Influence of bentonite as partial replacement of cement in basalt fiber concrete

Patel Ashish¹ and Ch. Srinivasarao².

¹PG student, Department of Civil Engineering, CMR Technical Campus, Hyderabad, India.
²Professor, Department of Civil Engineering, CMR Technical Campus, Hyderabad, India.

* Corresponding author e-mail: ¹ashishpatil5938@gmail.com, ²chigurupatisrinivas@gmail.com

Abstract. Concrete is commonly accepted construction material in the construction field. Concrete is second in terms of per-capita consumption in the world that is about approximately 500 kilograms. This leads to increase in consumption of Ordinary Portland Cement (OPC). The environment is at risk in terms of damage caused by Carbon dioxide (CO₂) emission during OPC manufacturing process. Hence this is the hour to reduce consumption of OPC by partial replacement. The present study focuses on finding of optimum percentage substitution of OPC with bentonite. As the concrete is weak in tension, basalt fiber is used in concrete to add the tensile properties to concrete. The investigation is carried out using cube, cylinders, and beams specimens with varying percentages of bentonite and basalt fiber by cement weight. The workability and mechanical properties like slump cone, compression, split tensile, flexure strength is measured for different combinations of fiber and bentonite in conventional and trial mix concrete. Specimens are casted, cured, and tested for 3, 7 and 28 days as per Indian standards. The test results of conventional concrete and trial mix concrete are compared, and it is observed that 10% bentonite replacement and 1.5% basalt fiber replacement give optimum results. From the study benefit of bentonite as partial replacement material to cement is recommended.

Keywords: Bentonite, Basalt fiber, Workability, Mechanical properties.

1. Introduction

Concrete is the man-made construction material used worldwide. Now a day’s urbanization is increasing rapidly attributable to movement of persons from rural areas to metropolitan areas for better standard of living. Hence this increases construction of new buildings which in turn increase consumption of concrete. The CO₂ emission increases due to many reasons one of the reasons is manufacturing of OPC. During manufacture of 1 metric ton OPC nearly around 0.9 ton of CO₂ is released in atmosphere. This results in reduction of OPC consumption by finding partial replacement materials. Some of the partial materials of cement namely fly ash, ground granulated blast furnace slag, metakaolin can be used. Organobentonite can be used as partial substitute material for cement [1]. There is a decrease in workability by the increase of bentonite content in concrete mix and recommended that partial use of ground granulated blast furnace slag and bentonite in cement [2]. It is...
observed that inclusion of basalt fiber in concrete improves split tensile strength, and compression strength of M20 concrete mix and recommended that optimum percentage use of basalt fiber for compression is 0.5% and for split tensile strength is 1.5% by cement weight [3]. Failure pattern of the specimen has more cracks than concrete without fibers than with the basalt fiber concrete and recommended that mechanical properties of concrete increases by inclusion of basalt fiber [4]. Found that basalt fiber addition gives higher compressive and tensile strength and recommended that 2% basalt fiber addition gives optimum results [5]. Basalt fiber is a potential material in construction sector to enhance the properties of concrete, and found it as a useful building material and can be recommended for use in construction [6]. Bentonite as a partial substitute material of OPC, and recommended 5% use of bentonite by weight of cement [7]. Addition of bentonite decrease in early age strength, use of 15% bentonite in cement replacement is recommended [8]. Sodium bentonite and fly ash can be used as partial substitute material for OPC, use of 25% fly ash and 15% bentonite by weight of OPC is recommended [9]. Bacteria enhance the strength of concrete, and recommended that use of bio concrete in general construction [10]. Bentonite and steel slag can be partially replaced in cement and fine aggregate [11]. Use of magnetized water for casting and curing of concrete there is 60% increases in strength [12]. In the present study author has chosen bentonite as partial replacement material to OPC which promotes use of natural product and reduces CO2 emission. Concrete is brittle in nature, to increase the ductility property of concrete fibers are embedded in concrete to overcome this problem. Some of the fibers used in concrete are polypropylene, steel, asbestos, organic, carbon fibers are used. In the present study basalt fiber is used. Workability test is carried on fresh concrete and mechanical properties are carried on hardened concrete specimens. Total of six trail mix were prepared and compared with conventional concrete. And it is recommended that 10% replacement of OPC with bentonite and 1.5% use of basalt fiber in concrete. Objectives of the present study are to analysis the fresh properties of concrete consisting bentonite and basalt fiber, to study the mechanical properties like compression strength, flexural strength, split tensile strength of concrete consisting bentonite and basalt fiber, finding optimum percentage replacement of bentonite and basalt fiber in concrete, to promote the usage of natural product as partial replacement of OPC and to reduce CO2 emission by use natural products.

