MECHANICAL PROPERTIES OF PARTIAL REPLACEMENT OF CEMENT WITH SUGARCANE BAGGASE ASH

Ch Ravi Teja¹, G Nipun², A Monica³

¹Assistant Professor, Department of Civil Engineering, V R Siddhartha Engineering College, Kanuru, Vijayawada, India
²Structural Engineer, SriSahitha Engineers and Developers, Vijayawada, India
³Assistant Professor, Department of Civil Engineering, V R Siddhartha Engineering College, Kanuru, Vijayawada, India
*Corresponding author: chrt@vrsiddhartha.ac.in

Abstract. Current study focuses on mechanical properties of Sugarcane Baggage Ash (ScBA) as a cementitious material and as pore filling material in concrete. With depleting natural resources these industrial waste materials not only helps as replacement material but also provides in numerous alternate benefits such as protecting environment, land fill compounds, saving energy etc. Difficulty of disposing of ScBA is already an environmental hazard. ScBA imparts high strength in early replacements and also reduces concrete permeability, also presence of silica in chemical composition imparts high chloride resistance and corrosion resistance. Mechanical properties were studied for 5%, 10%, 15% and 20% replacement with cement, compressive strength, split tensile and workability were studied and optimum was found to be at 10% replacement. Also durability studies were performed by conducting Rapid Chloride Penetration Test (RCPT) and durability is found to be higher than conventional concrete.

Keywords. Soft soil, coconut coir fibre, Epoxy resin, Stabilization.

1. Introduction

With growing economy and rapid increase in construction, there is high requirement of alternate materials in construction inorder to save the natural resources and thereby reducing impact on environment. In engineering materials applicable in construction concrete is considered as the most dynamic material. In this context there is high need for replacement in concrete mix with natural wastes such as Fly Ash, ScBA, Rice-husk etc[1]. ScBA is considered as waste material in current study as it is widely used in construction industry. it can be used in variety of building materials such as ceramic tiles, cement replacement, fine aggregate replacement etc. due to good pozzolanic properties of ScBA it can be chosen as alternate material in replacement in concrete mixes [2]. India is rich in its agricultural produce and natural fibers, has a large production of sugarcane, these natural fibers provide excellent increase in physical and mechanical properties upon replacement [3]. Baggage waste generated from indian sugar mills is produced in huge proportions and several ways of converting waste to usable material is being studied [9]. Researchers all around world are focusing on various ways of utilizing either industrial or agricultural wastes as raw materials, these waste reusing, ScBA is among such wastes in sugar refining [4]. Baggage Ash was already used to improve the strength parameters of flexible pavements [8] although results may differ when applied the same for structural concrete. Chloride penetration of concrete specimens can be determined by RCPT.
test, based on Faraday’s laws of electrolysis depositions are directly proportional to quantity of electricity considered in coulombs [7]. RCPT tests were conducted to assess the durability aspect of present study as per [6, 7].

Current study aims to evaluate mechanical properties with main focus on strength parameters such as compressive strength, split tensile strength. The workability aspect is also presented in the work. It is focused on 5%, 10%, 15%, 20% replacement of ScBA. Finally durability aspect was studied by performing RCPT on cylindrical specimens.

2. Material Tests

Preliminary tests on all materials Water, Fine Aggregate, Course Aggregate, ScBA were conducted as per codalprovisons.

2.1 Cement & ScB

Ordinary Portland Cement 43 grade is used in current study for replacement studies. Tests on cement were conducted as per guidelines followed by IS 269-2015. Similar tests were conducted on ScBA for obtaining parameters. Table 1 represents the material properties of ScBA where Specific gravity, mean particle size, density, min specific surface area, particle shape and color determined in the preliminary laboratory tests.

| Table 1. Material properties of Sugarcane Bagasse Ash |
|---------------------------------------------|
| S.No | Property                  | Value               |
| 1.   | Density                   | 575 kg/m³           |
| 2.   | Specific gravity          | 2.2                 |
| 3.   | Mean particle size        | 0.1-0.2             |
| 4.   | Min sp. surface area      | 2500m²/kg           |
| 5.   | Particle shape            | Spherical           |
| 6.   | Colour                    | Black               |

