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JIMMA INSTITUTE OF TECHNOLOGY

FACULITY OF CIVIL AND ENVIRONMENTAL ENGINEERING

HIGHWAY ENGINEERING STREAM

Experimental Investigation on partial Replacement of crushed base course material using River Gravel: A Case Study in kaffa zone.

Thesis submitted to the School of Graduate Studies of Jimma University in Partial Fulfillment of the Requirements for the Degree of Master of Science in Civil Engineering (Highway Engineering)

By:

Terefe Marito

March,2020

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Experimental Investigation On Partial Replacement of Crushed Base Course Material Using River Gravel

By

Terefe Marito

APPROVED BY BOARD OF EXAMINERS

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ABSTRACT

Highway development is one of the key actors to endore economic activities within a country. Ethiopia is doing its best to expand this development radiating from Addis Ababa City towards North to South and East to West directions. Hence, these developments resulted in greater demands on commercial or processed construction materials that are used for every project and it initiated the author to seek an alternative approach to find out pavement materials to utilize where the road construction become very expensive due to the increase costs on crushed stone aggregate. This was done through bleending naturally occurring river gravel with crushed stone aggregate, it required to understand the characteristics of River aggregate thoroughly in Ethiopia and specifically in kaffa context to enable their use in these engineering applications.

This research focused on the experimental investigation on partial replacement of crushed base course material using river gravel as unbound granular base course material for road pavement construction. The methods used in this research involved experimental analysis using laboratory tests. The samples used for physical and mechanical property tests selected randomly composed of a sample size of one for Crushed aggregate from kaffa zone which is around 60 Km from Bonga town while another samples for RG extracted from four River sources at the same location to crushed stone aggregate.

From these samples physical and mechanical properties tested to determine the sieve analysis, compaction, Atterberg's limit, Aggregate impact value, Aggregate crushing value, specific gravity, water absorption, CBR, Loss angles abrasion, flakiness index. The crushed stone aggregates tested on its initial state at 0% blending, while the following tests, blended with River gravel aggregates of 10%,20% ,30% and 40% by weight respectively.

Results indicated that as the increasing blending ratio of River gravel aggregates (RG) material, the CBR value increasese, which were similar to MDD. But, there were significantly increased in Abrasion value, Specific gravity, Impact value, Crushing value, and water absorption. Hence, it was found out that the optimum replacement by blending obtained at 30% RG and satisfied the ERA Standard specifications. It is therefore recommended that river gravel aggregates can be used as an unbound granular base course for road construction at 30% replacement of the crushed aggregates, specifically on project sites where there is the scarcity of aggregates from quarry sites.

Keywords: River gravel, crushed stone aggregate, Physical and Mechanical properties, Blended aggregates, Unbound granular materials

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ACRONYMS

ACV	Aggregate crushing value
ASTM	American society for testing and material
AASHTO	American association for testing of materials
AIV	Aggregate impact value
GB	Granular base
CBR	California bearing ratio
CSA	Crushed stone aggregate
CV	Crushing value
EPA	Environmental protection Authority
EIA	Environmental Impact Assessment
BS	British standard
LAA	Los Angeles abrasion
TFV	Ten percent fines value
RG	River gravel
WA	Western America
USGS	United states Geological Survey
TRRL	Transport and road Research Laboratory

CHAPTER ONE
INTRODUCTION

1.1: Background of the study

Naturally occurring granular materials are an important source for the base course or as subbase courses in the construction of flexible pavements. They include fine-grained materials such as well-graded silty and clayey sands (sand-clay), coarse and medium-grained materials such as natural gravels and materials produced by ripping and rolling rock which breaks down [1]. These materials are often used, but are not limited to, roads with low to medium traffic and surfaced with sprayed seals. However, when correctly applied their use on much more heavily trafficked roads has been successful. In recent years there have been a number of minor airports constructed for new mines in the arid Pilbara region of Western Australia [2].

Natural materials have been used also for runway construction on some of these airports where aircraft movements are less than about 10 per day and maximum aircraft size is about 100 seats. The term "natural material" is used here to mean a gravelly material occurring in nature as such, or which can be produced with only minimal crushing. Some processing to remove or breakdown oversize may still be necessary. However, a distinction is made between these "natural materials" and material produced by crushing hard rock and referred to as “crushed rock base [3].

River gravel, which is found in nature, consists of grains or fragments of rock. These materials are mined and they are used either in their natural state or after crushing, washing, and sizing. river gravel is also used for surfaces on unpaved roads [4]. Natural river gravels are the product of weathering and the action of wind or water, while manufactured fine aggregate and crushed stone coarse aggregate are produced by crushing natural stone. Crushing, screening, and washing may be used to process aggregates from either sand and gravel deposits or stone quarries. Synthetic aggregates may be either by products of an industrial process, in the case of blast-furnace slag, or products of processes developed to manufacture aggregates with special properties, as in the case of expanded clay, shale, or slate used for lightweight aggregates [5].

Currently, these abundant material particularly in the case of kaffa zone(bonga)is mostly used for the construction of concrete and unpaved road but no one tried to use this abundant river material for the construction of flexible pavement base course material. Therefore, this study mainly focused on the experimental evaluation on the physical and mechanical properties of River gravel (RG) blended in different ratios with crushed stone aggregate used as unbounded granular base material for road projects.

1.2. Statement of the problem

Globally, large amount of naturally occurring construction material produced each year. naturally occurring materials offer viable solutions to the concern, which is beneficial to both environment and economy.

River gravel is one of the most commonly used unbound granular material extracted from the river. It is the name given to gravel composed of small pieces of rounded stone of various colors, usually no larger than a large coin. It is named for the effect of many years of rounding of the edges of the stones due to a flow of water over it,as often takes place in river. An increased percentage of RG in base course could offer economic and environmental benefits [6].

The rapid economic growth in Ethiopia from 2004 to 2015(10.9%) and gauges the prospects for the future. In recent years, Ethiopia has dedicated three percent of GDP to road investments and investment program focuses mainly on rehabilitation, upgrading, and widening of the road [7].

Road construction has become very expensive due to the increase costs on crushed stone aggregate. crushed stone Aggregate is the main construction material for flexible pavement base course construction and concrete. Demand for this commercial aggregate material is high and will only increase in the future as cities grow and demand for infrastructure increases. Recent statistics showed the increasing demand of construction aggregate to reach 2.6 million metric tons by the year 2013 in Ethiopia. The production of aggregate materials increased by 31% compare to the year 2012[8]. Fresh Aggregate is expensive; hence, the use of naturally occurring river gravel aggregate, which is locally available and cheap, can either be used as partial replacement of fresh aggregate.

A study is needed to evaluate the suitability of river gravel as base course material without compromising the pavement performance. A successful application of high percentage River Gravel could contribute to the sustainability, in terms of costs and resource [9].

1.3. Research questions

The research questions that this study tried to clarify; are as follows:

1. What are the physical and mechanical properties of crushed aggregates and natural aggregates found in the study area?
2. How would be the values of the different parameters varied from the standard specifications when it is blended the two types of aggregates?
3. Which optimum amount of river aggregate that can be replaced by the crushed stone?

1.4 Research objectives

1.4.1. General objective

The general objective of this study is to Investigate the Utilization of River gravel in flexible pavement base course construction as partial replacement to crushed stone aggregate.

1.4.2. Specific objectives

- ✓ To determine the physical and mechanical properties of crushed aggregate and natural aggregate from the study area.
- ✓ To analyze and discuss the different parameters relative to their values in conformity with the standard specifications.
- ✓ To determine the optimum amount of river aggregates which can be replaced by the crushed stone.

1.5. Significance of the study

The result of the research study underlined the following crucial importance;

- It would strengthen the information on engineering characteristics of RG to establish as suitable unbounded granular material for pavements.
- It would reduce the cost of construction. Promote reducing the amount for crushed stone aggregate demanded and economic use of crushed stone aggregate for base materials in different traffic volume roads that is a viable solution for road sector problem.

- .RG as an alternative for partial replacement of commercial material leads to preservation of natural resources for the Economic aspect.
- Finally, use of RG as a pavement material provided a principal application for economic benefits to be gained as well as aspects of sustainability in the pavement material industry

1.6. Scope of the Research

The experimental study based on construction and river gravel, from different construction sites. These materials were blended together with different ratios to form new samples for the tests. Materials blended and tested to determine physical and mechanical properties. The laboratory experiments conducted, including classification tests, strength property tests, and mechanical tests. The classification and strength property was tested with the test methods of standard granular pavement materials. The mechanical properties were tested under performance tests like CBR test methods. After examining the properties of river gravel aggregate a, the possible replacement ratio of virgin aggregate with river aggregate used as unbounded granular pavement base course material is suggested.

CHAPTER TWO

RELATED LITERATURE REVIEW

2.1 Unbound pavement materials

This section gives guidance on the selection of unbound materials for use as base course, subbase, capping and selected subgrade layers. For lightly trafficked roads the requirements set out below may be too stringent and reference should be made to the *Low Volume Roads Design Manual*. The main categories with a brief summary of their characteristics are shown in Table 2.1.

Table 2. 1: Properties of Unbound Materials [10]

Code	Description	Summary of Specification
GB1	Fresh, crushed rock	Dense graded, unweathered crushed stone, non-plastic parent fines
GB2	Crushed weathered rock, gravel or boulders	Dense grading, PI < 6, soil or parent fines; PP <60
GB2A	Dry-bound and Water-bound Macadam	Aggregate properties as for GB2 (see text) PI < 6: PP < 60
GB3	Natural coarsely graded granular material, including processed and modified gravels	Dense grading, PI < 6 CBR after soaking > 80%
GS	Natural gravel	CBR after soaking > 30%
GC	Gravel or gravel-soil	Dense graded; CBR after soaking > 15%

Notes: 1. These specifications are sometimes modified according to site conditions, material type and principal use (see text).

2.PP = Plasticity Product = PI x (per cent passing 0.075mm sieve)

3.GB = Granular base course, GS = Granular sub-base, GC = Granular capping layer.

2.2. Base Course Materials

A wide range of materials can be used as unbound base course including crushed quarried rock, crushed and screened, mechanically stabilized, modified or naturally occurring 'as dug' or 'pit run' gravels. Their suitability for use depends primarily on the design traffic level of the pavement and climate. However, all base course materials must have a particle size distribution and particle shape which provide high mechanical stability and should contain sufficient fines (amount of material passing the 0.425 mm sieve) to produce a dense material when compacted [12].

2.2.1 Crushed Stone Graded crushed stone (GB1)

This material is produced by crushing fresh, quarried rock (GB1) and may be an all-in product, usually termed a 'crusher-run', or alternatively the material may be separated by screening and recombined to produce a desired particle size distribution, as per the specifications. Alternate gradation limits, depending on the local conditions for a particular project, are shown in Table 2.2. After crushing, the material should be angular in shape with a Flakiness Index of less than 35%, and preferably of less than 30%. If the amount of fine aggregate produced during the crushing operation is insufficient, non-plastic angular sand may be used to make up the deficiency. In constructing a crushed stone base course, the aim should be to achieve maximum Impermeability compatible with good compaction and high stability under traffic [13]

Table 2. 2: Grading Limits for Graded Crushed Stone Base Course Materials (GB1)

Test sieve (mm)	**Percentage by mass of total aggregate passing test sieve**		
	Nominal maximum particle size		
	37.5 mm	**28 mm**	**20 mm**
50	100	-	-
37.5	95 – 100	100	-
28	-	-	100
20	60 – 80	70 - 85	90 – 100
10	40 – 60	50 - 65	60 – 75

5	25 - 40	35 - 55	40 – 60
2.36	15 – 30	25 - 40	30 – 45
0.425	7 – 19	12 - 24	13 – 27
0.075 (1)	5 – 12	5 - 12	5 – 12

Note 1. For paver-laid materials a lower fines content may be accepted.

To ensure that the materials are sufficiently durable, they should satisfy the criteria given in Table 6.3. These are a minimum Ten Per Cent Fines Value (TFV) and limits on the maximum loss in strength following a period of 24 hours of soaking in water. The likely moisture conditions in the pavement are taken into account in broad terms based on annual rainfall. Alternatively, requirements expressed in terms of the results of the Aggregate Crushing Value (ACV) may be used. The ACV should, preferably, be less than 25 and always less than 29. Other simpler tests e.g. the Aggregate Impact Test may be used in quality control testing provided a relationship between the results of the chosen test and the TFV has been determined. Unique relationships do not exist between the results of the various tests but good correlations can be established for individual material types and these need to be determined locally [14]

Table 2. 3: Mechanical Strength Requirements (Ten Per Cent Fines Test) for the Aggregate Fraction of Crushed Stone Base Course Materials (GB1)

Typical Annual Rainfall (mm)	**Minimum Ten Percent Fines Values (kN)**	**Minimum Ratio Wet/Dry Test (%)**
>500	110	75
<500	110	60

The fine fraction of a GB1 material should be non-plastic.

