Influence of Copper Slag, Rice husk ash mixed with Alkali Activator for Pavement Construction

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Abstract

The demand for ecologically friendly and long-lasting building materials has required the search for new materials for pavement sub-base design. A sub-base design utilizing an alkaline activator involving the use of wastes and by-products from various industrial processes may be considered a promising alternative to sub-base traditional materials (crushing aggregates and gravel). This research studies emphasize Rice Husk Ash (RHA), Copper Slag (CS), and mixed with Alkaline Activator (Sodium Hydroxide (SH) and Sodium Silicate (SS)) are used as an alternative material for the construction of pavement. This paper is an experimental investigation by performing Compaction Tests, and Unconfined Compressive Strength (UCS) tests as per Indian Standard Code. The compaction tests and UCS tests have been performed for various combinations and various combinations were made using CS (90%, 80%, 70%, 60%, and 50%) and RHA (10%, 20%, 30%, 40%, and 50%). The percentage of alkali activator 3% and 6% was used. Further, the ratio of SH/SS 1:2 was used and the concentration of SH is 10M (molarity) used. Prepared samples have been cured for 7 days in the thermostatic temperature-controlled chamber at 60℃. On behalf of experimental results, the replacement of this waste material with traditional constructional material is beneficial economically as well as for the environment.

Keywords: Copper slag, Rice husk ash, Alkaline Activator, Compaction test, UCS test.

1. INTRODUCTION

Industrial waste disposal has become the most difficult problem to solve in today's world [1]. Globally, enormous amounts of trash are produced. Waste comes in two forms: liquid and solid. Residential buildings, medical facilities, and industries all generate a significant amount of waste. Due to the direct dumping of these wastes over the ground and near water bodies, soil and water pollution may increase, thereby depleting fertile land [2]. This has negative consequences for the ecosystem. Industrial wastes may be recycled and repurposed with the right tools for maximum efficiency. The current research emphasizes the usage of CS and RHA in pavement design.

Compared to the manufacture of copper, two to three times more CS is produced during the smelting process. Because CS and fine sand's comparable in physicochemical qualities, they may be used in a variety of applications, including soil stabilization, backfilling in retaining walls, embankment construction, pavement construction, rail ballast, concrete manufacture, and cement [3].

At various temperatures, the burning of rice husk, the RHA is also produced in rice mills. Approximately 200 kg of rice husk can be obtained from 1000 kg of paddy, which, when burned, creates around 40 kg of RHA. According to ASTM C-168, it has a large proportion of amorphous silica, making it a pozzolanic material (ASTM 1997) [4].

Cement and lime are widely used as additional materials in pavement building and soil stabilization across the world [5]. A large quantity of CO_2 is emitted during cement manufacture, which is hazardous to the environment. During the manufacture of one tonne of cement, about one tonne of CO_2 gas is emitted, which contributes to global warming. As a result, additional sustainable pozzolanic materials must be used to partially or entirely replace cement. Replacement for cement in soil stabilization and improvement, as well as in the development of novel composite materials AA can be used as a partial or complete [6].

Calcined clay and metakaolin are some of the natural sources of pozzolans. The chemical makeup of aluminosilicate materials influences the alkali-activation reaction products. AA reacts with high calcium binders to produce calcium-silicate-hydrate (C-S-H) gels. Low calcium binder gels (K-A-S-H) or Sodium Aluminosilicate Hydrate Gels (N-A-S-H) are made of potassium aluminum silicate hydrate and sodium aluminum silicate hydrate, respectively, where K stands for K+ cations and N stands for Na+ [7].

The composite includes CS and RHA combined with an AA are investigated for the compaction and UCS. This research might aid in the development of novel composite materials for pavement construction with improved mechanical qualities (sub-grade and sub-base). This study is part of a larger experimental examination that includes a particular compaction characteristic (OMC and MDD), UCS test, and the value of composite materials made up of AA, CS, and RHA. The current research is mostly concerned with:

- To study the different combinations of RHA, CS, and AA percentages that affect the compaction behavior.
- To study In RHA treated with AA composite material with CS, the curing period of 7 days affects the UCS of stress-strain behavior.