Chemical composition of ScBA is taken from [2]. Table 2 represents the Chemical composition of ScBA. Main composition is Silicon dioxide comprising of 78.34% of total volume, and other compounds as in Table 2. OPC 43 grade cement when mixed with ScBA with various percentages (5%, 10%, 15%, 20%) with particle size distribution represented in form of graph shown in Figure 1. with all proportions. Tests on cement for OPC 43 grade were performed and the results were presented in table 3.

| Table 2. Chemical Composition of ScBA |
|--------------------------------------|
| S.No | Description of properties | Percentage(%) |
| 1.   | Silicon dioxide           | 78.34         |
| 2.   | Aluminium                 | 8.55          |
| 3.   | Iron Oxide                | 3.61          |
| 4.   | Calcium oxide             | 2.15          |
| 5.   | Sodium oxide              | 0.12          |
| Test Parameter          | Result          | Limits as per (IS 269: 2015) |
|-------------------------|-----------------|------------------------------|
| 1. Type of cement chosen| PARASAKTHI CEMENT – OPC 43 |
| 2. Fineness:            | 2.2%            | < 10%                        |
| 3. Standard Consistency:| 28.00%          | ---                          |
| 4. Setting Time         |                 |                              |
| Initial                 | 120 min         | ≥ 30 min                     |
| Final                   | 245 min         | ≤ 600 min                    |
| 5. Compressive Strength |                 |                              |
| 3 Days                  | 24.67 MPa       | ≥ 27.00 Mpa                  |
| 7 Days                  | 35.00 MPa       | ≥ 37.00 Mpa                  |
| 28 Days                 | 44.33 MPa       | ≥ 53.00 Mpa                  |
| 6. Soundness:           | 0.1 mm          | < 10 mm                      |

2.2 Coarse Aggregates

Coarse aggregates passing through 12.5mm sieve and 20mm sieve were considered accordingly. These respective aggregates are cleaned with water and sun dried before testing. The test procedure was conducted by following guidelines of IS 383-2016 & IS SP 23:1982 the values are represented as shown in Table 4.
Table 4. Sieve analysis and material properties of Coarse aggregates 12.5mm

| IS Sieve | Wt. retained (gms) | % of Wt. Retained | % of Wt. Retained | % of wt. passing | Grading Limits (IS 383 : 2016) |
|----------|--------------------|--------------------|--------------------|------------------|-------------------------------|
| 63       | 0                  | 0.00               | 0.00               | 100.00           | 100                           |
| 40       | 595                | 11.90              | 11.90              | 88.10            | 85 - 100                      |
| 20       | 4340               | 86.80              | 98.70              | 1.30             | 0 - 20                        |
| 10       | 65                 | 1.30               | 100.00             | 0.00             | 0 - 5                         |
| Pan      | 0                  | 0.00               | 0.00               | 0.00             | 0                             |

2. Aggregate Impact Value :- 21.2% <30% IS SP 23 : 1982
3. Aggregate Crushing Value :- 22.8% <30%
4. Flakiness :- 11.8% <30%
5. Elongation Index :- 13.6% <30%
6. Specific Gravity :- 2.71 > 2.6
7. Water Absorption :- 0.38 %
8. Bulk density
   Loose :- 1430 Kg/Cum
   Compacted :- 1526 Kg/Cum

2.3 Fine Aggregates

Fine aggregates are tested as per IS 383 – 2016 and the results were represented in table 5. Fine aggregate was confined to Zone III based on sieve analysis tests. Also the bulk density (loosely compacted and closely compacted), Specific gravity, Fineness modulus were given and values are found to be within limits of codal provisions. It can be seen that maximum percentage of weight passing lies in Zone III.
Table 5. Sieve analysis of Fine Aggregates considered

| S.No | Sieve Size (mm) | Wt. Retained (gms) | Wt. Retained (%) | Cumulative Wt. Retained (%) | % of weight passing | Zone I | Zone II | Zone III | Zone IV |
|------|----------------|-------------------|-----------------|----------------------------|-------------------|--------|---------|----------|--------|
| 1    | 10             | 0                 | 0.0             | 0.0                        | 100.0             | 100    | 100     | 100      | 100    |
| 2    | 4.75           | 27                | 2.7             | 2.7                        | 97.3              | 90-100 | 90-100  | 90-100   | 95-100 |
| 3    | 2.36           | 72                | 7.2             | 9.9                        | 90.1              | 60-95  | 75-100  | 85-100   | 95-100 |
| 4    | 1.18           | 88                | 8.8             | 18.7                       | 81.3              | 30-70  | 55-90   | 75-100   | 90-100 |
| 5    | 0.6            | 132               | 13.2            | 31.9                       | 68.1              | 15-34  | 35-59   | 60-79    | 80-100 |
| 6    | 0.3            | 568               | 56.8            | 88.7                       | 11.3              | 5-20   | 8-30    | 12-40    | 15-50  |
| 7    | 0.15           | 76                | 7.6             | 96.3                       | 3.7               | 0-10   | 0-10    | 0-15     | 0-15   |
| 8    | 0.075          | 37                | 3.7             | 100.0                      | 0.0               | 0-5    | 0-5     | 0-5      | 0-5    |