These materials may be dumped and spread by grader but it is preferable to use a paver to ensure that the completed surface is smooth with a tight finish. The material is usually kept wet during transport and laying to reduce the likelihood of particle segregation. Thus they are often called ‘wet mix’ and should not be confused with ‘water-bound macadam’ The in situ dry density of the placed material should be a minimum of 98% of the maximum dry density obtained in the ASTM Test Method D 1557 (Heavy Compaction). The compacted thickness of each layer should not exceed 200 mm.

Crushed stone base courses constructed with proper care with the materials described above should have CBR values well in excess of 100 per cent. There is usually no need to carry out CBR tests during construction.

2.2.2 Dry-bound and Water-bound Macadam (GB2A)

Dry-bound macadam is a traditional form of construction and its performance can be comparable to that of a graded crushed stone. It is particularly applicable in areas where water is scarce or expensive to obtain and it is also suitable where lab our intensive construction is an economic option. The materials consist of nominal single-sized crushed stone and non-plastic fine aggregate (passing the 5.0 mm sieve). The fine material should preferably be well graded and consist of crushed rock fines or natural, angular pit sand. The dry-bound macadam process involves laying single-sized crushed stone of either 37.5 mm or

50 mm nominal size in a series of layers to achieve the design thickness. The compacted thickness of each layer should not exceed twice the nominal stone size. Each layer of coarse aggregate should be shaped and compacted and then the fine aggregate spread onto the surface and vibrated into the interstices to produce a dense layer. Any loose material remaining is brushed off and final compaction carried out, usually with a heavy smooth-wheeled roller. This sequence is then repeated until the design thickness is achieved. To aid the entry of the fines, the grading of the

37.5 mm nominal size stone should be towards the coarse end of the recommended range. Economy in the production process can be obtained if layers consisting of 50 mm nominal size stone and layers of 37.5 mm nominal size stone are both used to allow the required total thickness to be obtained more precisely and to make better overall use of the output from the crushing plant. Water-bound macadam is similar to dry-bound macadam. It also consists of two components namely a relatively single-sized stone with a nominal maximum particle size of 50 mm or 37.5 mm and well graded fine aggregate which passes the 5.0 mm sieve. The coarse material is usually produced from quarrying fresh rock. The crushed stone is laid, shaped and compacted and then fines are added, rolled and *washed* into the surface to produce a dense material. Care is necessary in this operation to ensure that water sensitive plastic materials in the sub-base or subgrade do not become saturated. The compacted thickness of each layer should not exceed twice the maximum size of the stone. The fine material should preferably be non-plastic and consist of crushed rock fines or natural, angular pit sand [15]. Typical grading limits for the coarse fraction of GB2A materials are given in Table 2.4. The grading of M2 and M4 correspond with nominal 50 mm and 37.5 mm single-sized aggregates and are appropriate for use with mechanically crushed aggregate. M1 and M3 are broader specifications. M1 has been used for hand broken stone but if suitable screens are available, M2, M3 and M4 are preferred.

Aggregate hardness, durability, particle shape and in situ density should each conform to those given above for graded crushed stone.

Table2. 4: Coarse Aggregate Gradings for Dry-bound and Water-bound Macadam

Test sieve size (mm)	**Percentage by mass of total aggregate passing test sieve**			
	M1	**M2**	**M3**	**M4(1)**
75	100	100	100	
50	85 - 100	85 - 100	85 - 100	100
37.5	35 - 70	0 - 30	0 - 50	85 - 100
28	0 - 15	0 - 5	0 - 10	0 - 40
20	0 - 10			0 - 5

Note 1 To aid entry of the fines, the coarser end of this grading is preferred

2.2.3 Naturally Occurring Granular Materials, Boulders, Weathered Rocks

Normal requirements for natural gravels and weathered rocks (GB2, GB3)

A wide range of materials including lateritic, calcareous and quartzitic gravels, river gravels, boulders and other transported gravels, or granular materials resulting from the weathering of rocks can be used successfully as base course materials. Table 2.5 contains three recommended particle size distributions for suitable materials corresponding to maximum nominal sizes of 37.5 mm, 20 mm and 10 mm. Only the two larger sizes should be considered for traffic in excess of 1.5 million ESAs. To ensure that the material has maximum mechanical stability, the particle size distribution should be approximately parallel with the grading envelope.

To meet the requirements consistently, screening and crushing of the larger sizes may be required. The fraction coarser than 10 mm should consist of more than 40 per cent of particles with angular, irregular or crushed faces. The mixing of materials from different sources may be warranted in order to achieve the required grading and surface finish. This may involve adding fine or coarse materials or combinations of the two [19].

Table 2. 5Recommended Particle Size Distributions for Mechanically Stable Natural Gravels & Weathered Rocks for use as Base Course Material (GB2, GB3)

Test sieve (mm)	**Percentage by mass of total aggregate passing test sieve**		
	Nominal maximum particle size		
	37.5 mm	**20 mm**	**10 mm**
50	100	-	-
37.5	80 – 100	100	-
20	60 – 80	80 – 100	100
10	45 – 65	55 – 80	80 – 100
5	30 – 50	40 – 60	50 – 70
2.36	20 – 40	30 – 50	35 – 50
0.425	10 – 25	12 – 27	12 – 30
0.075	5 – 15	5 – 15	5 – 15

All grading analyses should be done on materials that have been compacted. This is especially important if the aggregate fraction is susceptible to breakdown under compaction and in service. For materials whose stability decreases with breakdown, an aggregate hardness based on a minimum soaked Ten Per Cent Fines Value of 50 kN may be specified.

The fines of these materials should preferably be non-plastic but should normally never exceed a PI of 6.

If the PI approaches the upper limit of 6, it is desirable that the fines content be restricted to the lower end of the range. To ensure this, a maximum PP of 60 is recommended or alternatively a maximum Plasticity Modulus (PM) of 90 where:

PM = PI x (percentage passing the 0.425 mm sieve)

If difficulties are encountered in meeting the plasticity criteria, consideration should be given to modifying the material by the addition of a low percentage of hydrated lime or cement. When used as a base course, the material should be compacted to a density equal to or greater than 98 per cent of the maximum dry density achieved in the ASTM Test Method D 1557 (Heavy Compaction). When compacted to this density in the laboratory, the material should have a minimum CBR of 80% after four days immersion in water [20].

2.2.4 Low volume roads

For low volume roads (Chart A and traffic classes T1 and T2) the plasticity and strength requirements for the unbound materials can be relaxed, especially when the subgrade is strong and/or the climate is dry. In Ethiopia, the low altitude areas of the northeast (low areas of Tigray, Welo and Hererge regions) and southeast (Hererge and Bale) are dry throughout most of the year. In these low rainfall areas, typically with a mean annual rainfall of less than 500 mm, and where evaporation is high, moisture conditions beneath a well-sealed surface are unlikely to rise above the optimum moisture content determined in the ASTM Test Method D 1557 (Heavy Compaction). In such conditions, high strengths (CBR>80 %) are likely to develop even when natural gravels containing a substantial amount of plastic fines are used. In these situations and depending on subgrade strength, for the lowest traffic categories the maximum allowable PI can be increased to 9 and the minimum soaked CBR criterion reduced to 65% at the expected field density[21]

2.2.5 Materials of basic igneous origin

Materials in this group are sometimes weathered and may release additional plastic fines during construction or in service. Problems are likely to worsen if water enters the pavement and this can lead to rapid and premature failure. The state of decomposition also affects their long-term durability when stabilized with lime or cement. The group includes common rocks such as basalts and dolerites but also covers a wider variety of rocks and granular materials derived from their weathering, transportation or other alteration.

Normal aggregate tests are often unable to identify unsuitable materials in this group. Even large, apparently sound particles may contain minerals that are decomposed and potentially expansive. The release of these minerals may lead to a consequent loss in bearing capacity. There are several methods of identifying unsound aggregates. These include petrographic analysis to detect secondary (clay) minerals and the use of various chemical soundness tests, e.g. sodium or magnesium sulphate (ASTM C 88). Indicative limits based on these tests include:

(a) A maximum secondary mineral content of 20%,

(b) A maximum loss of 12% or 20% after 5 cycles in the sodium or magnesium sulphate tests respectively.

In most cases it is advisable to seek expert advice when considering their use, especially when new deposits are being evaluated. It is also important to subject the material to a range of tests since no specific method can consistently identify problem materials. Recommendations for appropriate test and limits for the durability of road base course materials can be found in Sampson [24].

In some areas of Ethiopia, weathered basalt gravels are available in large quantities. To study the performance of weathered basalt gravel, experimental roads were constructed in Ethiopia, namely on the Gelenso-Mechara project and Ghion-Jimma project under a Joint Road Research Project of the Ethiopian Transport Construction Authority and TRRL [21]. Results indicated that these materials stabilized with 3 per cent of lime and surface dressed should provide an acceptable alternative to crushed stone base construction for main roads in Ethiopia. A particular advantage of this material is that it avoids the problem of clay working up into the base, which is a frequent source of failure when using crushed stone over active clay.

2.2.6 Materials of marginal quality

Naturally occurring gravels which do not meet the normal specifications for base course materials have been used successfully. They include lateritic, calcareous and volcanic gravels.
In general, their use should be confined to the lower traffic categories (i.e. T1 and T2) unless local studies have shown that they have performed successfully at higher levels [21].
Laterite gravels with plasticity index in the range of 6-12 and plasticity modulus in the range of 150-250 are recommended for use as base course material for T3 level of traffic volume. The values towards the higher range are valid for semi-arid and arid areas of Ethiopia, i.e. with annual rainfall less than 500 mm.
The calcareous gravels, which include calcretes and marly limestone, deserve special mention. Typically, the plasticity requirements for these materials, all other things being equal, can be increased by up to 50% above the normal requirements in the same climatic area without any detrimental effect on the performance of otherwise mechanically stable bases. Strict control of grading is also less important and deviation from a continuous grading is tolerable.
Cinder gravels can also be used as a base course material in lightly trafficked (T1 and T2) Chart A and Chart B roads [28].

2.2.7 Pit sand (Coarse sand)

This type of sand is procured from deep pits of abundant supply. It has a property of being coarse grained which is sharp, angular and free from salts. It mostly has a reddish yellow color and mostly employed in concreting [15, 16, and 17].

2.2.8 River sand

The River sands are obtained, as the name implies, from banks or beds of rivers. River sand has the property of being fine and consists of fine rounded grains. The color of river sand is almost white and grayish. River sand is usually available in clean condition and is used for plastering [17].

2.2.9 Sea/Marine sand

As the name implies, sea sand is taken from sea shores. It has fine rounded grains and it is light brown in color. Sea sand is avoided for the purpose of constructing concrete structure since it contains salt and tends to absorb moisture from the atmosphere and brings dampness [16, 17].

2.3 fine aggregate/sand production

Sand is one of the most accessible natural resource that has been used since the earliest days of civilization mostly as a construction material.

According to USGS, the largest producer of sand and gravel in the world is the United States, produced 26.5 million metric tonnes of the materials. Italy ranks second with an annual production of over 14 million metric tonnes. The third place is occupied by Germany, producing 6.5 million metric tonnes [18].

Other major countries producing sand and gravel include the United Kingdom, Australia, France, Spain, Poland, Japan, Mexico, South Africa, Finland, Belgium, Egypt, India, Iran, Norway, Austria, Chile, Czech Republic, Turkey, Canada, Gambia, Bulgaria, Slovakia, South Korea, and Hungary [18].

A summary of the top fifteen producers of sand and gravel along with their production capacity is shown in table2.6

Table2. 6 : Top 15 producers of sand and gravel in the world [18]

Rank	Country	Production in Thousand Metric Tonnes
1	United States	26,500
2	Italy	14,000
3	Germany	6,500
4	United Kingdom	5,600
5	Australia	5,200
6	France	5,000
7	Spain	5,000
8	Poland	4,350
9	Japan	3,500
10	Mexico	2,800
11	South Africa	2,300

The production of fine aggregate starts with the exploration process where locating a suitable resource near the area is done. Once the exploration is done, it is followed by the mining process where the actual extraction of the material takes place. To enhance the quality of the extracted fine aggregate, it is further processed through washing, drying, sorting, and storing. This is followed by transportation to the final destination. Delivering to the final destination is not an end to the production process. A reclamation program is required where maintenance to the interrupted land takes place. A detailed description of each step is discussed below.

2.3.1. Exploration

A mining project begins once knowhow on the extent and value of the mineral ore deposit has been accomplished. Information on the location and value of the mineral ore deposit is obtained during the exploration phase. This phase includes surveys, field studies, and drilling test boreholes and other exploratory excavations [19].

The exploratory phase may involve clearing of wide areas of vegetation, to allow the entry of heavy vehicles mounted with drilling rigs. Many countries require a separate EIA for the exploratory phase of a mining project because the impacts of this phase can be intense and further phases of mining may not follow if exploration fails to find sufficient quantities of mineral ore deposits.