2. Experimental Investigation

RHA, CS, and AA (SS and SH) were employed in this experimental investigation. As described by Sharma and Kumar the CS and RHA have the same physical characteristics as reported in [8].

2.1. Copper slag

The experiment employed a blackish-colored CS. From the Hindustan Copper Limited (HCL) in Bharuch, Gujarat, India; CS was obtained and a sample is displayed in Figure 1. 18%, 3.50, 2.5, and 1.715 gm/cc respectively, are the OMC, SG, Fineness Modulus (FM), and MDD of CS. Table 1. summarises the physical characteristics of CS [8].

Figure 1. Raw materials copper slag

Table 1. Copper slag's physical propert

Copper slag's physical property		
S. No.	Physical properties	Value
1	Particle shape	Irregular
2	Appearance	Black and glassy
3	Maximum Dry Density	1.715 gm/cc
4	Optimum moisture content	18%
5	Fineness modulus	2.5
6	Specific gravity	3.50
7	Coefficient of Uniformity(Cu)	1.534 (Poorly graded)
8	Coefficient of Curvature (Cc)	0.960
	Particle Size	
9	> 425 micron	-
10	> 300 micron	4.16 %
11	> 150 micron	91.07 %
12	> 75 micron	3.65 %
13	< 75 micron	1.12 %

2.2. Rice husk ash

From Jalandhar, Punjab, India a local rice mill RHA was collected as shown in Figure 2. RHA's SG, OMC, MDD, and FM, respectively, were determined to be 2.06, 64%, 0.52 g/cc, and 1.43. Table 2. summarises the physical characteristics of CS [8].

Figure 2. Raw materials image Rice husk Ash

Table 2. The physical property of rice husk ash

The physical property of rice husk ash		
S.no	Physical properties	value
1	Particle shape	Irregular
2	appearance	Dark grey
3	Optimum moisture content	64%
4	Maximum Dry Density	0.52 gm/cc
5	Specific gravity	2.06
6	Fineness modulus	1.43
7	Coefficient of Uniformity	7.08
8	Coefficient of Curvature	0.44
	Particle Size	
9	> 425 micron	-
10	> 300 micron	0.32 %
11	> 150 micron	47.35 %
12	> 75 micron	5.760 %
13	< 75 micron	46.34

2.3. Alkali activator

In this experiment, SS and SH were employed as AA. As indicated in Figures 3. (a), (b), and (c), with 98 percent purity SH was accessible in flake form and SS was available in solution form as shown in Figure 3. Whereas an Activator Modulus (Ms) of 3.3 was observed. The term "activator modules" refers to the mass ratio of silicon dioxide to sodium oxide in AA. In a 1:2 ratio, sodium hydroxide and sodium silicate are mixed. 24 hours before usage dissolve the sodium hydroxide flakes in distilled water to make a 10M sodium hydroxide solution. A high pH environment is formed when an AA is used, which speeds up the hydration processes. So while using AA in lab work or other work we should wear proper gas masks and gloves to take care of its side effects.

Figure 3. Raw materials (a) sodium hydroxide solution, (b) sodium hydroxide flakes, (c) sodium silicate solution

3. EXPERIMENTAL PROGRAM

On RHA and CS with combinations of the binder AA treated with various percentages, sequences of laboratory tests are carried out. UCS test and the Standard proctor compaction test are the most common laboratory tests conducted. Both the UCS test and the standard proctor compaction test were conducted in accordance with Table 3, which lists the different ratios of RHA and CS when treated with AA, along with each combination's percentages. Combinations with RHA of Standard proctor compaction are conducted at 10%, 20%, 30%, 40%, and 50%, as well as AA of 3%, and 6%, and the Rest of the percentages CS. The same percentages of RHA of 10 %, 20 %, 30 %, 40 %, and 50 % are used in the UCS test, as well as CS of 90 %, 80 %, 70 %, 60 %, and 50 %, respectively, with AA of 3% and 6%.