Grading Zone

1. Gradation (Sieve Analysis)

2. Fineness Modulus: 2.70

3. Specific Gravity: 2.64

4. Bulk Density: Loose 1620 Kg/Cum

Compaction 1756 Kg/Cum

5. Silt Content: 1.20%

6. Average Moisture Content: 0.62

Standard consistency of cement with various percentages of ScBA was tested and the values were given in Table 6.

Table 6. Standard consistency of cement with % replacement of ScBA

| S.No | Replacement of bagasse ash in cement (%) | Consistency(%) |
|------|----------------------------------------|---------------|
| 1.   | 0                                      | 33            |
| 2.   | 5                                      | 34            |
| 3.   | 10                                     | 38            |
| 4.   | 15                                     | 42            |
| 5.   | 20                                     | 46            |

Tests on water used in mix were tested as per IS10500-2012 and same was utilized in the mix.
2.4 Concrete Mix Preparations

As per 10262-2019 mix for M30 concrete was prepared, cubes of 150x150x150mm dimensions, cylinders of 150mm dia and 300mm height for split tensile strength and durability studies were conducted in accordance with ASTM C1202 (2012). Mix was designed with 5%, 10%, 15%, 20% ScBA to evaluate the strength parameters. Concrete proportions for all five mixes were shown in Table 7. Water cement ratio and other weights were obtained from weight batching from mix specifications.

Table 7. Mix quantities by weights

| Type of Mix | w/c ratio | % ScBA | Water (Lt) | Cement (Kg) | FA (Kg) | CA12mm (Kg) | CA20mm (Kg) | ScBA (Kg) |
|-------------|-----------|--------|------------|-------------|--------|-------------|-------------|----------|
| ScBA0       | 0.30      | 0      | 2.43       | 8.15        | 10.36  | 7.77        | 7.77        | 0        |
| ScBA5       | 0.30      | 5      | 2.39       | 7.74        | 10.30  | 7.50        | 7.50        | 0.407    |
| ScBA10      | 0.30      | 10     | 2.40       | 7.33        | 10.32  | 7.62        | 7.62        | 0.815    |
| ScBA15      | 0.30      | 15     | 2.41       | 6.93        | 10.35  | 7.72        | 7.72        | 1.225    |
| ScBA20      | 0.30      | 20     | 2.42       | 6.52        | 10.34  | 7.74        | 7.74        | 1.630    |

Note: FA – Fine Aggregate, CA – Coarse Aggregate, ScBA0, 5, 10, 15, 20 – Sugarcane Bagasse Ash Percentage

3. Results and Discussions

3.1 Workability

Slump for conventional concrete is found to be higher results in higher workability and with different percentages of ScBA slump decreased with increase in ScBA content which results in lower workability for higher percentages of ScBA. Table 8 represents the values of Slump obtained with corresponding replacement of ScBA.

Table 8: Slump values (Workability)

| % ScBA | 0  | 5  | 10 | 15 | 20 |
|--------|----|----|----|----|----|
| Slump (mm) | 98 | 92 | 88 | 76 | 60 |

3.2 Compression Test:

Concrete cubes of 150mm dimensions were cured for 7, 28, 56 days and tested for different proportions of ScBA (upto 20%). Tests were conducted in Compressive Testing Machine (CTM) by
following the guidelines provided in IS 516: 1959. From the maximum load bearable by concrete cube specimens compressive strength obtained.

![Compressive Strength of concrete with varying percentages of ScBA](image)

Figure 2. Compressive Strength of concrete with varying percentages of ScBA

From Figure 2 of Compressive strength, it is observed that maximum strength with respect to 7 days curing was found with no replacement of ScBA whereas with age of concrete increasing it is found that strength at 10% replacement of ScBA showed significant improvement and immediate declination in strength with greater percentages of ScBA.