2.3.2. Mining

Mining is the actual removal of the material from the source. Before any actual mining is done at a site, overburden which is mainly composed of silt, loam, clay, or combinations of the three is removed from the top of the sand formation with the help of scrapers or tracked excavators and off-road haul trucks. Once the overburden has been removed, the sand is mined out either by open pit excavation or by dredging. Open pit excavation is carried out with power shovels, draglines, front end loaders, and bucket wheel excavators. Depending upon the geological formation, blasting may be used to loosen the sand deposit followed by the crushing process to reduce the size.

Mining by dredging involves mounting the equipment on boats or barges and removing the fine aggregate and gravel from the bottom of the water body by suction or bucket-type dredges [20,21].

Having obtained the mined mineral, the material may be directly used without further processing, taken directly to the washing process, stockpiled on site for later processing, or transported to a processing plant [21]

Although significant amounts of sand and gravel are used without processing, most sand and gravel are processed prior to use. Therefore, the materials are transported to the processing plant by suction pump, earth mover, barge, truck, belt conveyors, or other means [20].

2.3.3. Processing

Sand must be of uniform size and shape. To achieve this uniformity, the sand is run through a processing plant. The processing of sand and gravel involves the use of different combinations of washers, driers, screens, and classifiers to segregate particle sizes; crushers to reduce oversized material; and storage and loading facilities [20].

2.3.4 washing

The purpose of washing sand is to free it from fine particles, clay and organic impurities. Washing is done by spraying the sand with water as it is carried over a vibrating screen. The fine particles are washed off the sand and the coarse particles are carried along the screen by the vibration. Some processing operations also use what is known as an up flow clarifier to wash the sand. An up flow clarifier is essentially a tank where water and sand are continuously directed into the tank. The water washes the sand and the overflow water along with the fines flow over the tank while the washed sand falls by gravity to the bottom of the tank and is sent for further processing [21].

Modern quarries use attrition scrubbers which remove silt and gravel from the sand particles using the abrasive power of water and hydro-cyclone systems, which in turn use pressurized water jets to float the fine grains of sand away from the coarse grains. Solid particles that are separated from the finer sand particles are allowed to settle in silt lagoons [22].

2.3.5. Drying

Prior to sand being sized and stored as a final product, it typically goes through a drying process to reduce the moisture content. Once the sand has been washed, it is then sent to a surge pile where much of the water adhering to the sand particles infiltrates back into the ground. From the surge pile, the sand is sent to the dryer and screening operation [21].

2.3.6. Sorting and screening

After the sand passes through the drying phase, it is graded to produce the grain size needed for a particular purpose. Vibrating screens are used to screen the sand; these can be changed to produce the different grain sizes [22].

The screens separate the oversize material from the smaller, marketable sizes. Oversize material may be used for erosion control, reclamation, or other uses, or it may be directed to a crusher for size reduction, to produce crushed aggregate, or to produce manufactured sands.

Following crushing, the material is returned to the screening operation for sizing [20]. In modern processing plants, different grain sizes can be selected. The graded sand is then conveyed to storage silos or on to a bagging shed.

The whole operation is controlled from a central diagnostic desk, controlling flow and storage. The sand is tested several times at various stages of the process to ensure that it conforms to the specifications of that particular grade of sand [22]

Once washed, dried, graded and tested; the sand is stored in piles or bagged ready for transportation. In the case of the bagged sands, the correct weight of sand is deposited into each polythene sack, which is sealed and sprayed with a batch number, date and grade and moved to the waiting lorries [22].

2.3.7. Transporting

Transportation of sand from the time it is mined, processed, and eventually delivered to the location where it is going to be used can take many mediums depending upon the location of the mine, the processing facility and the destination where the sand will ultimately be used. Transportation is a key element of the supply process and a large part of the delivered price. Within the mine, the sand may be transported by front-end loaders, large open-topped off road trucks, or dump trucks [21]. Vehicular traffic on local roads will have an impact on the service life and condition of the roads.

CHAPTER THREE
MATERIALS AND METHODOLOGY

3.1: Study Area.

The research study was conducted in the kaffa zone, which is located in the south nation nationalities and peoples Regional State, at a distance 460Km from Addis Ababa. Its astronomical location is between $6^{0}24'$ to $7\ ^{0}70'$N and $35^{0}\ 69\ '$to $36^{0}78'$E

Figure 3.1: Map of study area (source: Google map)

3.2 Study period

This study was conducted from JULY 2019 to October 2019

3.3 Study design

This section provided details about the experimental tests conducted during the study and a discussion of the results obtained. The study design of this paper included the Experimental investigation on crushed stone aggregate, river gravel and blended aggregates collected from the study area. It was tested the existing physical and mechanical properties for each sample, followed by mixing river gravel and crushed stone aggregate by 10%, 20%, 30%, and 40% replacement by weight of river gravel. The physical and mechanical properties tested and its associated laboratory results were discussed.

The details of the research process are shown in the flow chart below.

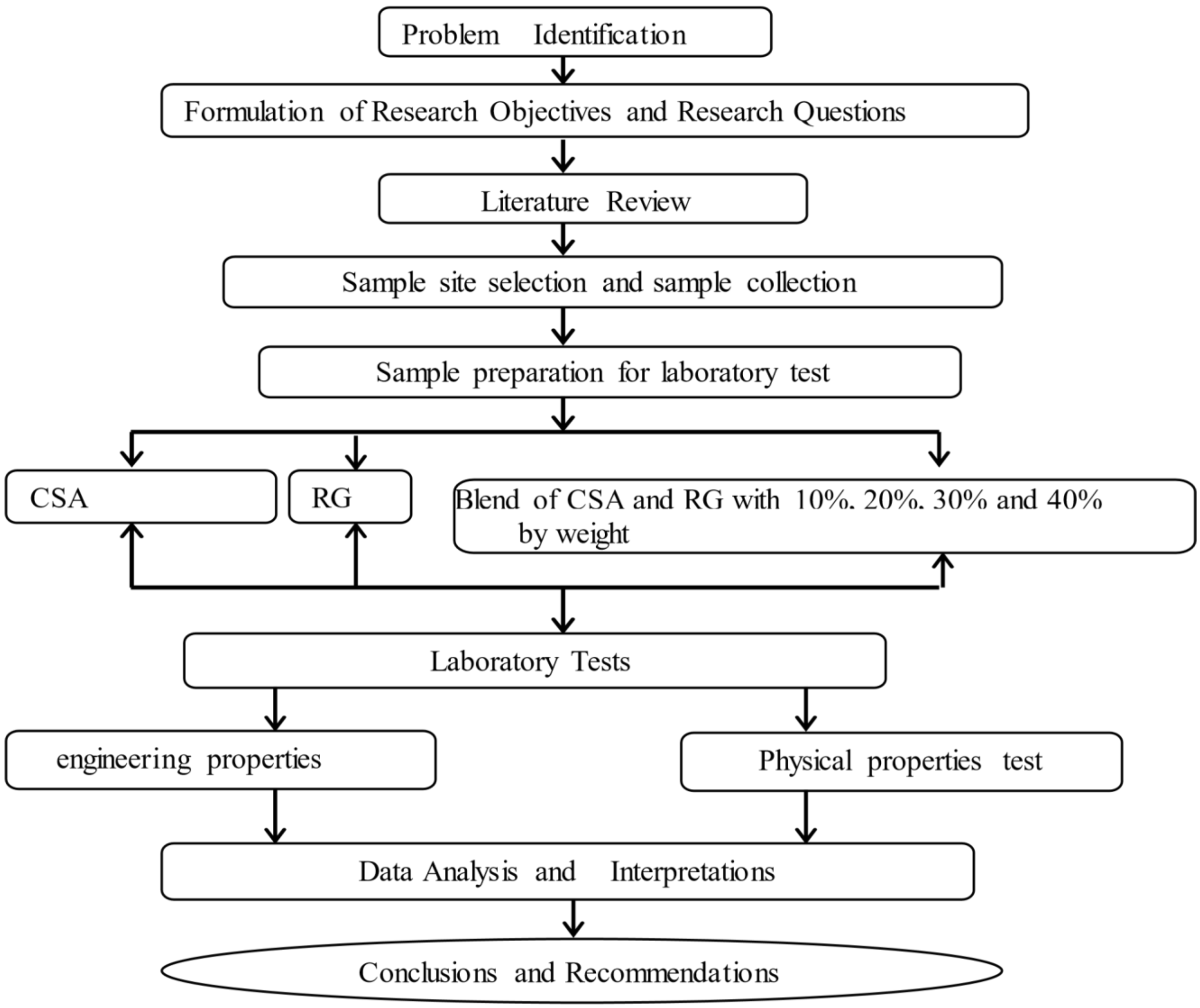

Figure 3.2: Flow chart of the study design

3.4 Population

The population for this study considered river aggregate(gravel) and crushed stone aggregate of the selected research study location.

3.5 Sample collection and sampling procedure

In this research study, the River gravel had been taken from four selected river sources in kaffa zone. the steps followed to extract and utilize the sample was Mining using the Aid of traditional tools such as shovels and buckets Then Transporting, Washing, Drying and Utilizing. The river gravel from these locations was considered to use for blending with the crushed stone aggregate as partial replacement to reduce cost of construction. Virgin aggregates(CSA) were also taken from the same location to river gravel, with a distance of 60kms from bonga town. The number of samples used for this study was estimated accordingly to the test specimen computed, based on the total quantities needed for the number of tests required to conduct physical and mechanical properties of river gravel, virgin aggregate and blended samples. All samples performed in accordance with the procedures of ASTM, and the results compared with AASHTO and ERA Standard Specifications for unbounded granular pavement base course material.

3.6 Study variables

There were two types of variables that were taken into consideration

3.6.1 Independent variables

- Abrasion value
- Flakiness index
- CBR value
- Particle size analysis
- Moisture content
- Specific gravity
- Compaction
- Crushing value

- Impact value
- percentage of blending

3.6.2 Dependent variables:

Performance of RG, crushed stone aggregate and blended crushed stone aggregate as base course material.

3.7. Methods and Laboratory Experimental Works Procedure

3.7.1 Test methods and specifications

TABLE 3. 1: TEST METHODS AND SPECIFICATIONS

Test Methods	Specifications
Sieve analysis	AASHTO T-27
Specific gravity and absorption	AASHTO T85
Compaction	AASTO T99
Atterberg limit	AASHTO T90
Los Angeles abrasion	ASTM C131
CBR	AASHTO T193
Flakiness index	ASTM D3398
Crush and impact value	ASTM

3.7.2 Testing Program

To evaluate the possibility of using river gravel of the unbound base as a replacement of the crushed stone aggregate, different percentages of the crushed stone aggregate were replaced with the river gravel. By this, six different types of mixture were produced. The mixture containing 100% of crushed stone aggregate was considered as the control material, and 4 different mixtures were made by replacing 10, 20, 30% and 40% of the crushed stone aggregate with the river gravel. The replaced particles include the coarse, middle size, and fines, each at the same ratio. The figure below shows the sample for crushed stone aggregate and river gravel collected and mined from the production site found in kaffa zone 60 km from bonga town and river sources of the same location that considered for the study.

figure 3.3: Photo taken during sample collection (source:Agenghehu Marito)

3.7.3 Laboratory tests on crushed stone aggregate and river gravel

3.7.3.1 Particle Size Analysis

All the samples set the gradation limits of materials that are used as granular base course layers for pavement for construction. The gradation of a material is an indicator of other properties such as permeability, frost susceptibility, and shear strength. This routine test consisted of shaking a sample of known mass through a stack of sieves in descending sizes. The standard procedure of this method is outlined in AASHTO T27, Standard Test Method for Sieve Analysis of Fine and coarse aggregates.

The figure below shows the sieve analysis tests for river gravel and crushed stone aggregate.

Figure 3.4: photo taken during gradation test for both RG and CSA (source: Merid mesfin)

3.7.3.2 Atterberg Limits

The plasticity index measured by considering materials passing No. 40 (0.425mm) sieve size material, was evaluated using Atterberg Limits. Plastic limits are used to identify the moisture content at which a material begins to exhibit plastic behavior. The liquid limit is used to define when the material behaves as a viscous liquid. The numerical difference between the two limits is called the Plasticity Index (PI) which indicates the magnitude of the range of moisture contents a material will remain in a plastic state. The figure below shows both liquid and plastic tastes were conducted by using the digital liquid limit test instrument

figure 3.5: photo taken during liquid limit test (source: Ahadu Mengiste)

3.7.3.3 Moisture-Density Relationship by modified proctor test

Laboratory compaction was used to establish a relationship between moisture content and dry density, which is then used to determine the estimated Optimum moisture content and maximum dry density. To do this, a representative sample was compacted into a mold, of known volume, through a range of moisture contents and the resulting calculated dry densities which were plotted versus the moisture contents.