Table 3. Combination scheme

Combinations	Mixed proportions	Title	Molarity of NaOH solution (M)	$NaOH/Na_2SiO_3$ ratio
A	90%CS+10%RHA+3%AA 80%CS+20%RHA+3%AA 70%CS+30%RHA+3%AA 60%CS+40%RHA+3%AA 50%CS+50%RHA+3%AA	A1 A2 A3 A4 A5	10 M	1:2
B	90%CS+10%RHA+6%AA 80%CS+20%RHA+6%AA 70%CS+30%RHA+6%AA 60%CS+40%RHA+6%AA 50%CS+50%RHA+6%AA	B1 B2 B3 B4 B5	10 M	1:2

4. THE TESTING PROCEDURE AND SAMPLE PREPARATION

In the beginning, oven-dried RHA and CS were completely mixed in a big steel tray by hand. To avoid moisture, RHA and CS were placed in sealed containers. At a temperature of 105° C in an ambient temperature-controlled chamber, the airtight container was put. Following that, standard proctor compaction tests were performed. The mold size is 105 mm in diameter and 115.5 mm height was taken for all A and B combinations and also following the IS code-2720, part VII, 1980 [9]. In this experiment, the making of AA was employed by SH and SS. Before the 24-hour test, the SH solution was mixed. All of the combinations A and B are specified in Table 3.1. A 10 M (molarity) SH solution was utilized. The SS on the other hand is in a solution form so the mixing of both (SS and SH) was employed immediately. The SH/SS ratio utilized for all AA combinations is 1:2.
The UCS samples (38 mm in diameter and 76 mm in height) were made with a mixture of CS, RHA, and AA. Standard compaction was used to prepare all of the specimens. The molds were cast after 24-hour samples of UCS were extracted as shown in Figure 4. Furthermore, the UCS samples were ambient cured for 7 days, respectively. UCS testing is carried out following IS code-2720, part X, 1991 [10] at the displacement of 1.25 mm/min.

Figure 4. UCS samples after 24 h casting

5. RESULTS AND DISCUSSION

Standard proctor compaction tests and UCS tests are used to calculate the impact of RHA and CS treated with AA on mechanical characteristics. The following segments provide a comprehensive discussion and analysis of the findings.

5.1. Results from compaction test

Figures 5. and 6. Show how OMC and MDD change with different amounts of AA and RHA. The values of OMC and MDD were found to increase and decrease respectively, while the amount of RHA was increased from 10% to 50% at a constant amount of AA 3%, and 6%. In combination A, where the amount of AA is held constant at 3%, Figure 5 demonstrates that when the amount of RHA added to CS increases There is a decrease in MDD value but an increase in OMC value. For combinations-B with 6% of AA, similar MDD and OMC patterns were observed as shown in Figure 6. The highest MDD values found for combinations A and B are 1.77 g/cc and 1.84 g/cc respectively, with OMC values of 15.25 % and 12.50 %. A1 (90%CS+10%RHA+3%AA) and B1 (90%CS+10%RHA+6%AA) are the best mixes for combinations A and B. Furthermore, the lowest MDD values In combination A and B, results are obtained at 0.76 g/cc and 0.71 g/cc respectively, with OMC values of 38.20 % and 29.20 %. Figures 5 and 6 indicate the cumulative effects of increasing RHA on OMC and MDD with individual AA content is increases of 3% and 6% denoted by combinations A and B, respectively. Increasing the RHA content decreases the MDD while increasing OMC in all of the combinations. The lower SG relative to that of CS is responsible for the reduction in MDD value that occurs when RHA concentration is increased. The lower SG values of lightweight materials account for the decrease in MDD values [8]. Because the AA utilized in Some of the water content is replaced by this research, which is in liquid form so necessary the MDD decreases with the OMC increase. These findings show an innovative, environmentally friendly composite material produced in this work by combining CS and RHA with AA may be employed in a variety of a wide range of civil engineering applications retaining wall backfill, pavement sub-base, and subgrade.

