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# Redash Base Course Materials with Crushed Stone Aggregates

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**Abstract -** *The shortage of crushed stone aggregate (CSA) supplies along with the increase in processing and hauling cost have encouraged the use of red-ash material are involved into regular practice in various country around the world. However, red-ash material may be not conventional road making materials and need to improvement. This study was intended to investigate the use of red-ash through blending with CSA as base course materials. The effects of Physical(Gradation, limit test, particles shape, SG, water absorption)and mechanical (compaction, CBR, materials strength) properties test have been conducted to examine and characterize red-ashand CSA in first phase at natural state, and the second phase of study was aim to derive the optimum allowable replacement of CSA blended with red-ashin different proportion red-ash/CSA (10/90, 20/80, 30/70, 40/60, 50/50)% by total weights with respect to their engineering properties as compared results with specification for highly trafficked unbound base course (GB1) of asphalt concrete materials. According to AASHTO soil classification system the natural and blends of red-ash-CSA were classified under A-1-a.*

*From laboratories test results for blended red-ash aggregate gives ACV, AIV, LAA, SG, CBR and Water absorption of 7.9%, 9.5%, 7.8%, 2.31, 42.1% and 0.98% respectively. Also, the mechanical blending of 30% red-ash aggregate and 70% CSA test results were 15.7%, 12.8%, 16.5%, 107.63%, 2.67 and 1.24% for ACV, AIV, LAA, CBR, SG, Water absorption values respectively with 143KN and 114KN when soaked and un socked in water for TFV results. The results obtained from Gradation, Atterberg's limits, SG and water absorption ACV, AIV, LAA, Compaction and CBR indicate that Mixes containing 30% red-ash contents were successful replaced CSA in highly trafficked unbound road base course layer of Asphalt concretes. Therefore, it is recommended to use the red-ashfor road construction project in places wherein abundant materials are available.*

***Key Words***: CBR, CSA, GB1, LAA, Mechanical blending, red-ash, Strength

## 1. INTRODUCTION

Currently Ethiopian government is allocating a huge amount of resources to construct highways for the country development and the road sector plays role for the economic development of the country.

The road network in Ethiopia provides the dominant mode of freight and passenger transport and thus plays a vital role in the economy of the country. The network comprises a huge national asset that requires adherence to appropriate standards for design, construction and maintenance in order to provide a high level of service. As the length of the road network is increasing, appropriate choice of methods to preserve this investment becomes increasingly important.

The use of cheaper construction materials without loss of performance is crucial for developing country like Ethiopia. Hence a continuous increase in the cost of conventional construction materials, the researcher explored possible alternative and cheaper in overall cost of construction without compromising safety. The study was intended to investigate the use of red-ashas base course material through blending with crushed stone aggregate. Different laboratory tests have been conducted on samples that have been collected to study material properties and find maximum replacement rate of CSA with red-ashneeded to produce material that can be used as alternative base course construction material.

Those tests were, Sieve analysis, ACV, TFV, AIV, LAA, Modified compaction test, CBR, SG and Water absorption tests were used to investigate the materials in the laboratory. The possibility of partially replacing conventional crushed stone aggregate with red-ash was assessed to minimize the cost of road construction by incorporating the removed and cheaper construction materials in road projects to the extent they cannot significantly decrease the strength and stability of the whole compacted mass in a base course layer of flexible pavement.

### 1.1 Statement of the problem

Successive road improvement and expansion of road network play the crucial role for economic development and to maintain sustainable development of our country. The most common type of pavement structure used for highway construction is flexible pavement which is made up of natural or treated subgrade, unbound sub – base and base – course materials and bituminous bound surfacing materials. The quality of these pavement structures largely depends on aggregate materials which are the main constituents of pavement structural layers [1]. Since top strata of road pavements (Base course layer) would need high-quality material for construction of asphalt pavement, the locally available material at road project may not provide the projected quality and may not be accessible.

Therefore, searching materials beyond 10Km would induce additional cost and can offer the contractors to delays the construction industry. In spite of the steady rise in prices and a shortage of virgin aggregates that is necessary for the production of asphalt concrete base layers. To overcome such problems, appropriate modification and utilization of available marginal materials is the best alternative. All of this has attracted the attention of researcher to modify and utilize the available marginal material that is less expensive and environmentally friendly. Currently, the use of red-ash in base, and sub-base courses is not common red-ash will reduce the cost of highway construction.