This graph is used to estimate the maximum density and corresponding moisture content. modified proctor test methods following the procedure set forth by AASHTO T180, the Moisture-Density Relations of aggregate **Using a 4.5-kg Rammer and a 305-mm Drop,** to define optimum moisture and maximum dry density used in the river gravel and crushed stone aggregate

the figure below shows the compaction test that was conducted by using the compaction test apparatus

Figure 3.6: photo taken during compaction test for both samples (source: shimelies Agito)

3.7.3.4 Specific Gravity and Absorption

These tests were performed to determine the weight of the materials. The light material has less Specific gravity than heavier materials. In terms of aggregate, specific gravity is a numerical value showing the number of times heavier an aggregate particle is when it is compared to an equal volume of water. Many researchers state that Most naturally occurring aggregates have a specific gravity of 2.6 to 2.7, although values as low as 2.4 or as high as 3.0 have been encountered. The specific gravity of an aggregate is not an indication of the quality of the aggregate itself; however, it can be an indication of potential problems and is needed for computations involving volume and mass. Another property derived from the specific gravity test is water absorption. Absorption has been used as an indicator of aggregate durability as related to freezing and thawing. High absorption has been used as an indicator of aggregate durability as related to freezing and thawing. High absorption has been used as a sign of unsound aggregates.

3.7.3.5 Los Angeles Abrasion

A sample of each material was subjected to the L. A. Abrasion test according to ASTM C 131. This test was developed for the characterization of aggregates for pavement base course material and concrete mixture design as well. A 5-kg sample of each RG and Crushed stone aggregate was prepared according to Grading A. The test required that each material sample is placed with 12 steel spheres inside a metal drum that rotated at a speed of approximately 30rpm for 500 revolutions. The weight loss of the sample, in percent, was measured after the tested sample was sieved through 1.70 mm sieve and the mass retained washed and oven dried at 110°C.

Figure 3.7: photo taken during abrasion test of sample(source: Tesfahun Meshesha)

3.7.3.6 Aggregate Crushing Value

As stated by another researcher, aggregate crushing value provides the ability of any aggregates to resist the crushing of weak figure and the stronger aggregates, i.e. the greater its ability to resist crushing. Samples were prepared by sieving and aggregate passing the 12.5 mm sieve and retained on 10 mm sieve is selected for standard test Compression testing machine with a load of 40 tones is applied for 10 minutes and finer materials were sieved by using 2.36 IS sieve.

3.7.3.7 Index of Aggregate Particle Shape and Texture

This parameter was tested to determine the percentage of flaky and elongated particles In case of gravel or coarse aggregate it is determined by its Angularity Number. Flakiness and Elongation tests are conducted on coarse aggregates to assess the shape of aggregates hence an aggregate which is flaky or elongated are detrimental to the higher workability and stability of mixes for the base course during compaction. But they are flakier, not conducive to good interlocking and hence the mixes with an excess of such particles are difficult to compact to the required degree. For base course and construction of bituminous and cement concrete types, the presence of flaky and elongated particles is considered undesirable as they may cause inherent weakness with probabilities of breaking down under heavy loads.

Figure 3.8: photo taken during flakiness index test (Source: Nasir Faris)

3.7.3.8 Aggregate impact value

This test was conducted to determine the resistance of the aggregate to a sudden shock or an Impact which in some aggregates differs from its resistance to a slope Compressive load in crushing test. This test can be carried on a cylindrical stone specimen known as a Page Impact test. The test applies to a standard fraction aggregate passing 12.5 and retained on10 mm IS sieve, and the tested specimen is subjected to a sum of 15 blows, each being performed at an interval of not less than 1-second.

The crushed aggregate is then removed from the cup and the whole of it is sieved on the 2.36 mm sieve until no significant amount passes and the fraction passing the sieve is weighted accurately to 0.1gram.

Figure 3.9: photo taken during impact value test (Source: Dejene.D)

CHAPTER FOUR

RESULTS AND DISCUSSION

This chapter delivers evidence on the laboratory results of River gravel and crushed stone aggregate through different mixture ratio used for unbounded material for road pavement with specifications. A total of six samples were utilized within this research project, from these 100% crushed stone aggregates as a control point and the others were mixed ratio with River gravel. river gravel aggregate content in the mixtures: samples were prepared by 10%,20%, 30% and 40% replacement of RG

4.2 Test Results for physical property a n d mechanical property of virgin aggregate and River gravel materials

As emphasized from Chapter three, a number of classification tests were shown on the six (6) material samples. The physical and mechanical tests included particle size analyses, Atterberg limits, coarse aggregate specific gravity and absorption, Los Angeles Abrasion, aggregate angularity, aggregate crush and impact test, Atterberg limits test, compaction and the CBR tests performed on the six (6) samples. The following subdivisions presented the results of all tests conducted on the RG materials, crushed stone aggregate and RG blended samples.

4.2.1. Particle size analysis result for RG and crushed aggregates

The test was performed on RG material due to The insufficient amount or well graded material found in the RG material, it did not satisfy the gradation requirements of the specification. Or beyond the limit of upper and lower limit of the ERA Specification. The materials were coarser than the commercial or processed crushed aggregate used for the base course**.** Test results were listed in table 4.1.

Table 4. 1: Particle size analysis of RG only

Sieve size	Wt. retained in each sieve(gm)	Percent retained	Cumulative percent retained	Percent passing		ERA specification	
					Cumulative % passing	Upper Limit	Lower Limit
37.5	0	0	0	100	100	100	100
26.5	457.7	4.5	4.5	95.5	95.5	100	80
19.5	1640.3	16.40	20.9	83.6	79.1	80	60
9.5	429.3	4.29	55.41	95.71	44.59	60	40
4.75	2114.5	21.14	76.55	78.26	23.45	40	25
2.36	174.1	1.74	78.29	98.26	21.71	30	15
0.500	650	6.5	96.99	93.5	3.01	19	7
0.425	68.9	0.68	97.67	99.32	2.33		
0.075	74.73	0.74	99.8	99.26	0.2	12	5

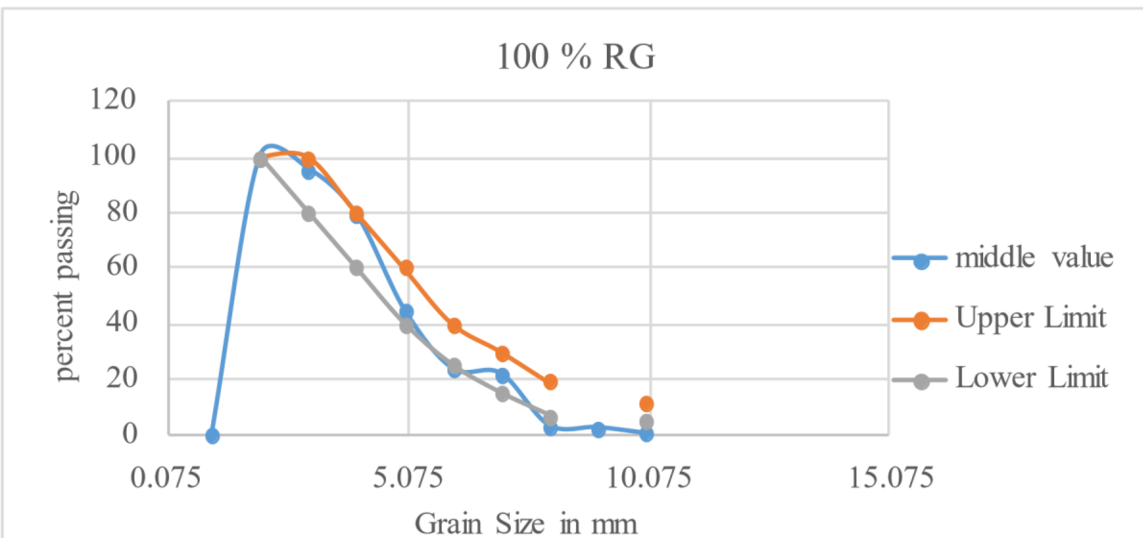

Figure 4.1: Grain size analysis for 100%RG

The table 4.1and figure 4.1 indicated that the RG Material Collected from the stated site 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 limit and coarse more than the recommended ERA Specification Values.

TABLE 4. 2: PARTICLE SIZANALYSIS OF CSA ONLY

Figure 4. 2: Grain size Analysis for 100%CSA

The Table 4.2 and figure 4.2 result shows that gradation of CSA Collected from quarry site is parallel to upper and lower limits of the ERA Specification recommended Value for GB1, which means it would exist between the specification limit as we compare with the ERA specification for GB1, Granular unbound base course layer.

TABLE 4. 3: PARTICLE SIZE ANALYSIS OF 10%RG &90%CSA

Sieve size	Wt retained in each sieve(gm)	Percent retained	Cumulative percent retained	Percent passing		ERA specification	
					Cumulative % passing	Upper Limit	Lower Limit
37.5	0	0	0	100	100	100	100
26.5	557.7	5.577	5.57	94.42	94.43	100	80
19.5	1877.47	18.77	24.34	81.23	75.66	80	60
13.2/12.5	4022.2	40.22	64.56	59.78			
9.5	529.3	5.29	69.85	94.71	30.15	60	40
4.75	2114.5	21.14	90.99	78.86	9.01	40	25
2.36	174.1	1.74	92.73	98.26	7.27	30	15
0.500	650	6.5	99.23	93.5	0.777	19	7
0.075	74.73	0.74	99.97	99.26	0.77	12	5

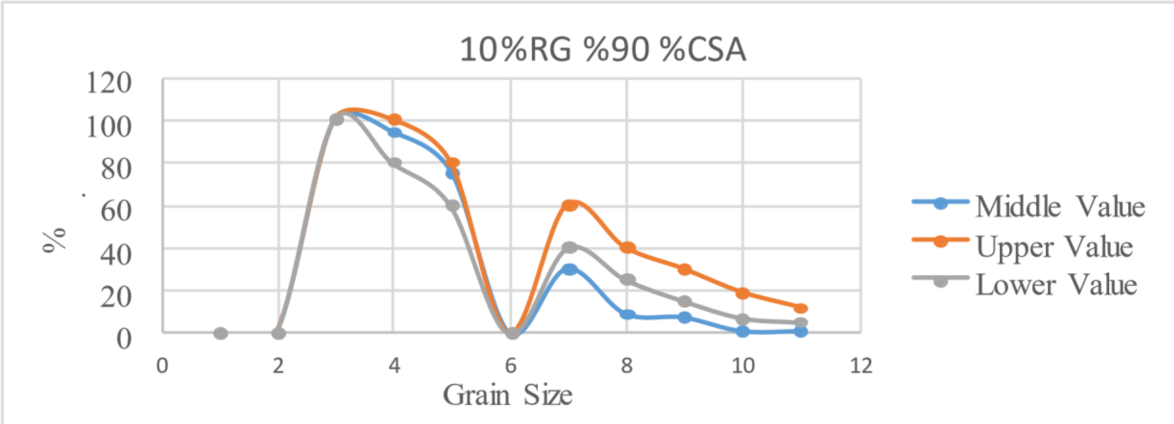

Figure 4. 3: Grain size Analysis For 10%RG &90%CSA

The Table 4.3and figure 4.3 result shows that gradation of 10% RG with 90%CSA is not parallel to upper and lower limits of the ERA Specification recommended Value for GB1, which means it would not exist between the specification limit as we compare with the ERA specification for GB1, Granular unbound base course layer.