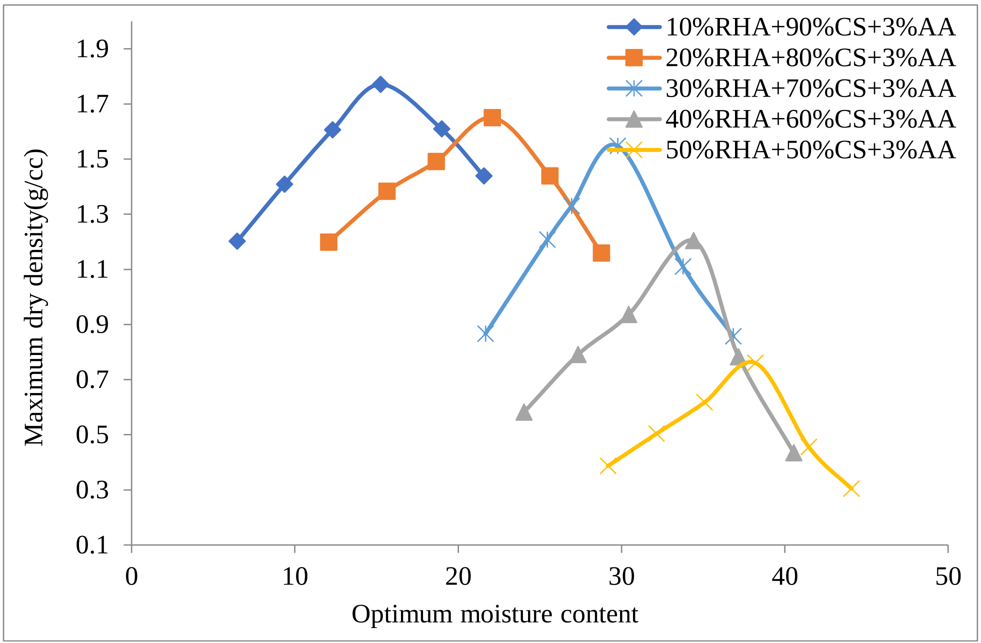

Figure 5. Combination- A Standard Proctor compaction curve with 3% AA

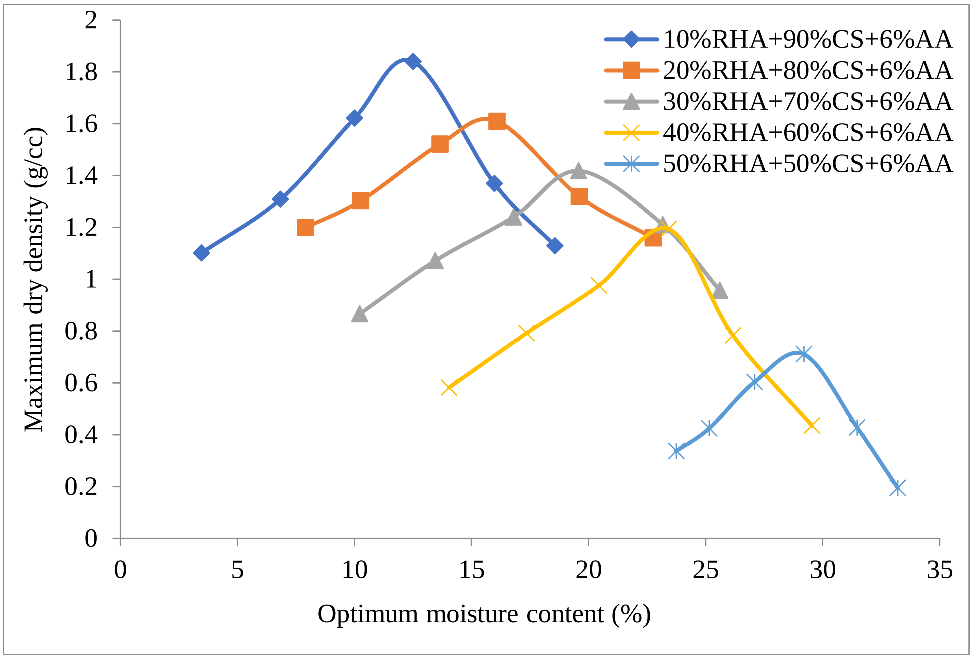

Figure 6. Combination- B Standard Proctor compaction curves with 6% AA

5.2. Unconfined compressive strength test

Behavior responses of strain and stress Figure 7 and 8 demonstrate the stress-strain behavior of various mixtures (combination-A and B) after 7 days of curing. The stress increase as the strain values increase up to a particular maximum level, beyond which the stress values drastically decreased as the strain values increase. For combinations A and B, the composite materials demonstrate brittle failure. The relation between strain and stress behavior of combination-A the RHA with CS at different percentages of 10%, 20%, 30%, 40%, and 50% constant quantity of AA is shown in Figure 7. (3%). The curve shows that increasing the percentage of RHA (up to 20%) while keeping the quantity of AA (3%) constant increases the UCS values. Stresses and strains that lead to maximum failure of around 3815.68 kPa and 1.97 %, respectively, have been observed at 20% RHA and 3% AA. Furthermore, the stated Stresses and strains that lead to minimum failure, are 1130.44 kPa and 1.57 percent, respectively. Figure 8. Depicts the relation behavior of combination-B under stress and strain the CS with RHA at various percentages of AA, such as 10%, 20%, 30%, 40%, and 50% at AA content 6%. The graph shows that as the proportion of RHA is raised to 20% but the percentage of AA is kept constant (6%), the UCS values increase. Stresses and strains that lead to maximum failure for 20% RHA and 6% AA were determined to be 4410.11 kPa and 2.36%. Furthermore, the reported Stresses and strains that lead to minimum failure are 1408.34 kPa and 1.97 percent, respectively.

With the inclusion of alumina, and calcium, After hardening, CS is bound to AA by its cementitious properties and the silica in the CS, RHA, and AA are all factors that contribute to the increase in UCS values.

