Mechanical Properties of Concrete with Bottom Ash as Partial Replacement of Fine Aggregate

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Abstract. The fine aggregate is one of the important constituent in preparing concrete. Nowadays, fine aggregate is not fond in abundant quantity and so many replacements were done for river sand like crusher sand, M-sand, bottom ash etc. In this study the replacement is done partially for the fine aggregate with bottom ash which is extracted from Mettur Power Plant. The bottom ash and sand proportions is taken as 10:90, 20:80, 30:70, 40:60, 50:50 (M1,M2,M3,M4 and M5 respectively). The basic tests for all material used in concrete preparation were determined. M20 grade of concrete is casted and the test on fresh concrete is determined for conventional and partially replaced concrete. The specimens (beams, cylinders and cubes) were casted and kept under curing for 7 and 28 days from the cured concrete specimen’s hardened concrete test were determined. The strength of concrete for ratios 10:90 and 20:80 are having nearly equal strength comparing to normal concrete. Hence ratio 20:80 is advisable by this experimental study.

1. Introduction
Concrete is a material with strength and longevity. It has emerged as the dominant construction material for the infrastructure. In addition to being durable, concrete is easily prepared and fabricated from readily available constituents like cement, sand, and coarse aggregate. It is widely used in all types of structural systems. The challenges for our civil engineering community are to develop the concept of sustainable development in construction aside and this sustainable development should be a reasonable cost. There have been some considerable developments in the research of bottom ash in concrete production. The increase in the performance of this type of concrete is only due to a delay in pozzolanic reaction. The compressive strength, flexural strength and density of bottom ash concrete decrease with an increase in the percentage of bottom ash level.

[1] Abdulhameed Umar Abubakar et al, used bottom ash and fly ash as the partial replacement for fine aggregates and cement respectively in the range of 0, 5, 10, 15 & 20% with equal percentages for M35 grade of concrete .from their study it is clear that increased curing is required to attain maximum compressive strength and the targeted strength was achieved at 56 days curing period. [2]. P. Aggarwal, Y. Aggarwal, s.m. Gupta, in their study they used bottom ash as a partial replacement of fine aggregate from 0% to 50% and found the strength of concrete is increased with an increase in curing time through various mechanical properties. [3]A S Cadersa
and I Auckburally in their study, they have replaced bottom as a partial replacement of fine aggregate in the increments of 20% up to 80% replacement and found that 20% replacement provides favorable results. [4]. Chou-Fu Liang and Hung-Yu Wang studied the moisture content of bottom ash which is used in fine and coarse aggregate and suggested the water-cement ratio of 0.45 through their test results. [5]. Dinesh Kumar G, et al, used Coal bottom ash as a partial replacement of fine aggregate for M25 grade of concrete in the increments of 10% up to 50% and found that up to 20% of fine aggregate can be replaced with bottom ash. [7]. Kandagaddala Revanth Kumar et al., used bottom ash and marine sand as partial replacement of fine aggregate and studied the strength properties of concrete and found lower compressive strength and suggested to equate to a lower grade of concrete. [8]. Kiran Kumar M S et al. used bottom ash for the partial replacement of fine aggregate up to 50% in the increments of 10% and suggested for 10% replacement of bottom ash from their results. [9]. Kula, L et al, in their research used colemante waste, coal bottom ash, and fly ash for the replacement of cement and found the mechanical properties of the same through the various test from their test results they have concluded the materials can be used as cementitious materials. [10] Kylasnath M and Ranjan Abraham, used bottom ash as a partial replacement in the increments of 5% up to 30% in M60 grade of concrete, and mechanical properties were studied. Through their investigation, it is clear that the strength of concrete with bottom ash is getting decreased due to slow pozzolanic action. [11]. Ratchayut Kasemchaisiri and Somnuk Tangtermsirikul, they studied the properties of SCC incorporating Bottom ash as replacement of fine aggregate in increments of 10% from 0% to 30%. From their experimental study, they recommended a 10% replacement will give the desired strength at 56 days curing due to the pozzolanic reaction. [12]. Remya Raju, Mathews M. Paul, K. A. Aboobacker in their research they used bottom ash and replaced up to 30% for fine aggregate with M35 grade of concrete and fund there is the declination in workability and found that the tensile strength of concrete is improved with the addition of bottom ash. [13]. Sabisha Aliyar and Remya Raju used bottom ash and washed bottom ash as a partial replacement and compares the strength properties of concrete through the various test. They used the bottom ash and washed bottom ash in the increments of 5% up to 30% and found that beyond 10% replacement there are fewer changes in the strength of concrete. [14]. V. Sandeep Kumar and K.Konda Reddy used bottom ash as fine aggregate replacement in addition to steel fiber and studied the hardened properties of concrete for M25 grade of concrete. [15]. Dr. R. G. D’ Souza, he studied the compressive strength of bottom ash replaced concrete for different grades of concrete and found 100% replacement of fine aggregate with bottom ash produces high compressive strength. [16]. Yogesh Aggarwal and Rafat Siddique used the by-products bottom ash and waste foundry sand in various percentages (0-60%) and studied the mechanical behavior of concrete.

From various studies undergone from the above literature, we choose to use the bottom ash (waste from Mettur Thermal power plant) as a partial replacement of fine aggregate. The replacement will be done from 0% to 50% for M20 grade of concrete. The hardened concrete test like compressive strength, Split tensile strength, and flexural strength of cured concrete was tested and results were tabulated and discussed.