Table 4. 4: particle size analysis of 20%RG &80%CSA

Sieve size	Wt retained in each sieve(gm)	Percent retained	Cumulative percent retained	Percent passing	Cumulative % passing	ERA Specification Upper Limit	Lower Limit
37.5	0	0	0	100	100	100	100
26.5	436.7	4.36	4.36	95.64	95.64	100	80
19.5	1363.45	13.63	17.99	86.37	82.01	80	60
13.2/12.5	1012.2	10.12	28.11	89.88			
9.5	819.3	8.29	36.4	91.71	63.6	60	40
4.75	3114.5	31.14	67.54	68.86	32.46	40	25
2.36	1174.1	11.74	79.28	88.26	20.72	30	15
0.500	1660	16.5	95.78	83.5	4.22	19	7
0.075	419.75	4.19	99.97	95.81	0.03	12	5

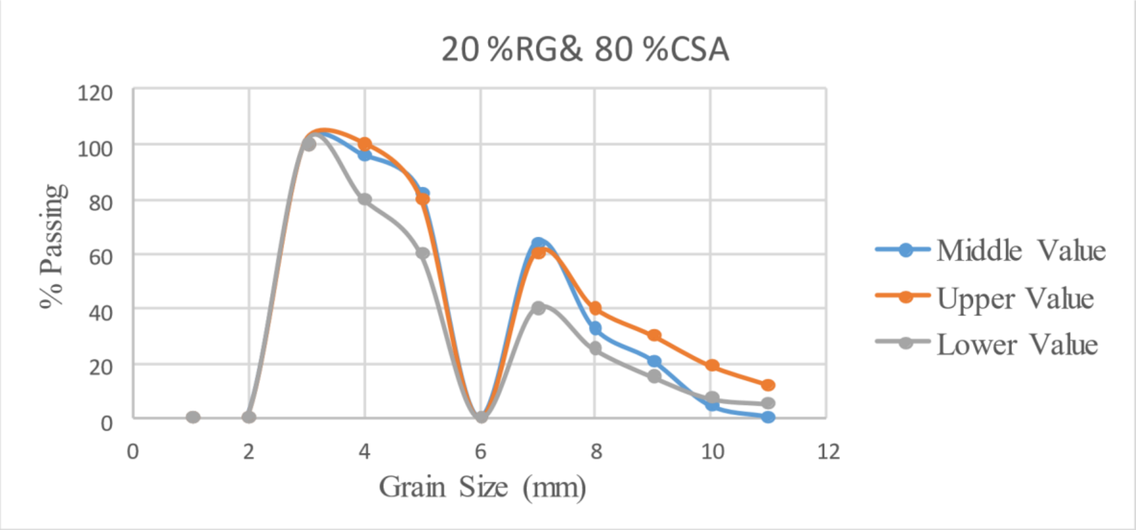

Figure.4.4 sieve analysis for 20%RG &80%CSA

The Table 4.4 and figure 4.4 result shows that gradation test result of 20% RG with 80%CSA is not parallel to upper and lower limits of the ERA Specification recommended Value for GB1, which means it would not exist between the specification limit as we compare with the ERA specification for GB1, Granular unbound base course layer.

TABLE 4. 5: PARTICLE SIZE ANALYSIS OF 30% RG &70% CSA

Sieve size(mm)	Wt retained in each sieve(gm)	Percent retained	Cumulative percent retained	Percent passing		ERA specification	
					Cumulative % passing	Upper Limit	Lower Limit
37.5	0	0	0	100	100	100	100
26.5	400.7	4.00	4	96	96	100	80
19.5	1653.45	16.53	20.53	83.47	79.47	80	60
9.5	1950	19.5	40.03	80.5	59.97	60	40
4.75	3000.5	30.05	70.08	69.95	29.92	40	25
2.36	1074.1	10.74	80.82	89.26	19.18	30	15
0.500	1000	1	81.82	99	18.18	19	7
0.075	708.3	7.08	88.9	92.92	11.1	12	5

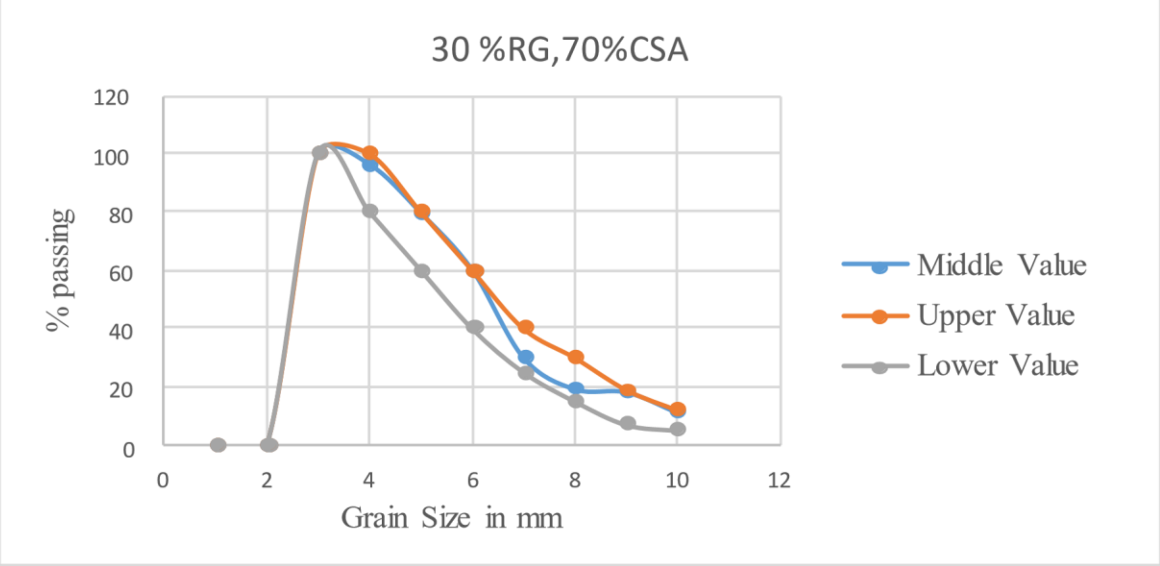

Figure 4. 5: Grain Size Analysis for 30 %RG,70%CSA

The Table 4.5 and figure 4.5 result shows that gradation test result of 30% RG with 70%CSA is agree with the ERA standard specification after trial and error, which means it would exist between the specification limit as we compare with the ERA specification for GB1, Granular unbound base course layer. in a such a way that the cumulative percent passing through 19.5,9.5 ,0.500 and 0.075 mm sieve touches the upper limit of the standard specification

Table 4. 6: particle size analysis of 40%RG &60%CSA

Sieve size (mm)	Wt retained in each sieve(gm)	Percent retained	Cumulative percent retained	Percent passing		ERA specification	
					Cumulative % passing	Upper Limit	Lower Limit
37.5	0	0	0	100	100	100	100
26.5	436.7	4.36	4.36	95.64	95.64	100	80
19.5	1253.45	13.53	17.89	86.47	82.11	80	60
9.5	829.3	8.29	36.3	91.71	63.7	60	40
4.75	3114.5	31.14	67.44	68.86	32.56	40	25
2.36	1174.1	11.74	79.18	88.26	20.82	30	15
0.500	2650	16.5	95.68	83.5	4.32	19	7
0.075	429.75	4.29	99.97	95.71	0.03	12	5

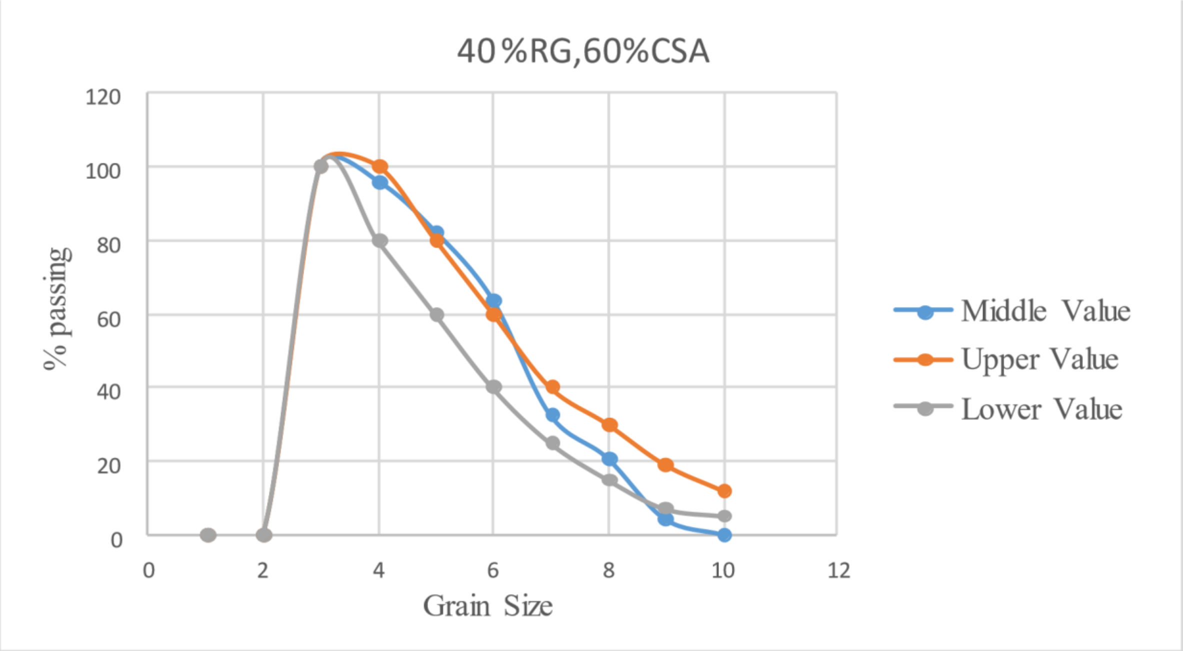

Figure 4. 6: Grain Size Analysis for 40 %RG,60%CSA

The Table 4.6 and figure 4.6 result shows that gradation test result of 40% RG with 60%CSA at this blending ratio of river gravel with crushed stone aggregate fail to agree with the ERA standard specification, which means it would not exist between the specification limit as we compare with the ERA specification for GB1, Granular unbound base course layer.

4.2.2 COMPACTION TEST RESULT OF ALL TEST SAMPLES

Modified proctor compaction test (AASTHO T 180) was conducted on the six test samples, for RG crushed aggregate and blended materials the maximum dry density (MDD) and optimum moisture content (OMC) were illustrated in Table 4.7 below. From the laboratory investigation for both RG and CSA, the table 4.7 below clearly indicated that river gravel has higher OMC Than crushed stone aggregate as the percentage of river gravel increases from 10 % to 40% correspondingly MDD increases from 2.09 to 2.26 and full fill the ERA requirements of compaction for base course material.

Table 4. 7: Moisture density relationship of RCA and CSA

	OMC	MDD	Specification
100%crushed stone	7.2	2.23	MDD >1.7
100% RG	9.62	2.21	
10%RG &90%CSA	6.12	2.09	
20%RG &80%CSA	7.62	2.16	
30%RG &70%CSA	5.89	2.17	
40%RG &60%CSA	6.54	2.26	

the figure 4.7 to 4.12 below shows the relationship between compaction curve for all test samples