### 3.3 Split Tensile Strength

Split Tensile Strength was determined by casting cylindrical specimen of 150mm diameter and 300mm height. Results obtained were represented in Figure 3.

![Split Tensile Strength with replacement](image)

Figure 3: Split Tensile Strength with replacement

From the figure 3 it can observed that maximum tensile strength is at 10% replacement of ScBA which is greater than conventional concrete.
3.4 Rapid Chloride Penetration Test

Rapid Chloride Penetration Test (RCPT) was conducted on 28 and 56 days old concrete in accordance with ASTM C1202 (2012) codal specifications. Test results were represented in below, which the overall chloride ion permeability decreases with increase in ScBA content, from the table it can observed that penetration of chloride ions decreases with increase in ScBA content. It might be due to high amount of Silicon dioxide present in the composition. Also it can be seen that durability is slightly better than conventional concrete. Table 9 represents the chloride ion charge passed.

| ScBA % | 28 Days | 56 Days |
|--------|---------|---------|
|        | Charge-Passed (Coulombs) | Chloride Ion Permeability | Charge-Passed (Coulombs) | Chloride Ion Permeability |
| 0      | 1598    | L       | 1266    | L       |
| 5      | 1420    | L       | 1156    | L       |
| 10     | 1335    | L       | 1122    | L       |
| 15     | 1235    | L       | 1058    | L       |
| 20     | 1153    | L       | 1011    | L       |

Note: L – Low, 1000-2000 – Low (According to ASTM C1202 (2012))

4. Conclusions

Mechanical properties and durability based on chloride ion permeability were studied for 0, 5%, 10%, 15%, 20% replacement of ScBA. High compressive strength, Split tensile strength were observed at 10% replacement of ScBA and strength immedietly declined at higher percentages of ScBA. Workability decreases with higher replacement of ScBA although strength decreased. Durability also increases with higher ScBA content compared with durability of Conventional concrete, durability is said to be slightly higher than conventional concrete.

Although it is established that ScBA has decent durability and higher strength at 10% replacement further need to study with closer percentages around 10% which gives the optimum replacement percentage.
References

[1] Akshaydhawan, Nakulgupta, Rajesh goyal, K Ksaxena, 2020, Evaluation of mechanical properties of concrete manufactured with fly ash, bagasse ash and banana fibre, *Materials Today: Proceedings*

[2] PoojaJha, A K  Sachan, R P  Singh, 2020, Agro-waste sugarcane bagasse ash (ScBA) as partial replacement of binder material in concrete, *Materials Today: Proceedings*

[3] G Hemath Kumar, HBabuvishwanath, Rajesh Purohit, PramodSahu, R SRana, 2017 Investigations on Mechanical Properties of Glass and Sugarcane Fiber Polymer Matrix Composites, *Materials Today: Proceedings, Volume 4*, Issue 4, Part D, 2017, Pages 5408-5420,

[4] Prashant O Modani, M RVyawahare, 2013, Utilization of Bagasse Ash as a Partial Replacement of Fine Aggregate in Concrete, *Procedia Engineering, Volume 51*, Pages 25-29

[5] Elias MolaeiRaisi, JavadVaseghiAmiri, Mohammad Reza Davoodi, 2018, Mechanical performance of self-compacting concrete incorporating rice husk ash, *Construction and Building Materials, Volume 177*, Pages 148-157

[6] Chikkala RaviTeja, GorantlaNipun, SajjaSatish, 2019, Durability of Robust Self Compacting Hybrid Fiber Reinforced Concrete, *International Journal of Recent Technology and Engineering, Volume 8*, Pages 1749-1755

[7] Kang-Shiun Huang, Chung-Chia Yang, 2018, Using RCPT determine the migration coefficient to assess the durability of concrete, *Construction and Building Materials, Volume 167*, Pages 822-830.

[8] BManjula Devi, Hemant S Chore, 2020, Feasibility study on bagasse ash as light weight material for road construction, *Materials Today: Proceedings, Volume 27*, Part 2, Pages 1668-1673.

[9] DeepankarVarshney, Prasad Mandade, YogendraShastri, 2019, Multi-objective optimization of sugarcane bagasse utilization in an Indian sugar mill, *Sustainable Production and Consumption, Volume 18*, Pages 96-114.