## 1.2 Objectives of the study

1. To determine the engineering properties of red-ash.
2. To analyse the strength of the modified aggregate base course materials and to compare with the ERA standard specification.
3.To determine optimum percentage of red-ash replaced in crushed stone aggregate for base course.

## 2. MATERIALS AND RESEARCH METHODOLOGY

Although, the red-ash is spreading throughout the country the study area for this research had been located in Wolaita Sodo Which is found at a distance 370 Km from Addis Ababa. The study design for this study was an experimental type of study that was started by collecting samples from the study area. Different stages were involved to determine physical and mechanical properties of these materials in a laboratory by experiment. Those were taking samples, Preparation of samples for each laboratory tests, Laboratory tests to check suitability of red-ash materials and CSA and the process of blending by 0%, 10%, 20%30%, 40% and 50% of red-ash by weight with conventional crushed stone to find out maximum replacement amount that satisfies requirements of Sampling technique. The following tests were carried out includes: Sieve analysis, Atterberg's limits, compaction and CBR tests, ACV, TFV, AIV, LAA, SG and Water absorption had been conducted on red-ashsamples collected from locations

**Table -1:** Blending ratios

| No | Sample Designation | % of replaced red-ash by weight | % of Crushed stone aggregate |
|---|---|---|---|
| 1 | red-ash-0 | 100(red-ash) | 0 |
| 2 | red-ash -1 | 0 (CSA) | 100 |
| 3 | red-ash -2 | 10 | 90 |
| 4 | red-ash -3 | 20 | 80 |
| 5 | red-ash -4 | 30 | 70 |
| 6 | red-ash -5 | 40 | 60 |
| 7 | red-ash-6 | 50 | 50 |

## 3. RED-ASH AND CSA SAMPLES

The result of laboratory investigation and data analysis that conducted to study the effect of using red-ash with crushed stone aggregate for base course material of Asphalt concrete. The experiments evaluate the Mechanical and physical properties of red-ash. AASHTO, BS and ERA manuals specifications were the followed procedure during specimens taken, and laboratories test were performed. The samples were collected and laboratory tests conducted on neat red-ash, CSA and varying percentage of red-ash and CSA in different proportion by weight based. The purpose of this test study was to determine the practicability of red-ashfor unbound base course layer, for highly trafficked roads in Ethiopia country as an improvement for base course layer.

The result was expressed by a plot of percent finer (% passing) by weight against the size of soil particles in millimeters on a log scale.

**Table-2:** Sieve analysis of blended neat red-ash samples

| Sieve size(mm) | Weight retained | % retained | Cumulative % retained | % passing | ERA specification for GB1 | |
|---|---|---|---|---|---|---|
| | | | | | Lower limit | Upper limit |
| 50 | 0 | 0 | 0 | 100 | 100 | 100 |
| 37.5 | 0 | 0 | 0 | 100 | 95 | 100 |
| 25 | 330.5 | 11.0 | 11.0 | 89 | 80 | 100 |
| 19 | 305 | 10.2 | 21.2 | 78.8 | 60 | 80 |
| 9.5 | 458.5 | 15.3 | 36.5 | 63.5 | 40 | 60 |
| 4.75 | 380.5 | 12.7 | 49.2 | 50.8 | 25 | 40 |
| 2.36 | 582.5 | 19.4 | 68.5 | 31.5 | 15 | 30 |
| 0.6 | 275.5 | 9.2 | 77.7 | 22.3 | | |
| 0.425 | 125 | 4.2 | 81.9 | 18.1 | 7 | 19 |
| 0.15 | 145.5 | 4.9 | 86.8 | 13.2 | | |
| 0.075 | 75 | 2.5 | 89.3 | 10.7 | 5 | 12 |
| Total passing 0.075mm | 322 | 10.7 | 100.0 | | | |

