. The volume of voids % also determined as per ASTM C 642 – 06 but with the same size of specimens. From the obtained results we had done discussions and finally conclude the present work.

## IV. EXPERIMENTAL PROGRAM

Table 1 Details of mixes as per experimental program

| S. No | Mix. | Cement (%) | Sand (%) | CA (%) | W/C ratio | B.P-Brick powder (%) |
|---|---|---|---|---|---|---|
| 1 | C.M | 100 | 100 | 100 | 0.42 | Nil |
| 2 | M1 | 90 | 100 | 100 | 0.42 | 10 |
| 3 | M2 | 85 | 100 | 100 | 0.42 | 15 |
| 4 | M3 | 80 | 100 | 100 | 0.42 | 20 |

In Table 1 C.M-Control Mix, C.A-Coarse Aggregate,
M1-10% replacement of B.P in the mix,
M2-20% replacement of B.P in the mix and
M3-30% replacement of B.P in the mix

The experimental work is designed to test the performance of B.P in place of cement for making of mortar and concrete. Mainly, Soundness test and compressive strength tests are performed on cement and cement mortar and mechanical properties of concrete like compressive strength and split tensile tests determined as per Indian standards by partial replacement of cement with brick powder. Mixing process done in manual way and constant W/C maintained in all stages. At the same time volume of voids % in cement determined as per ASTM C 642 – 06. We approached to perform this test on cement cubes of size 70.6mmX70.6mmX70.6mm. The material properties are determined as per IS standards and design mix is prepared as per IS 456-2000 and IS 10262-2009. The red clay burnt brick are crushed manually and the brick powder is sieved through 90micron IS sieve then the passing material is utilized in place of cement in different mixes.

## V. RESULTS AND DISCUSSIONS

### 5.1 Results

In this experimental work, locally available sand was taken and segregated as three grades like Grade-1, Grade-2, and Grade-3.The grade classifications are:

Grade-1- grains which passes through IS 1.18 mm and retained on 600 micron sieve. Grade-2- grains which passes through 600 micron and retained on 300 micron sieve. Grade-3- grains which passes through 150 micron and retained on 90 micron sieve.53 grade of cement and available ground water is used for making of mortar and concrete. The cement and the combination of three grades are used in proportion 1:3 in preparation of cement mortar. Initially the physical properties of cement and sand are determined as per Indian Standards and different mortars mixes are prepared with partial replacement of cement by using Brick Powder(B.P).Soundness test for durability of cement and compressive strength tests are performed on control mix and as well as on remaining mixes. No vibrating machine is used in making of mortar and concrete specimens. Manual compaction is carried out for all the mixes.

Table 2 Test results of Cement

| Name of the test | Result | IS Code |
|---|---|---|
| 1.Fineness of cement | | IS 4031 (Part 1) - 1988 |
| 2. Consistency of cement | 29% | IS 4031 (Part 4) - 1988 |
| 3. Setting time of cement<br>a.) Initial<br>b.) final | <br>37 minutes<br>479 minutes | IS 4031 (Part 5) - 1988 |

Table 3 Compressive strength results of Mortar mixes

| S.No. | Mortar Mix | Result (N/mm²) | |
|---|---|---|---|
| | | 7days | 28 days |
| 1. | Control mix | 11.57 | 23.4 |
| 2. | MM10B.P | 13.91 | 18.38 |
| 3. | MM15B.P | 13.29 | 19.72 |
| 4. | MM20B.P | 11.12 | 23.2 |

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MM-Mortar Mix

Table 4 Test results of Fine aggregate

| S.No | Name of the test | Result | IS Code |
|---|---|---|---|
| 1. | Fineness modulus | 1.871 | IS 383 - 1970 |
| | Confirming zone | Zone-IV | |

Table 5 Test results of coarse aggregate

| S.No. | Name of the test | Result |
|---|---|---|
| 1. | Fineness modulus | 6.3 |
| 2. | Specific gravity | 2.67 |

Table 6 Soundness Test results of cement paste

| S.No. | Mix | Result (mm) |
|---|---|---|
| 1. | Controlmix | 0.2 |
| 2. | CP10 B.P | 0.16 |
| 3. | CP15 B.P | 0.18 |
| 4. | CP 20 B.P | 0.13 |

In Table 6

CP10B.P: The cement paste is prepared by using 10% brick powder

CP15B.P: The cement paste is prepared by using 15% brick powder

CP 20 B.P: The cement paste is prepared by using 20% brick powder

### 5.2 DISCUSSIONS

The following discussions were drawn based on test results of cement mortar and concrete prepared with and without brick powder.