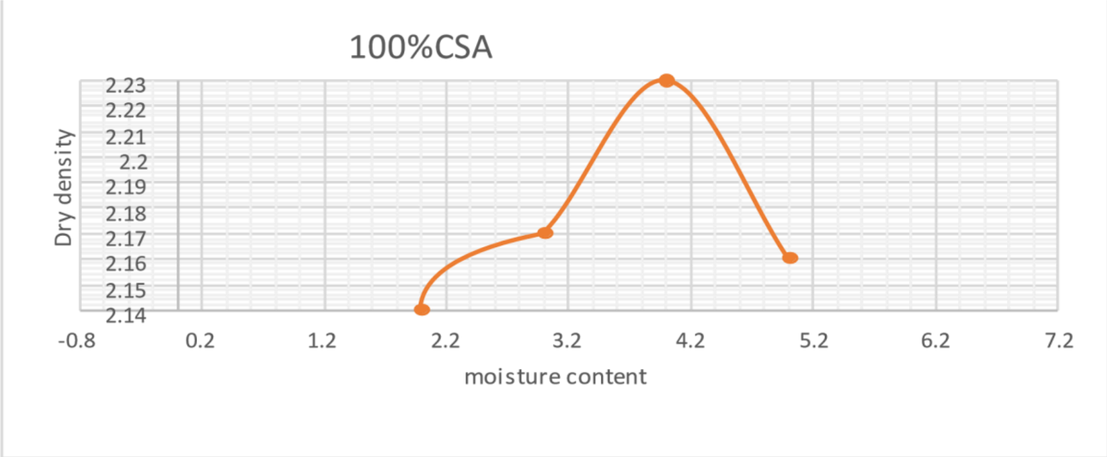

Figure 4.7: Compaction curve for CSA

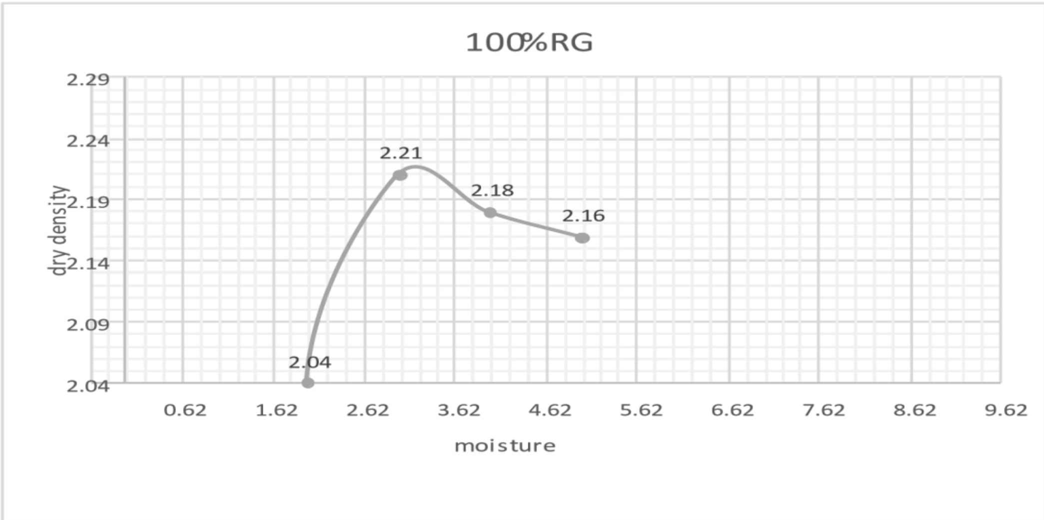

Figure 4.8: Compaction curve for RG

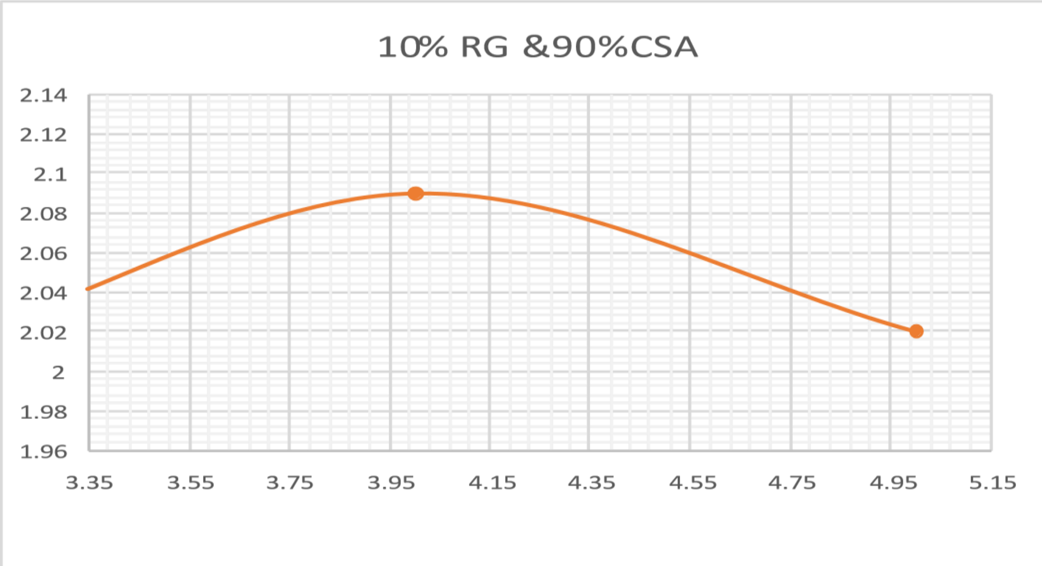

Figure 4.9: Compaction curve for 10%RG &90%CSA

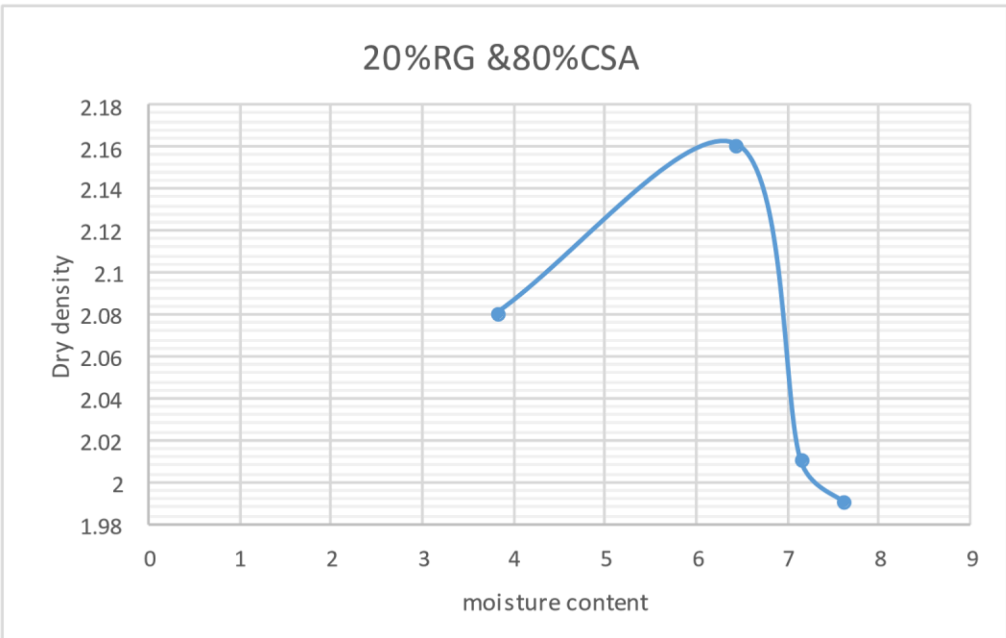

FIGURE 4.10: COMPACTION CURVE FOR 20%RG&80%CSA

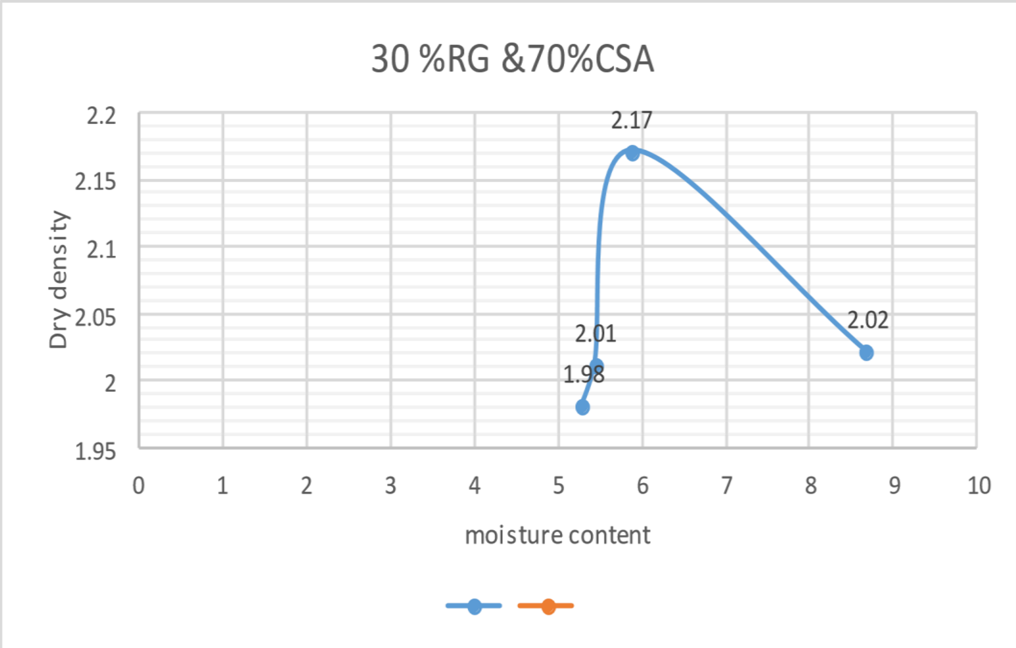

Figure 4.11: compaction curve for 30 %rg&70%CSA

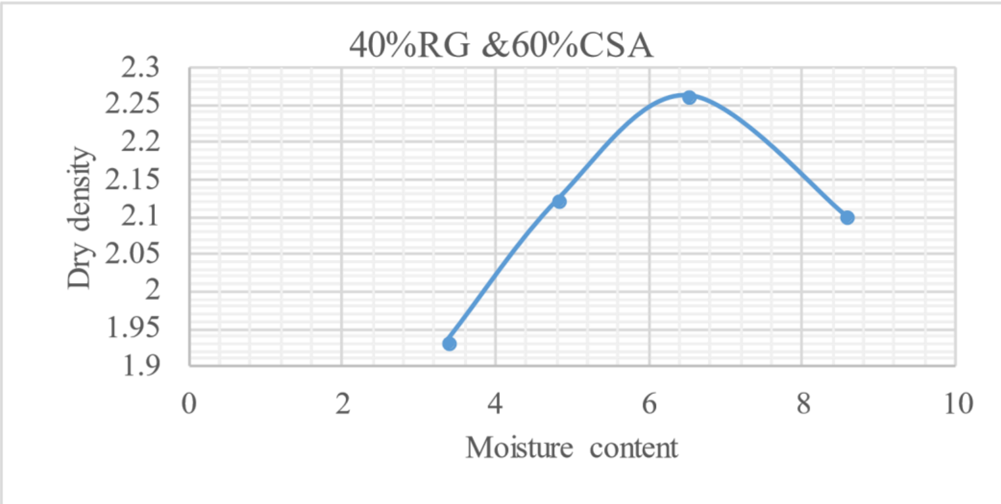

figure 4.12: Compaction curve for 40%RG &60CSA

4.2.3 Atterberg's limits of RG and crushed aggregate

This test was conducted to determine the liquid limit, plastic limit, and plasticity index of granular materials. In this case, both RG and crushed aggregates in table 4.8 indicated in the limit of ERA specification. The plastic index of River gravel is approximately twice that of the plastic index for crushed stone this was due to the presence of some dust material found on the river gravel.

Table 4. 8: Atterberg's limit test result of RG and crushed aggregate

Sample type	Liquid limit	Plastic limit	Plasticity index	Specification
100% Crushed	24.6	22.5	2.1	PI <6
100% RG	30.12	26.12	4	

4 2.4 Flakiness index result of RG and crushed aggregate

This test was made for determining particle shape of aggregate by using the percentages of flaky and elongated particles contained in it. In this test, both crushed aggregate and RCA materials satisfied the lower limit of the ERA specification for base course material which was less than 30%. According to the result flakiness index, ranges from maximum value of 18.99% of crushed aggregate and to minimum value of 17.90% of RG materials, which was much less than the maximum limit of ERA Specification

Table 4. 9: Flakiness index test result for net crushed aggregate and RG

Sample type	**Flakiness index**	ERA specification
100% RG	17.90 %	Maximum limit of Flakiness index in Percentage, not exceed 30%
100% crushed	18.99%	

4.2.5 Aggregate impact value test result for all test samples

This test was conducted to determine the resistance of aggregate materials under sadden or impact load. The test can have carried on cylindrical stone specimen known as a page Impact test and samples for this test were taken materials passed 12.5 mm IS sieve and retained on 10 mm. Crushed samples were removed from the test mold and sieved on 2.36 mm sieve and the result was weighted. the aggregate impact value result in each cases were satisfied the specification which were all less than 30.

Table 4. 10: Aggregate impact value test result for all test samples

Sample type	AIV	Specification

100% RG	13.38	
100% CRUSHED	10.26	AIV<30
10%RG &90%CSA	6.57	
20%RG &80%CSA	8.42	
30%RG &70%CSA	9.44	
40%RG &60%CSA	8.76	

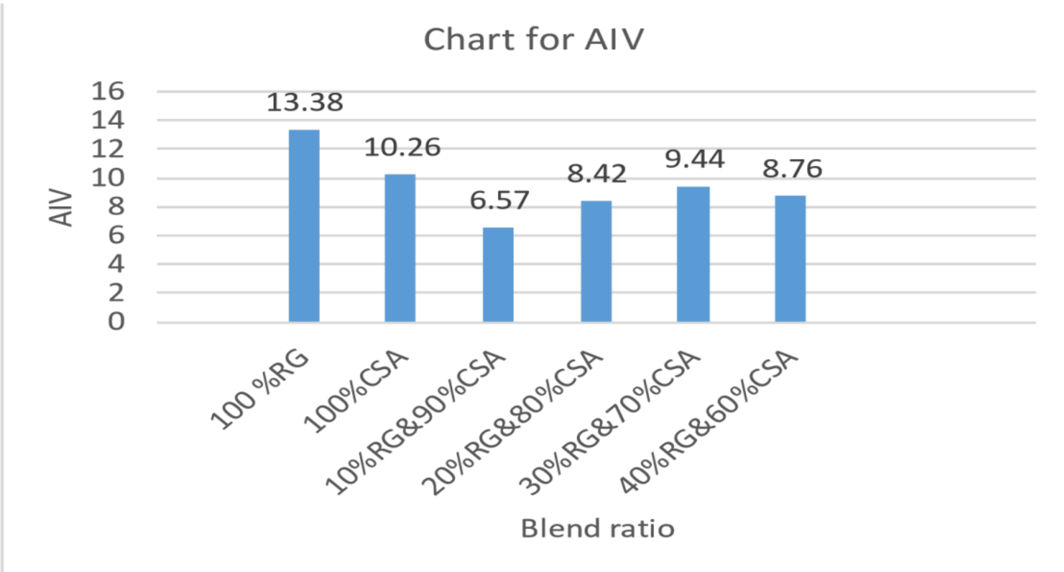

figure 4.13: Impact value chart for all samples

The above chart 4.13 Presented the aggregate impact value for all test samples river gravel, crushed stone aggregate and blended samples, it was clearly indicated that at the blending ratio of 10%RGand 90%CSA Shows the highest resistance under sadden load impact and neat river gravel has lower impact value

4.2.6 Aggregate crushing value test all test samples

This test was used to determine the strength and toughness of coarse aggregates under a gradually applied load. ACV was determined by measuring the material passing a 2.36 mm, BS Sieve after crushing under a load of 400 KN applied to test specimens containing fractions of aggregates passing 12.5 mm and retained on 10mm BS sieves. The test samples were pulverized in a compression testing machine after 24 hours of drying in an oven and letting them cool. Test result shows that all test aggregates were aggregate crush value of less than 29%.