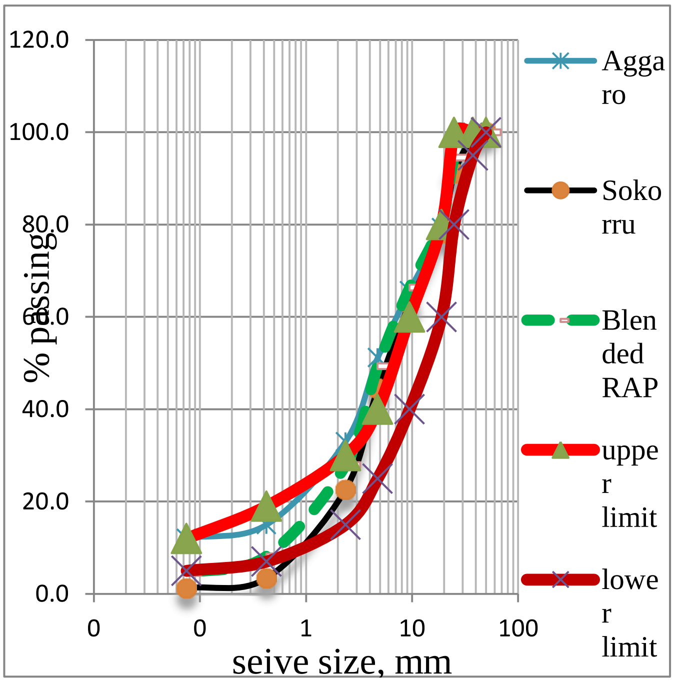


**Chart -1**: Particle size distribution curve for RAP

The result indicated that the RAP materials collected from the stated site and the blending of both places failed to fit within the gradation limit of the ERA manual specification for GB1 road base course. This means their gradation curve is not parallel with upper and lower limit of the specification by having fine material less than specified and course more than the recommended ERA specification values.

## 4. RAP-CSA BLENDED SAMPLE

RAP from the stated sources was fractioned above or below the ERA specification designated for a base course to evaluate their engineering properties. Therefore, it requires augmentation with fresh aggregate to meet the standard specification. Through trial and error, 40%RAP blended with 60% fresh aggregate were fully fitted with ERA specification for GB1 base course material which is normally used for a heavy trafficked road in Ethiopia. This 40%RAP can be replaced for CSA by having gradation curve within the tolerable limit of GB1 since all blends proportion are parallels to the limited curves requirement, i.e., the upper and lower limit value of the RAP-CSA mixes up to 40% RAP were within the ERA specification. This gives the physical properties of RAP are similar to those of crushed basalt stone at the limited percent.

Mass sample before wash ($M_1$) =4517 (g)
Mass of sample after wash ($M_2$) =4312 (g)
Total Passing0.075mm sieve ($M_1$-$M_2$) =205 (g)

**Table-3:** Gradation result for blending red-ash samples in equal proportion by weight base

| Sieve size | Weight retained (g) (a) | % retained b=(a*100/4517) | Cumulative % retained (c) | % passing d=(100-c) |
|---|---|---|---|---|
| 50 | 0 | 0 | 0 | 100 |
| 37.5 | 32 | 0.70 | 0.7 | 99.3 |
| 25 | 215 | 4.76 | 5.46 | 94.54 |
| 19 | 1130 | 25.01 | 30.47 | 69.53 |
| 9.5 | 1925 | 42.61 | 73.08 | 26.92 |
| 4.75 | 645 | 14.28 | 87.36 | 12.64 |
| 2.36 | 210 | 4.65 | 92.01 | 7.99 |
| 0.425 | 95 | 2.1 | 94.11 | 5.88 |
| 0.075 | 60 | 1.33 | 95.45 | 4.55 |
| Total passing 0.075mm sieve | 205 | 4.55 | | |