2. Methodology

The amount of cement, aggregate and water required for preparing concrete is determined through mix design. The ingredients are mixed by hand mixing. The moulds are lined with oil to prevent sticking of the concrete inside the mould. The fresh concrete is then filled in layers approximately 5 cm deep and is subjected to 25 strokes with tamping rod to avoid air voids in the specimens and the surface is leveled using a trowel. The moulds with concrete are kept in room temperature for 24 hours, the marked specimens are then removed from the moulds and submerged in water for curing. The curing water is to be renewed for every seven days and the testing specimens are to be kept in contact with water till it is taken for testing. Before testing a specimen, the surfaces of the specimens and testing machine are wiped clean and placed in the machine to apply the load.
3. Preliminary tests conducted

The initial and final setting time for cement is determined to be 30 minutes and 6 hours 30 minutes respectively. The specific gravity test of fine aggregate and coarse aggregate was determined and found to be 1.51 and 2.58 respectively. In coarse aggregate other test like impact value, crushing value tests are conducted and the following results are observed respectively 10.43% and 25.17%. The slump value of fresh concrete is found as 30mm.

4. Mechanical properties of concrete

4.1 Cube’s compressive strength

| S. No | Mix ratio | Compressive value of 7 days (N/mm²) | Compressive value of 28 days (N/mm²) |
|-------|-----------|-------------------------------------|--------------------------------------|
| 1     | N.C       | 19.20                               | 25.5                                 |
| 2     | M1        | 21.00                               | 27.6                                 |
| 3     | M2        | 19.25                               | 24.8                                 |
| 4     | M3        | 12.40                               | 18.9                                 |
| 5     | M4        | 8.00                                | 16.4                                 |
| 6     | M5        | 9.70                                | 13.8                                 |

Figure 1. Compressive Strength of Cubes

Cube’s Compressive Strength after 7 and 28 days curing is listed in the Table 1 and respective bar chart is given in Fig 1. This clearly shows that, the strength of ratio M2(20:80) gives nearly equal strength as conventional concrete for curing periods of 7 days and 28 days.
4.2 Cylinder’s compressive strength

Table 2. Compressive Strength of Cylinders

| S. No | Mix ratio | Compressive value of 7 days (N/mm²) | Compressive value of 28 days (N/mm²) |
|-------|-----------|-------------------------------------|-------------------------------------|
| 1     | NC        | 3.5                                 | 6.7                                 |
| 2     | M1        | 4.1                                 | 7.5                                 |
| 3     | M2        | 3.7                                 | 6.6                                 |
| 4     | M3        | 3.43                                | 5.36                                |
| 5     | M4        | 3.12                                | 4.56                                |
| 6     | M5        | 2.08                                | 3.37                                |

Figure 2. Compressive Strength of Cylinders

Cylinder’s Compressive strength after 7 days and 28 days curing is listed in the Table 2 and respective bar chart is given in Fig 2. This clearly shows that, the ratio M3 (30:70) gives nearly equal strength as conventional concrete for 7 days curing and strength of ratio M2 (20:80) gives nearly equal strength as normal concrete for 28 days curing.

4.3 Cylinder’s split tensile strength

Table 3. Cylinder’s Split Tensile Strength

| S. No | Mix ratio | Split Tensile strength of 7 days (N/mm²) | Split Tensile strength of 28 days (N/mm²) |
|-------|-----------|------------------------------------------|------------------------------------------|
| 1     | NC        | 2.8                                      | 3.5                                      |
| 2     | M1        | 2.5                                      | 2.08                                     |
| 3     | M2        | 2.3                                      | 3.98                                     |
| 4     | M3        | 1.74                                     | 2.71                                     |
| 5     | M4        | 1.56                                     | 1.53                                     |
| 6     | M5        | 1.29                                     | 1.35                                     |
Cylinders Split tensile strength after 7 days and 28 days curing is listed in the Table 3 and respective bar chart is given in Fig 3. This clearly shows that, the ratio M1(10:90) gives nearly equal strength as conventional concrete for 7 days curing and strength of ratio M2 (20:80) gives nearly equal strength as normal concrete for 28 days curing.

4.4 Flexural Strength of beam

Table 4. Flexural Strength of Beams

| S. No | Mix ratio | Flexural Strength of 7 days (N/mm²) | Flexural Strength of 28 days (N/mm²) |
|-------|-----------|-------------------------------------|-------------------------------------|
| 1     | N.C       | 11                                  | 10.2                                |
| 2     | M1        | 10.125                               | 9.83                                |
| 3     | M2        | 10.75                                | 12.81                               |
| 4     | M3        | 8.04                                 | 9.33                                |
| 5     | M4        | 8.5                                  | 7.6                                 |
| 6     | M5        | 7.55                                 | 6.4                                 |

Figure 3. Split Tensile Strength of Cylinders

Figure 4. Flexural Strength of Beams
Flexural strength of concrete beams after 7 and 28 days curing is listed in the Table 4 and respective bar chart is given in Fig 4. This clearly shows that, the ratio M2( 20:80) gives nearly equal strength as conventional concrete after 7 and 28 days curing period.

5. Conclusion
Density of concrete will decrease with increase in bottom ash content due to the low specific gravity of bottom ash. Bottom ash absorbs more water hence the workability of concrete is decreased. Bottom ash can be used with admixtures. The strength of concrete for ratios 10:90 and 20:80 are having nearly equal strength comparing to normal concrete. Hence ratio 20:80 is recommended. The replacement of Bottom ash enables the maximum waste utilization from the thermal power plants and can avoid dumping of the same in land.

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