Table 4. 11: Aggregate crushing value test result for all samples

Sample type	**Aggregate crushing**	**Specification**
100% RG	17.1	ACV <29%
100% Crushed	12.52	
10%RG &90%CSA	8.49	
20%RG &80%CSA	14.67	
30%RG &70%CSA	16.06	
40%RG &60%CSA	16.180	

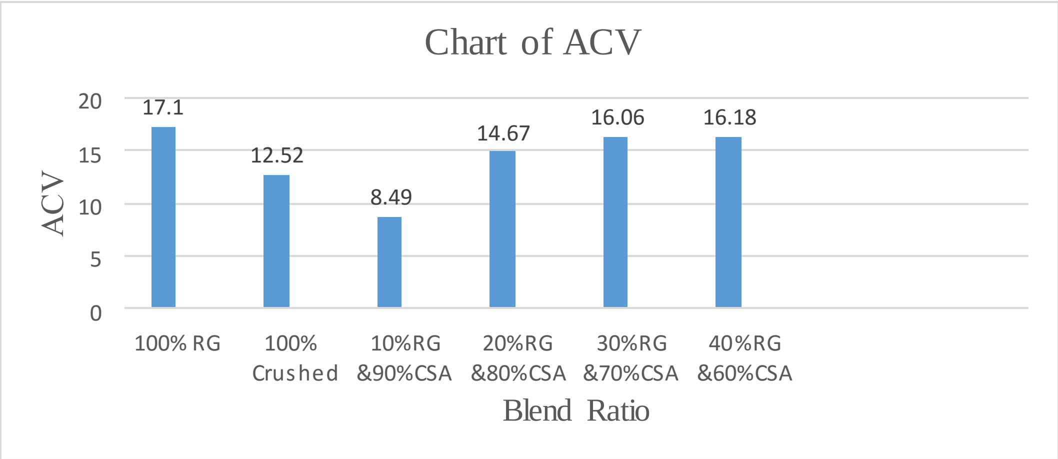

Figure 4.14: crushing value chart for all samples

Both test parameters aggregate impact value and crushing value in the above figure 4.13 and figure 4.14 shows the values were highest at the same blending ratio of 10%RG and 90%CSA and aggregate crushing value was lowest at the blending ratio of 40%RG and 60%CSA.

4.2.7 Abrasion resistance test results for all samples

This method was used to measure the hardness and resistance of the base course materials. During compaction, the abrasion resistance test applied only to coarse aggregates. The aggregates varied in their resistance to fracturing under impact (toughness) and breaking down into smaller pieces from abrasive action (hardness). The acceptable limits were set by the Los Angeles Abrasion Test AASHTO T-96. The limits vary from 30 to 51 percent, depending on the classification of the aggregate.

Table 4. 12: Abrasion test result for all samples

Sample type	**Aggregate abrasion**	**ERA specification**
100% RG	4.81	LAA value <51%
100 % crushed	4.25	
10%RG&90%CSA	8.01	
20%RG&80%CSA	7.91	
30%RG&70%CSA	3.48	
40%RG&60%CSA	6.28	

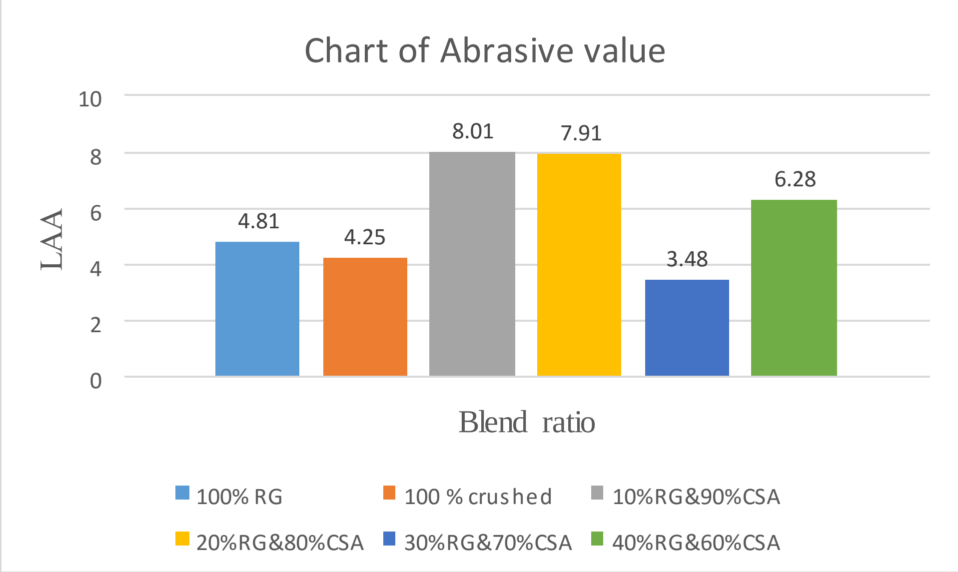

figure 4.15: los Angeles abrasive value chart for all samples

The figure 4.15 shows abrasive value for all test samples it was clearly indicated that the abrasive value for test sample was high at the blending ratio of 30%RG and 70%CSA and has lower value at the blending ratio of 10%RG and 90%CSA.

4.2.8 Specific Gravity and Absorption result of RG and crushed aggregate

The Bulk specific gravity was the characteristic generally used for calculation of the volume occupied by the aggregate in various mixtures containing aggregate including different mortars that were proportioned or analyzed on an absolute volume basis. The bulk specific gravity determined on the saturated-surface-dry basis was used if the aggregates were wet, that was if its absorption has been satisfied.CSA materials have the higher water absorption than RG because of more amount of fine material in the crushed stone aggregate and less amount of fine material in the natural river gravel.

TABLE 4. 13: SPECIFIC GRAVITY TEST RESULT OF RG AND CRUSHED AGGREGATE

Sample type	Bulk specific Gravity	SSD	Water Absorption	Specification
100% RG	3.80	3.80	0.75	Gravity >2.6
100 crushed	3.11	3.13	1.15	
10%RG	3.44	3.47	1.10	

20%RG	3.03	3.06	1.00	
30%RG	3.00	3.00	0.65	
40%RG	3.02	3.09	3.00	

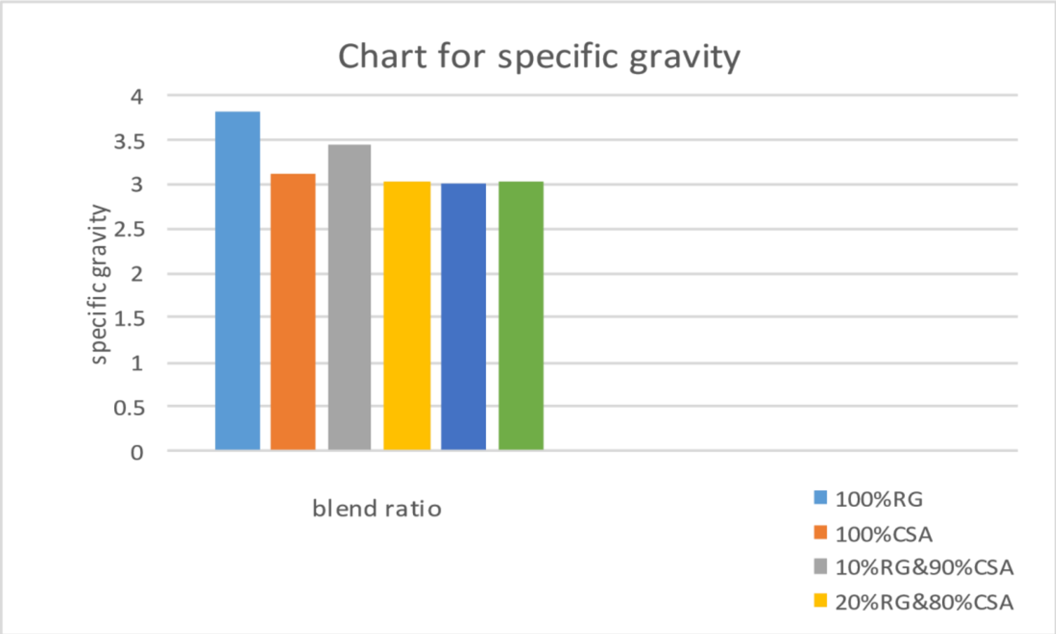

figure 4.16: chart for specific gravity of all samples

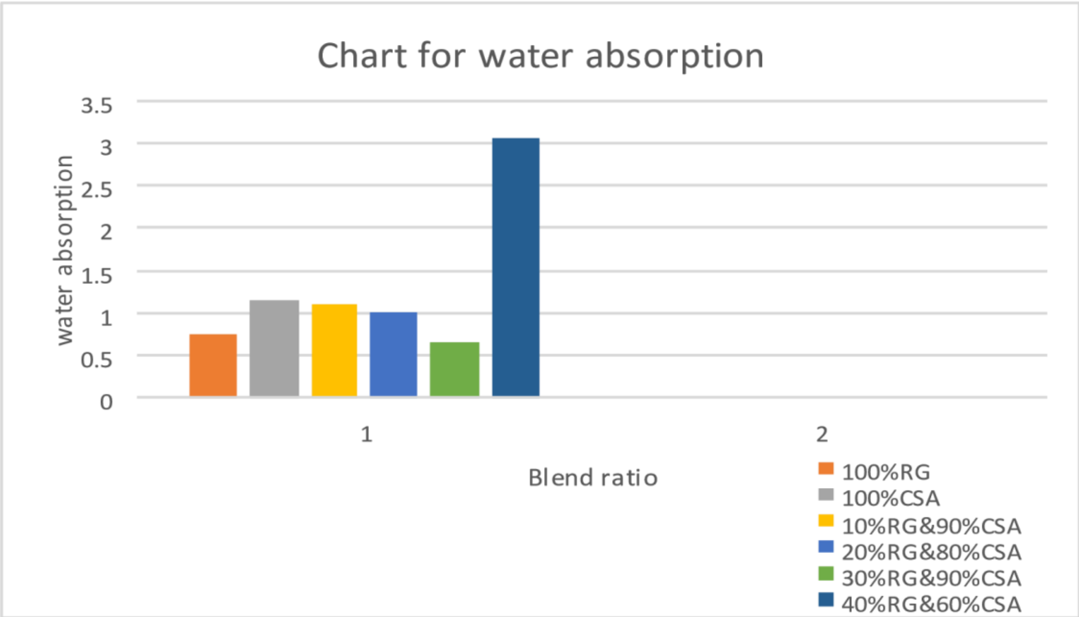

figure 4.17: chart for water absorption of all samples

4.3.9 Effect on California bearing ratio

The California Bearing Ratio (CBR) test was shown to estimate the strength of separately of the six material samples. The CBR experiments were performed on samples compacted to 10, 30 and 65 blows per lift using Modified comp active effort.

The CBR values were determined by comparing the loads sustained by the test specimens at piston penetrations of 2.54 mm and 5.08 mm with the loads sustained by the standard crushed gravel at the same penetration depths.

According to ERA manual, for the base course material, the minimum soaked California Bearing Ratio (CBR) shall be at least 80% when determined following the requirements of AASHTO T- 180. The Californian Bearing Ratio (CBR) was determined at a density of 98% of the maximum dry density when determined in accordance with the requirements of AASHTO T-180 method

The experiment result indicated that the amount of RG increases CBR value Correspondingly increases and The average CBR values for the RG and Crushed stone aggregate were 69% and 104% respectively.

All the tested samples were on the limit of ERA specification which was greater than 80%. Except for the CBR value of river gravel.