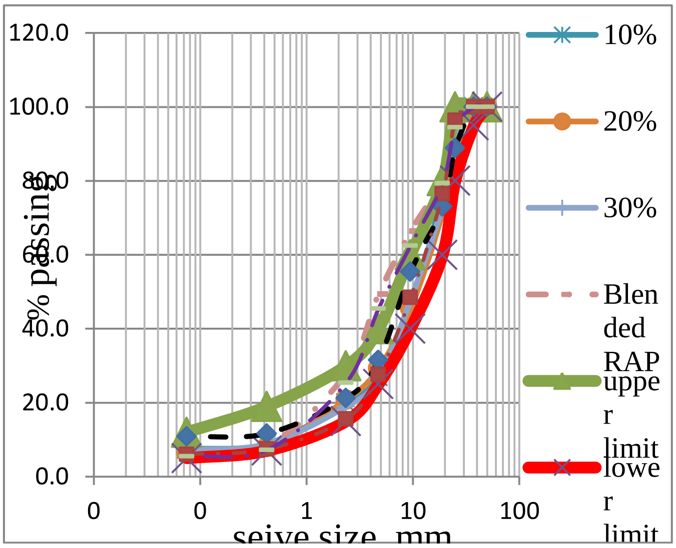


**Chart -2**: Particle size distribution curve for red-ash-CSA mixes

## 5. EFFECT OF ATTERBERG'S LIMIT

During the liquid limit test for red-ash, materials passing 0.425mm was unable to make a paste to be placed in Casagrande's cup of liquid limit testing apparatus to record no. Of blows needed to close the groove opening which is the basic procedure for a liquid limit test. In addition to this, the red-ash was also observed to crumble before reaching a thickness of 3.2mm, when rolled in an attempt to determine the plastic limit of the material. This occurs because of sandy nature of red-ash and according to the observations materials of this type are regarded as non-plastic about according to Section 7.3.1 of AASHTO T–90. Hence both red-ashand CSA have a liquid limit

(LL<25%) and plastic limit (PL<6) and it is satisfied according to the specification.

**Table-4:** AASHTO soil classification for red-ash and CSA before blended

| Sample reference | % passing sieve | | | Atterberg's limits | | | Classification |
|---|---|---|---|---|---|---|---|
| | 2mm | 0.4mm | 0.075 | LL | PL | PI | |
| red-ash 1 | 33 | 15 | 12 | NP | | | A- 1 - a |
| red-ash 2 | 22 | 3.4 | 1.3 | | | | A- 1 - a |
| Blended red-ash | 27 | 8.2 | 4.5 | | | | A- 1 - a |
| Neat CSA | 21 | 11.7 | 10 | 3.4 | 0 | 3.42 | A- 1 - a |

For those materials depend on AASHTO soil classification system the material are granular materials since less than 35% of total samples was passing #200 (0.075mm) sieve size. But, this granular classification also had A-1, A-3 and A-2 sub-classification. Hence again depend on soil passing #10, #40 and #200 sieve size and LL and PL the soil was classified. From the values indicated in the table all materials are classified as A-1-a type of soils having less than 15% of particles passing 0.075mm, less than 30% passes the no. 40 sieve and less than 50% pass the No. 10 sieve and PI < 6. The material constitutes gravel and sandstone fragment. In the AASHTO classification system, and A-1-a soil is preferred for highway construction soil.

## 6. SPECIFIC GRAVITY AND WATER ABSORPTION OF AGGREGATE

The aggregate density with relative to water is decreased with the increasing red-ash amount after blended with CSA. The change of result was observed from table. When it was blended with a different percent of crushed stone aggregate. The aggregates particles in the red-ash were partially covered in asphalt, which decreased the specific gravity. The result of the discussion was concluded in the form of a table for all the assessed parameters. Table 5 shows that the variation of the test results in each trial when it was blended with crushed stone aggregate. ERA specification recommends that specific gravity of 2.65 and above for GB1 base course material. Hence, the result analysis except blended neat red-ash the rest fit the requirements for specific gravity as the value is greater than specifications. red-ash sample has specific gravity range from 2.3 to 2.4 which indicate lightweight nature of red-ash and also implies that lower density of red-ash gives lower specific gravity. This is due to minimal fine material in red-ashparticles. For red-ashmix with CSA by percent in weight based, Water absorption range from 1.08% to 1.35%, and show low effective porosity. The neat CSA average absorption is 1.44% by mass with range values of 1.23% to about 1.65% with a minimum and maximum value respectively. Low water absorption neat red-ash, while compared to neat CSA, shows that neat red-ash material were not absorbed more water than that of CSA .As a percent of red-ash blending were increased the both Specific gravity, and water absorption values are decreased as shown in table.