2. Materials and Methodology

2.1 Ordinary Portland Cement (OPC):
Ordinary Portland Cement of 53 grade is used in this study as per IS: 269-2015. The physical properties of OPC are shown in Table 1.

| Properties         | Values | IS CODE            |
|--------------------|--------|--------------------|
| Consistency        | 33%    | IS: 5513-1996      |
| Initial setting time | 48 minutes | IS: 4031 part-2-1998 |
| Final setting time  | 252 minutes | IS: 4031 part-5-1998 |
| Fineness           | 1%     | IS: 4031-part-1-1996 |
| Specific gravity   | 3.13   | IS: 2702-part-3    |

2.2 Fine aggregate (FA):
Manufactured sand conforming with IS: 383-2016 is used in this study. The properties of manufactured sand are shown in Table 2.
Table 2. Physical properties of Fine aggregate.

| Properties       | Value  | IS CODE                        |
|------------------|--------|--------------------------------|
| Specific gravity | 2.34   | IS: 2386 part-3-1963            |
| Sieve analysis   | Zone II| IS: 383-1970                   |
| Water absorption | 6.4%   | IS: 2386 part-3-1963            |

2.3 Coarse aggregate (CA):

20 mm size angular shape of coarse aggregate confirming IS:383-2016 was used in this study. The physical properties of coarse aggregate are depicted in below Table 3.

Table 3. Physical properties of Coarse aggregate.

| Properties       | Value  | IS CODE                        |
|------------------|--------|--------------------------------|
| Specific gravity | 2.78   | IS: 2386 part-3-1963            |
| Water absorption | 1.6%   | -                              |

2.4 Basalt Fiber (BSF):

In this presentstudy chopped basalt fiber is used. The physical properties are shown in Table 4.

Table 4. Physical properties of Basalt fiber (Provided by Vaishnav Composites).

| Properties         | Value                  |
|--------------------|------------------------|
| Density of filament| 2.7 kg/dm³             |
| Melting point      | 1350 °C                |
| Diameter           | 13-20 μm               |
| Length             | 12 mm                  |
| Moisture content   | <0.3%                  |
| Loss on Ignition   | <0.5%                  |

2.5 Bentonite Powder (BN):

Bentonite is a partial replacement material used in this study. The physical properties of bentonite are shown in below Table 5.

Table 5. Physical properties of Bentonite powder (Provided by Gantra Minerals and Mines).

| Properties         | Value                   |
|--------------------|-------------------------|
| Moisture           | 12%                     |
| pH                 | 8.5                     |
| Bulk density       | 1.2 tons/m³             |
| Sand content       | 3%                      |
| Colour             | Brownish                |

2.6 Water:

Portable water available in the lab is used for casting and curing in this study.

2.7 Chemical Admixture (SP):

In the present study polycarboxylate ether based superplasticizer are used. The properties of superplasticizer are depicted in the Table 6.
Table 6. Specification of Superplasticizer (Provided by Fratellanza Chemicals).

| Property             | Value  |
|----------------------|--------|
| Specific gravity     | 1.08   |
| pH                   | 6      |
| Colour               | Light brown |
| Chloride content     | Nil    |

Materials used in the study are shown in below figures.

Figure 1. Basalt fiber
Figure 2. Bentonite
Figure 3. Superplasticizer

2.8 Design mix:

The design mix is carried as per IS: 10262-2019 for M40 grade concrete. The materials quantity for 1 m$^3$ are shown in Table 7.

Table 7. Material quantity for conventional M40 Grade concrete (Kg/m$^3$).

| Materials          | OPC | Fine aggregate | Coarse aggregate | water | Superplasticizer |
|--------------------|-----|----------------|------------------|-------|-----------------|
| Weight             | 421 | 652            | 1197             | 169   | 2.95            |

In this study trial mix where prepared in which OPC is partially replaced by bentonite powder at 5%, 10% and 15%. The basalt fiber at 1% and 1.5% are considered. Table 8. explains the percentage replacement in detail.