**A) Discussions based on test results of cement mortar**

1. The compressive strength of control mix after 7 and 28 days of curing period are 11.57 N/mm$^2$ and 23.4 N/mm$^2$ respectively.
   - Locally available different grades of sand affect the strength of mortar and concrete mixes. The binding nature depends on the size and shape of sand particles. If the particles are very fine, there is no proper binding between ingredients then the strength is decreased. In the present study the sand confirming to zone IV, it is fine sand. Due to scarcity of river sand we used locally available sand in this work.

Table 7 Test results of volume of voids % in mortar

| S.No | Mix | Compressive strength(N/mm$^2$) | | Split Tensile strength(N/mm$^2$) | |
|---|---|---|---|---|---|
| | | 7days | 28days | 7days | 28days |
| 1. | Control mix | 25.07 | 33.24 | 1.94 | 2.45 |
| 2. | CM10B. P | 24.57 | 33.91 | 1.82 | 2.51 |
| 3. | CM15B. P | 24.61 | 35.56 | 1.99 | 2.67 |
| 4. | | 22.09 | 31.24 | 1.62 | 1.84 |

| S.No. | Mortar Mix | Result |
|---|---|---|
| 1. | Control mix | 9.6% |
| 2. | MM10B.P | 9.32% |
| 3. | MM15B.P | 9.04% |
| 4. | MM20B.P | 6.32% |

Table 8 Compressive & Split Tensile strengths results of Concrete Mixes

   - The fineness modulus result of taken fine aggregate confirms that it belongs to very fine sand. Due to fineness the bonding between cement and sand particles are inadequate for achieving required strength.
   - Due to lack of proper machine vibration, the strength may not have achieved after curing period.

2 The soundness test results do not show any effect on control mix and remaining mixes. The obtained results all are within permissible limits of Indian Standards. Hence the brick powder plays the similar role of cement in durability aspect.

3 Adding of brick powder at different percentages in the mortar mixes, it is observed that the 7 days compressive strength is decreased but 28 days of compressive strength is gradually increased in all stages.

4 Chemical Reaction of Brick powder with Cement:
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:

Portland cement + Water → Calcium Silicate Hydrate
$Ca(OH)2 + CO2 \rightarrow CaCO3 + H2O$

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

Pozzolana + $Ca(OH)2$ + water → C-H-S (Glue)

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The former reaction of Portland cement with water is fast reaction which provides early strength to the 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, it causes strength of concrete at the age of 28 days

5 The replacement of cement with brick powder at 10%, 15%, and 20%, the volume of voids is 9.32 %, 9.04% and 6.32 % respectively in all mortar mixes. It is observed that due to fineness of brick powder, the voids space is occupied by the fine particles. Hence the compressive strength also gradually increased in all stages.

6 At 20% partial replacement of cement the 28 days compressive strength is almost equal to control mix.

7 From the test results of volume of voids %, it is observed that the voids % is more in control mix when compared to the remaining mixes. As per my point of view this test may not give complete accurate results due to usage of mortar cubes in place concrete specimens.

**B) Discussions based on test results of hardened concrete**

1. The 28 days compressive strength of control specimen is 33.24N/mm$^2$.Due to lack of quality of sand the strength not achieved properly.
2. It is observed that the 28days compressive strength is increased at 15% replacement material when compared to 10% replacement but later it is decreased at 20% replacement of B.P.
3. As a reference of control specimen the 7 days strength is decreased by 2%, 1.83%, and12% at 10%, 15%, and 20% replacement of B.P but the 28 days strength is increased 2%, 7% and again decreased 6% at the same replacement of B.P respectively.
4. As a reference of 7 days strength the 28 days strength increased 38%, 45% and 41.42% at 10%, 15%, and 20% replacement of B.P respectively.
5. When comparing all the split tensile results, the better result came at 15% replacement of B.P that is increased by 9% when compared to 28 days strength of control specimen and at the same time 25% of strength is decreased by 20% replacement of B.P.
6. It was noticed that the percentage decrement in split tensile strength is equal to four times of compressive strength decrement obtained when compared to control specimen at 20% replacement of B.P.

## VI. CONCLUION & RECOMMENDATIONS

### A) Conclusion

1. From the above said discussions it was concluded that the compressive strength showed satisfactory result at 15 % replacement of B.P in place of cement in concrete preparation. The compressive strength and split tensile strengths are increased by 7% and 9% when compared to control specimen. Hence up to 15% B.P may consider satisfactorily as replacement material of cement in concrete making.
2. The compressive strength of mortar mix is almost same at 20% replacement of B.P when compared to control mix hence 20% B.P is allowable for preparation of mortar.

### B) Recommendations

1. Durability tests recommended for final conclusion
2. Identification of the size of particles of brick powder in concrete making can give better conclusions
3. Temperature in brick powder may effect the hydration process so it is researchable area.
4. Chemical reaction between B.P and cement in hydration process will take place in accurate conclusions.

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