**Table-5:** Specific gravity and Water absorption of aggregate results

| Samples Designations | Specific gravity | | | Water absorption (%) |
|---|---|---|---|---|
| | Apparent | Bulk(dry) | Bulk(SSD) | |
| red-ash-0 | 2.4 | 2.31 | 2.34 | 0.92 |
| red-ash-1 | 2.86 | 2.78 | 2.81 | 1.44 |
| red-ash-2 | 2.81 | 2.72 | 2.75 | 1.35 |
| red-ash-3 | 2.79 | 2.70 | 2.73 | 1.27 |
| red-ash-4 | 2.76 | 2.67 | 2.71 | 1.24 |
| red-ash-5 | 2.76 | 2.66 | 2.70 | 1.23 |
| red-ash-6 | 2.67 | 2.61 | 2.64 | 1.20 |

## 7. FLAKINESS INDEX EFFECT

Flakiness index is usually conducted for checking the suitability of material produced by crushing operation to avoid flaky materials because they offer reduced resistance to traffic load during their service life. Red-ash used in this tested was mostly rounded particles; hence visual inspection was enough to determine as it has no problem on natural red-ash aggregate. According to Table flakiness index conducted for fresh stone aggregate that used for this tested indicate that the aggregate sample used were suitable for base course materials having flakiness index about 13.94% which is much less than the maximum limit of ERA specification, that does not exceed 30%.

**Table-6:** Flakiness index for CSA samples.

| Sieve Analysis | | | Gauging | | |
|---|---|---|---|---|---|
| Sieve size (mm) | Wt. Ret consists of at least 200 pieces (w1) g | %Ret | Gauge range | Wt. of sample passing the gauge (w2) g | ERA specification |
| 50 | 1350 | 25.96 | 63-50 | 190 | Maximum limit of Flakiness index in % Not exceed 30% |
| 37.5 | 1150 | 22.11 | 50-37.50 | 165 | |
| 28 | 900 | 17.31 | 37.5-28 | 120 | |
| 20 | 600 | 11.54 | 28-20 | 80 | |
| 14 | 550 | 10.57 | 20-14 | 65 | |
| 10 | 350 | 6.73 | 14-10 | 60 | |
| 6.3 | 300 | 5.78 | 10-6.3 | 45 | |
| Total | 5200 | 100 | | 725 | |
| Flakiness index (%) | | 13.94 | | | < 30% |

## 8. EFFECTS OF AGGREGATE IMPACT VALUES

Aggregate impact value tests were conducted for red-ash sample CSA samples and on a sample prepared by red-ash blended with CSA samples to determine its strength under impact wheel load.

### 8.1 AIV test Result of unblended red-ash and natural CSA Material

Result shows that red-ash collected from two different road site have nearly similar AIV test while CSA attained higher value than red-ash contents. This laboratory result shows at natural state red-ash aggregate were good resistance to sudden shock or impact occurred due to vehicles than that of CSA tested here. This could be because the aggregate used in red-ash during construction has good resistance to impact and the red-ash was covered by asphalt content that would resist to crushed under sudden force.

**Table-7:** Flakiness index for CSA samples.

| Samples | AIV (%) | Specification |
|---|---|---|
| red-ash 1 | 10.4 | AIV<30 % |
| red-ash 2 | 9.35 | |
| Blending both red-ash | 9.5 | |
| CSA | 18.7 | |

### 8.2 Result of blended red-ash- CSA Materials

The summer of test result for red-ash-CSA blends with a different replacement rate of red-ash with crushed natural aggregate (10% to 50%) shown in table explains that AIV were decreased slightly from 15.8% to 12.5% as a sample of red-ash contents increased in proportional percent to CSA samples. Hence as per ERA specification, both RAP and blended red-ash-CSA proved good resistance under sudden traffic force.

**Table-8:** Results of AIV test for Blends of red-ashwith CSA samples.

| % of red-ash added for AIV test | 10 | 20 | 30 | 40 | 50 | CSA-only | red-ash-only |
|---|---|---|---|---|---|---|---|
| AIV (%) | 15.8 | 14.2 | 12.8 | 13.7 | 12.5 | 18.7 | 9.5 |
| Specification | AIV≤30% | | | | | | |

## 9. EFFECTS OF LOS ANGELES ABRASION TEST

All quarried red-ash samples, CSA and samples prepared by blending of red-ash with CSA in different proportion by their weight were tested for LAA to evaluate the Mechanical strength of the material and judge their suitability according to ERA specification for base course material.