Table 8. Material quantity for trial mix M40 grade concrete (kg/m$^3$).

| Mix Id | Mix Description | OPC | BN | FA  | CA  | Water | BSF | SP   |
|--------|-----------------|-----|----|-----|-----|-------|-----|------|
| A1     | BN5%+BF1%       | 399.95 | 21.05 | 651.11 | 1196.84 | 168.35 | 4.21 | 2.95 |
| A2     | BN10%+BF1%      | 378.9  | 42.1  | 651.11 | 1196.84 | 168.35 | 4.21 | 2.95 |
| A3     | BN15%+BF1%      | 357.85 | 63.15 | 651.11 | 1196.84 | 168.35 | 4.21 | 2.95 |
| A4     | BN5%+BF1.5%     | 399.95 | 21.05 | 651.11 | 1196.84 | 168.35 | 6.32 | 2.95 |
| A5     | BN10%+BF1.5%    | 378.9  | 42.1  | 651.11 | 1196.84 | 168.35 | 6.32 | 2.95 |
| A6     | BN15%+BF1.5%    | 357.85 | 63.15 | 651.11 | 1196.84 | 168.35 | 6.32 | 2.95 |

Mechanical properties of concrete like compression, flexure, split tensile strength of both conventional and trial mix concrete are evaluated by casting cube specimens of size 150mm x 150mm x 150mm, beam specimen of size 500mm x 100mm x 100mm, and cylinder specimen of size 150mm in diameter and 300mm in height are casted and cured in portable water before testing for 3, 7 and for 28 days.
3. Test Results and Discussions

3.1 Workability Test:

Workability of fresh concrete is measured with the help of slump cone test as per IS: 1199-1959. The mix is designed for a targeted slump of 100 mm. It is observed that due to addition bentonite and basalt fiber to concrete workability of fresh concrete is decreasing which is then adjusted by addition of superplasticizer is depicted in below Table9.

| Mix Id | Superplasticizer Dosage as per mix (ml) | Superplasticizer Dosage consumed (ml) | % Variation |
|--------|----------------------------------------|-------------------------------------|-------------|
| A1     | 2731                                   | 2917                                | 1.06        |
| A2     | 3111                                   | 4630                                | 1.69        |
| A3     | 4630                                   | 5787                                | 2.12        |
| A4     | 5787                                   | 6167                                | 2.26        |
| A5     | 6250                                   | 6250                                | 2.29        |

3.2 Compression Strength Test:

Concrete cube specimens were tested for compression strength as per IS: 516-2018. The concrete specimens are cured for 3, 7 and 28 days before testing. Figure 2. shows the compressive strength of concrete at 3, 7 and 28 days.

It is observed from Figure 2. that maximum compressive strength is achieved in mix A5 in which OPC is partially replaced by bentonite and basalt fiber at 10% and 1.5% respectively. Strength achieved in Mix A5 because of packing effect (size, shape) of bentonite particles. On the other hand, it is also observed that due to addition of bentonite there is reduction in early age strength while in comparison with conventional concrete.
3.3 Split tensile Strength Test:
Concrete cylinder specimens were tested for split tensile strength as per IS: 516-2018. The concrete specimens are cured for 3, 7 and 28 days before testing. Figure 3 shows the split tensile strength of concrete at 3, 7 and 28 days.

![Figure 5. Split Tensile Strength Test Results.](image)

The Figure 3 shows the split tensile strength of concrete is optimum in mix A5. The optimum mix A5 shows there is an increase in split tensile strength when fiber is added to concrete while in comparison with conventional concrete. This is because of packing effect (size, shape) of bentonite particles and tensile properties of basalt fiber.

3.4 Flexural Strength Test:
Concrete beam specimens were tested for flexural strength test as per IS: 516-2018. The concrete specimens are cured for 3, 7 and 28 days before testing. Figure 4 shows the split tensile strength of concrete at 3, 7 and 28 days.

![Figure 6. Flexural Strength Test Results.](image)
Figure 4. shows that mix-A5 containing 10% bentonite and 1.5% basalt fiber showing maximum flexure strength due to addition of basalt fiber while in comparison with conventional concrete. This is because of packing effect (size, shape) of bentonite particles and tensile properties of basalt fiber.

Testing facilities of slump, compression, spilt tensile, flexure strength test setups shown in below figures.

5. Conclusions:

- Workability of fresh concrete decreases as the quantity of bentonite increases. The targeted slump of 100mm is obtained by adjusting the dosage of superplasticizer.
- Compressive, split tensile and flexural strength of concrete increases due to addition of basalt fiber in concrete.
- The optimum replacement of OPC with bentonite is 10% by weight of cement.
- The optimum percentage usage of basalt fiber is 1.5% by weight of cement.
- It is recommended that 10% replacement of OPC with bentonite and 1.5% use of basalt fiber in concrete.
- The study revealed that use of natural product are beneficial in terms of engineering properties enhancement of concrete.
- Use of natural product reduces CO₂ emission.
- In all general constructions such School Buildings, Hospital, College, Shopping Complex, Residential Apartments, and Industrial Buildings.
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