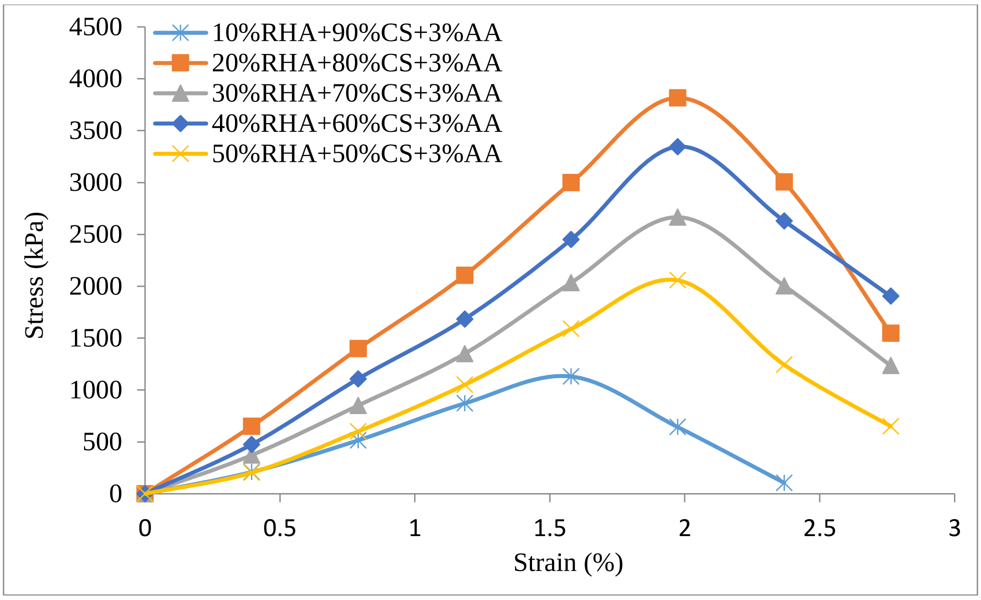

Figure 7. Combination-A’s Stress-strain curves after 7 days of curing

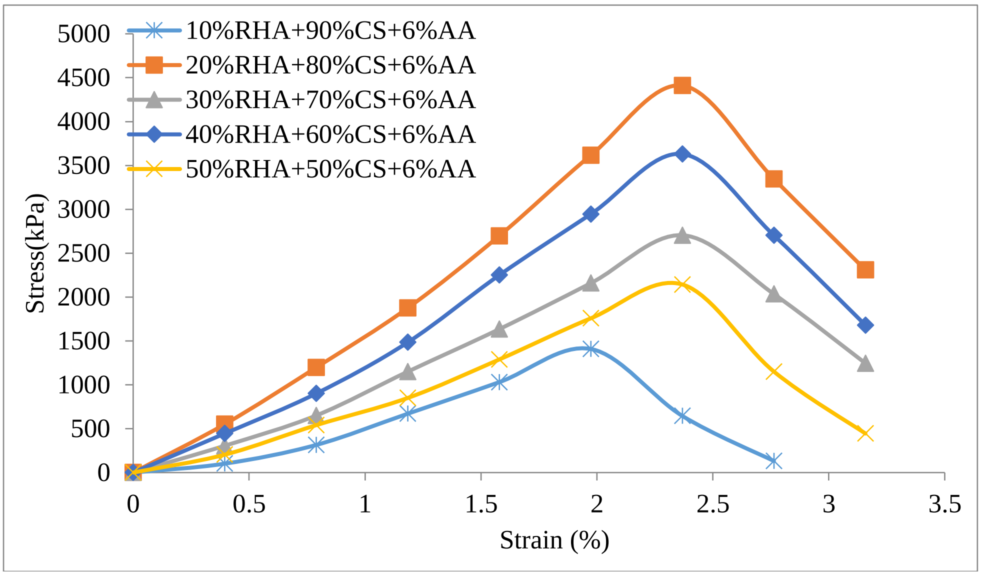

Figure 7. Combination-B’s Stress-strain curves after 7 days of curing

6. Conclusions

An experimental evaluation of compaction and UCS in a composite including RHA and CS mixed with an AA was provided in this paper. These tests' results are given and analyzed in depth. The following are the primary results gained from this research:

- The best combination for the newly created sustainable composite material is 80%CS+20%RHA+6%AA they may be used in a variety of applications, including soil stabilization, backfilling in retaining walls, and embankment construction, pavement construction, rail ballast, concrete manufacture, and cement since it has improved geotechnical qualities.
- Using AA as a binder material instead of traditional binders like cement and lime minimizes the carbon footprint and CO_2 emission, which would otherwise be substantial when traditional binders are manufactured.
- For RHA content of roughly 20% and 20%, respectively, the maximum UCS values for combination-A and B are observed. The combination-B with 20% RHA (80% CS+20% RHA+6% AA) achieved the greatest UCS value (4410.11 kPa).
- The stress-strain curve behavior demonstrated that the UCS tested materials have brittle fractures for varied combinations. The percentages of RHA and CS, as well as the amount of additional material, influence it.
- The creation of composite materials use of industrial wastes, such as the RHA and CS treated with AA used in this study, provides a cost-effective way to dispose of waste, as well as solving the waste disposal problem, environmentally benign, and saves virgin resources.
- The demand for ecologically friendly and long-lasting building materials has required the search for new materials for pavement sub-base design. A sub-base design utilizing an alkaline activator involving the use of wastes and by-products from various industrial processes may be considered a promising alternative.

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