**Table-9**: Results of LAA test for neat red-ash and CSA samples

| Samples | LAA (%) | Specification |
|---|---|---|
| red-ash 1 | 6.2 | LAA ≤ 51% |
| red-ash 2 | 10.1 | |
| blended red-ash | 7.8 | |
| CSA | 27.0 | |

The result of the material test shows that even before blending red-ash with CSA all samples of red-ash were within the allowable ERA specification requirement. This implies that red-ash material is so hardest material to resist wearing load happen on it, and it was coved by asphalt that would resist as it was not crushed under any load. Hence the material has high resistance to abrasion than the tested CSA.

## 10. RESULTS

The tested red-ash contents material were satisfying principal mechanical properties of stones materials, which are satisfactory resistance to crushing under the roller during construction of the road and adequate resistance to surface abrasion under traffic loads due to vehicles. The red-ash- CSA blends aggregate tested in replacement of unbound base course GB1 with 10%, 20%, 30%, 40% and 50%of red-ash with its complement of CSA were give (15.8%-12.5% for AIV), (18.1%-12.8% for ACV) and (25%-11.6% for LAA) were the maximum and minimum value of the test, which implies that all mixes were strong enough used for base course layer of GB1 layer according to ERA specification.

As shown in charts the low values shows that the fraction of aggregate crushed is low and hence stronger and tougher the aggregate and it can capable of withstanding on higher wheel loads due to traffics. The best combination was observed on every combination of red-ash and CSA; an even natural red-ash sample provides to be more durable than CSA materials that were tested. Since all test results are within ERA specification.

Important properties that need to be determined are OMC and MDD of the CSA and red-ash aggregates in natural and blended proportional. A batch of five samples was tested for each blended and unblended red-ash and natural CSA samples. Specimens prepared for CBR and Procter compaction tests used the materials with maximum particle size of 19 mm according to AASTHO T180 procedures to determine the optimum water contents and maximum dry densities.

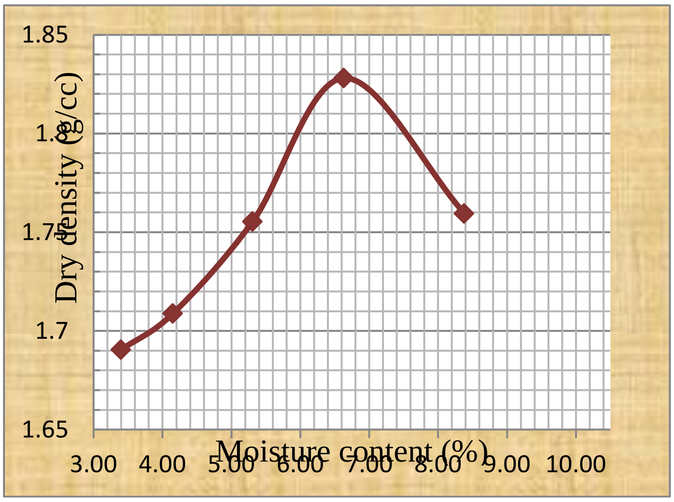


**Chart -3:** Dry density vs. Moisture content curve for blended neat red-ash

### 10.1 Results of the test conducted on blended red-ash with CSA material samples

For various blends of red-ash with pure aggregate, some trends were noted Regarding the effect of red-ash content on the MDD and OMC of material. From the result, we observe that the increase in red-ash content of the blend leads to a decrease in maximum dry density and OMC values this is Due to the coat on asphalt concrete prevent compaction by consolidation and minimizing the number of fines in red-ash particles. Hence as the red-ash contents in CSA-red-ash blends by weights were increased, the density was decreased, and its permeability was increased that were from 2.20g/cc to 1.98g/cc as red-ash contents increased in 10% to 50% respectively. The increased permeability also limits the soils ability to hold enough water to allow the soil particles to easily shift and properly interlock during compaction. Which is leads to a reduction in the required water to achieve MDD. Therefore CSA had a higher density (2.22g/cc) an average value of 2.18 g/cc minimum and 2.26g/cc maximum values than pure and blended red-ash(1.83g/cc) in average values in mixes.

**Table-10:** Compaction test on blended CSA and red-ash

| Samples Designations | Material Descriptions | OMC (%) | MDD (g/cc) |
|---|---|---|---|
| red-ash-1 | Neat CSA | 7.46 | 2.22 |
| red-ash-2 | CSA- red-ashblend | 7.35 | 2.20 |
| RAP-3 | CSA- red-ashblend | 7.21 | 2.17 |
| red-ash-4 | CSA- red-ashblend | 7.13 | 2.09 |
| red-ash-5 | CSA- red-ashblend | 6.94 | 2.05 |
| red-ash-6 | CSA- red-ashblend | 6.88 | 1.98 |
| red-ash-0 | red-ash | 6.64 | 1.83 |

### 10.2 Test Result on Blended RAP-CSA samples

As shown table when red-ash content was increased in the mixes CBR values were reduced which implies that blending red-ash with CSA leads to reduce CBR values of the mixes. We see from the **Error! Reference source not found.** adding red-ashas low as 30% into CSA can reduce CBR value below GB1 base course material expansiveness of the materials is also measured by swelling properties. It can be concluding that the higher the compaction effort (dry density), the higher CBR that can be achieved. From table show, the maximum and minimum swelling were ranging from 0.24 to 0.11 respectively. But ERA specification for base course material gives maximum swelling of 2<=. Therefore, the material was not expansiveness properties when blended.

## 11. CONCLUSIONS

Experimental findings were evaluated on the mechanical and physical properties of red-ashmaterial under different laboratory tests. Based on the laboratory results, the following conclusions were drawn:

1.The evaluation results show that red-ash has less resistance to crushing under the roller during road construction and when it is opened to traffic with ACV in range of 7.1% and 10.5%, AIV of 9.3% and 10.4%, LAA of 6.2% and 10.1%, in maximum to minimum values respectively. However, the CBR of red-ash was low with value of 42.1%. The specific gravity of tested red-ash was ranging 1.3 to 1.9, and water absorption was very low due to covered by asphalt contents in the range of 0.83% to 1.05%. However, some properties were PL<25%, PI<6% and the ACV and AIV<30%, LAA<51% of red-ash, the CBR <80%, TFV<111KN, SG<2.65 gradations are not in range of ERA specification. Therefore, red-ash can't be used for high traffic roads GB1 base course layer of Asphalt concrete without modifying of their properties.

2. As investigating the results of modified aggregates based on weight gives, ACV was varying from 18.1% to 12.8%, AIV (15.8%-12.5%), LAA (25%-11.6%), Specific gravity (1.28-1.91), CBR value (69.4%-80.1%), TFV (185kN-119kN when soaked and 164kN-104kN when un soaked), and PI (3.92%) when mixed in respecting from 10%-50% red-ashand its complements CSA. According to ERA specification for GB1 unbound base course materials to be used for base course of highly trafficked roads, the laboratory tests results of ACV<29%, AIV<30%, TFV>111kN, LAA<51%, CBR >100%, Specific gravity >2.65, and PI <6%.

3. The use of red-ash with unbound road base layers Asphalt concrete after blending with CSA as per ERA specification for GB1 base course standard is technically viable. CBR, Specific gravity, water absorption and loss due to crushing stress were decreased with increasing

red-ashcontent in blending proportion. It was observed that 30% by weight replacement of CSA with red-ash aggregate was successfully used for GB1 base course layer as CBR and TFV tests results, As it was seen from Gradation and Specific gravity results from 40% of blended and also from water absorption, liquid limit, plastic limit and plastic index show that all (50%) the blended red-ash-CSA percent can be easily used for GB1 base course layer accordingly ERA standard. As it measured by standard laboratory tests, it could be concluded that replacing 30% red-ash contents by weight with CSA can be the optimum contents that suitable to be used in pavements base course layer.

## 12. RECOMMENDATION

a. ERA should allow the use of red-ash marginal aggregates for highly trafficked road base course layer in the flexible pavement to no more than 30% by weight
b. Different blends give different mechanical and physical properties. Hence, further study is needed to test more variation of red-ash blended with CSA in different mixes percent.
c. Considering a further study inbuilt condition with full-scale experiment are needed on using various red-ashgradation since laboratories test only predicts field performance of red-ashand red-ash-CSA blends aggregate.
d. This research was done with specificred-ashand CSA quarry site, and only first day collected from each site due to a time frame of the study. However, other resource my produce different results. Hence further studies will be needed.
e. Proper techniques should be used to obtaining and stockpiling red-ashto maintain its quality. Since it can be mixed with pavement layer during milling or crushing.
f. Utilization of red-ash in roads construction industries is form of sustainable construction and it is more advisable to recycling than disposing in developing country such as Ethiopia.

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