While the swell test result showed that RG and its blended samples are within the limit of the ERA specification indicating a swell value of less than 2%

TABLE 4. 14: ALL CBR TEST RESULTS OF SIX SAMPLES

Sample Type	Compaction test			CBR test results				CBR At 98% MDD	ERA specification ion
	OMC (%)	MDD (g/cc)	98% Of MDD	No of Blow	DD (g/cc)	Swell in %	CBR		
100%RG	9.62	2.21	2.16	65	2.21	1.50	68	69%	CBR<80
				30	2.07	1.48	65		
				10	1.85	1.45	53.8		
100%CSA	6.52	2.23	2.19	65	2.32	1.20	66.7	104%	CBR>80 %
				30	2.21	1.16	93.4		
				10	2.19	1.10	98		
10%RG	6.12	2.09	2.04	65	2.73	1.6	93	93%	CBR>80 %
				30	2.24	1.42	52.8		
				10	2.21	1.30	50.3		
20%RG	6.45	2.16	2.11	65	2.23	1.30	98.7	100%	CBR>80 %
				30	2.19	1.25	60.8		
				10	2.11	1.10	56.3		
30%RG	5.89	2.17	2.12	65	2.17	1.10	100.45	106%	
				30	2.10	1.00	105.9		
				10	2.06	1.60	110.5		
40%RG	6.54	2.26	2.21	65	2.23	0.9	115.70	111%	CBR>80 %
				30	2.2	0.75	110.9		
				10	2.15	0.500	106.65		

TABLE 4. 15: SUMMARY OF ALL PHYSICAL AND MECHANICAL PROPERTY TEST RESULTS FOR CRUSHED AGGREGATE, RG AND BLENDED SAMPLE

Parameters	RG 100/0	RG 0/100	RG 10/90	RG 20/80	RG 30/70	RG 40/60	ERA Specification
Specific Gravity	3.80	3.13	3.47	3.06	3.00	3.09	SSD >2.6
Absorption in%	0.75	1.15	1.10	1.80	0.65	3.00	Not more than 2%
OMC	9.62	7.2	6.12	7.62	5.89	6.54	MDD >1.7
Dry density	2.21	2.23	2.09	2.16	2.17	2.26	
LL	30.12	24.6					
PL	26.12	22.5					
PI	4	2.1					PI<6%
Los Angeles	4.81	4.25	8.01	7.91	3.48	6.28	LAA≤51
Crush value	17.1	12.52	8.49	14.67	16.06	16.18	ACV≤29
Impact value	13.38	10.26	6.57	8.42	9.44	8.76	AIV≤30
Flakiness Index	17.90	18.99					FIV≤30%
CBR	69	104	93	100	106	111	CBR>80%
Swell in %							

The above table shows the laboratory test results for the RG material on the different properties which are within the limit of the standard specifications for base course material except for California bearing ratio (CBR) value of material were out of the specification. but the amount of RG content increases in the mixture from 10% to 40% MDD Increases and CBR value also increases, the specific gravity decreases from 3.47 to 3.00 and water absorption increases from 1.10 to 1.80 decreases to 0.65 and increases to 3.00. This specifies the crushed stone aggregate material absorbed more water than River gravel. Likewise, the Plasticity index of both material samples was satisfied with the specified limit for base course material which was less than 6%. Flakiness index in the above table shows for all six samples, less than 30

CHAPTER FIVE
CONCLUSION AND RECCOMMENDATION

5.1 Conclusion

In this study, the river aggregate(gravel) from the river sources of kaffa zone and crushed aggregate samples from the same location to river gravel at a distance of 60 km were performed in the laboratory in different blending proportions to evaluate the partial replacement of crushed base course material using river gravel. Based on these samples, the crushed aggregate without any percentage replacement of river Aggregates(gravel) was measured as the control mixture, whereas the proportion increments of blending RG with crushed aggregate were 0%, 10%, 20%, 30%, and 40% by weight. All experiments for physical and mechanical properties were done. Hereunder is the conclusions based on the laboratory test results:

- The gradation limit of the RG and mixed samples, except 30% replacement, were beyond on the specified limit of base course material as per Standard, Specification, due to the particle sizes of RG materials which were Insufficient amount of fines and coarser than crushed aggregate used for a base course.
- River gravel has nearly the same toughness as the crushed stone aggregates, with maximum percent loss in Los Angeles test which was less than 51% as per ERA Standard Specification.
- The 100% RG may not applied for a base course in heavily trafficked pavement roads because, less resistance to crushing load, lower MDD, and also to the limit of fine content of the gradation. It did not fit the upper and lower limit of ERA specification
- Besides, water absorption of the river aggregate(gravel) indicated lower values than the blended samples, to much lower the water absorption value of the blended sample it is recommended to increase the content of river gravel in the mixture
- The maximum dry density (MDD) of the unbound base material increases with increasing the river gravel aggregate content.
- The CBR value of crushed stone aggregate increases as the percentage of River Gravel Increases from 10% to 40%
- The optimum moisture content of the unbound aggregate varies from 5.89 % to 7.62 with increasing the Amount of river gravel in the mixture.

- Direct application of river gravel as unbound base course material for road construction may result in the reduction of specific gravity, MDD, and CBR, but the values were within the range of the Standard Specifications.
- CBR test results gained from the river gravel showed the lowest value which means, the values of CBR do not approve with the ERA specification for roads and bridges for using the later as a base course layer

Therefore, the use of River gravel (RG) at 30% replacement by weight of crushed stone aggregates for base course construction is possible. Besides, it can help to decrease the environment effect caused by mass extraction of river gravel improve and most of all conserve the crushed stone or processed aggregates which have an economic benefit.

5.2. RECOMMENDATION

- It is recommended to use of River Gravel Aggregates (RG) at 30% replacement by weight of the virgin or natural (crushed) aggregates with the correct gradation, including the addition of fine materials as a binder to meet the gradation limit for base course material.
- The laboratory test results can be served as a basis to justify the optimum percentage component partially replaced by RG for use in base course construction. While such improvement, the item of work is forwarded to the concerned agency to incorporate as an alternative material in their Standard Specifications.
- In some related research undertakings, further studies on the RG are also suggested to conduct an in-depth investigation on its properties (i.e., Chemical, physical & mechanical) which may affect the performance of the pavement layers.
- Finally, it is recommended to consider or investigate the percentage of River gravel which has not been considered in this study for a better finding of the study

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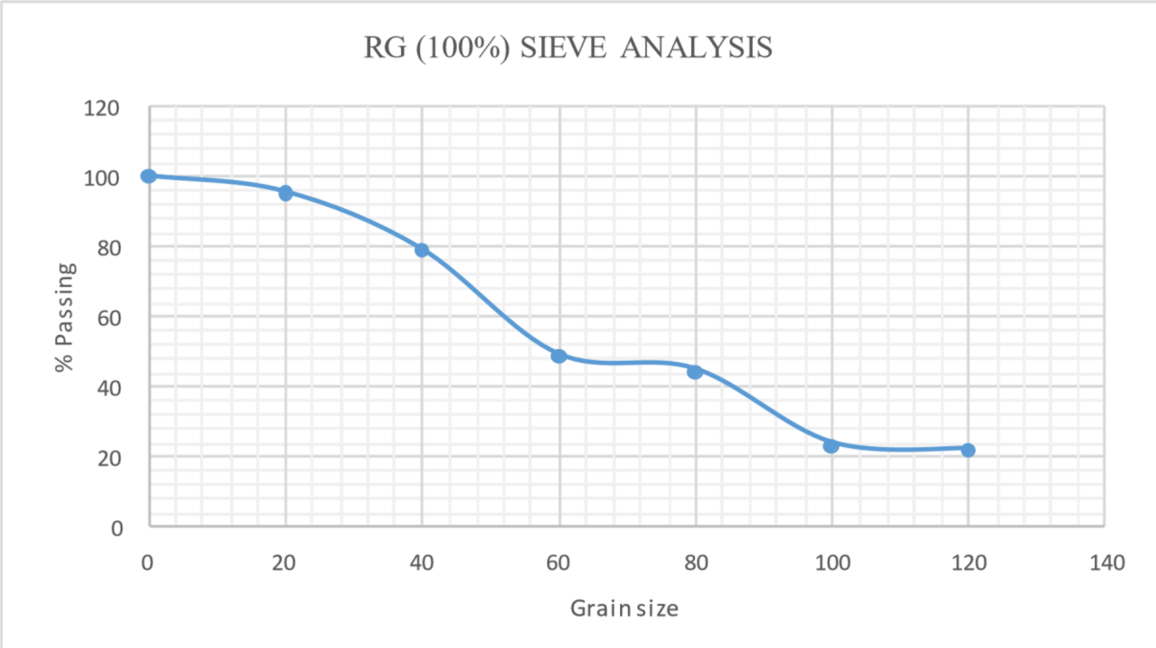
APENDIX 1

TEST RESULTS OF RG

1) Gradation test result for RG material

Sieve size	Wt retained in each sieve(gm)	Percent retained	Cumulative percent retained	Percen t passing g	Cumulative % e passing	ERA specification	
						Upper r Limit	Lower Limit
37.5	0	0	0	100	100	100	100
26.5	457.7	4.5	4.5	95.5	95.5	100	80
19.5	1640.1	16.40	20.9	83.6	79.1	80	60
13.2/12.5	3022.2	30.22	51.12	69.78	48.88		
9.5	429.3	4.29	55.41	95.71	44.59	60	40
4.75	2114.5	21.14	76.55	78.86	23.45	40	25
2.36	174.1	1.74	78.29	98.26	21.71	30	15
1.7	600	6	84.29	94	15.71		
1.18	620	6.2	90.49	93.8	9.51		
0.500	650	6.5	96.99	93.5	3.01	19	7
0.425	68.9	0.68	97.67	99.32	2.33		
0.030	75.53	0.75	98.42	99.25	1.58		
0.150	72.93	0.72	99.14	99.28	0.86		
0.075	74.73	0.74	99.8	99.26	0.2	12	5
Pan	0	0	99.8				



2)Plastic limit and liquid limit test result for RG

Description	Plastic limit	liquid limit
Can code	Plrg	RG-3
Mass of empty can	19.72	19.09
Mass of can +wet soil	29.34	50.53
Mass of can+dry soil	26.77	43.63
Mass of dry soil	7.05	24.54
Mass of water	2.57	6.9
Water content	26.54	30.12

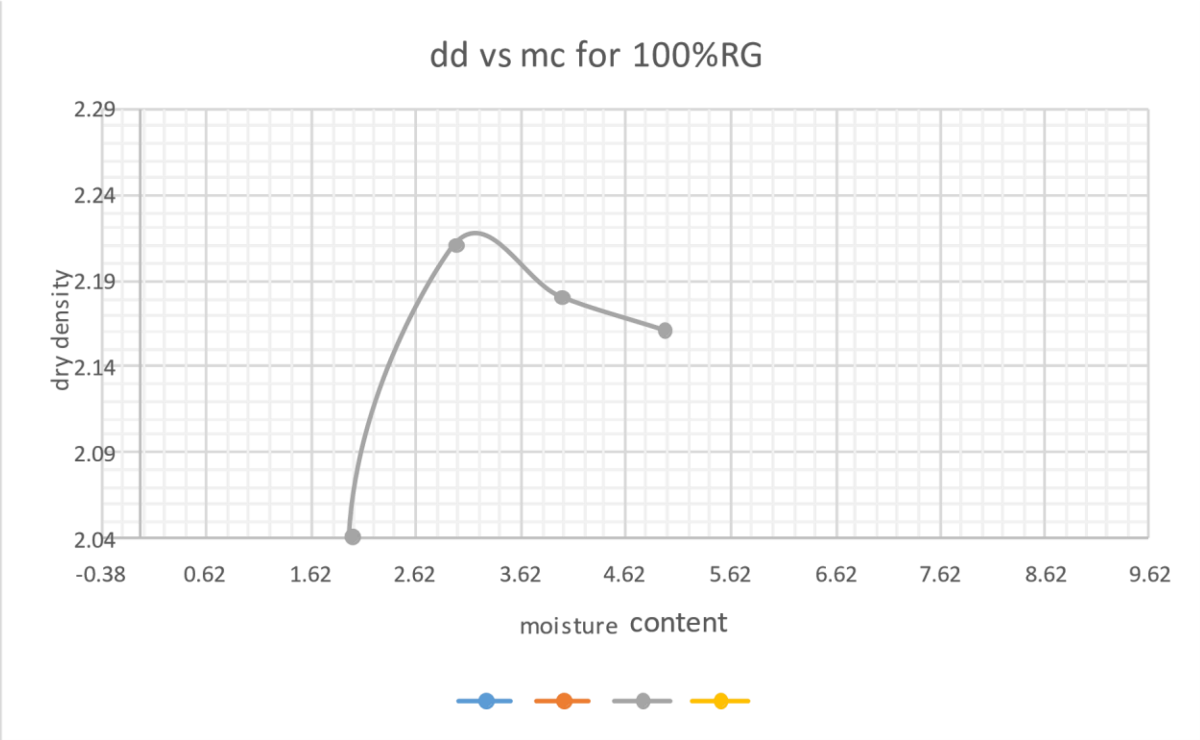
3)FLAKINESS INDEX TEST RESULT

FLAKINESS INDEX		**100%RG**		
Sieve size	Wt retained on each sieve	Percent retained	Gauge range	Wt of sample passes the gauge
50mm	0	0	0	0
37.5	0	0	0	0
28	306.5			32.19
20	1436.5			437.5
14	1043.1			132.6
10	733.6			36
6.3	74.5			4.6
Total	3593.6			643.4
FI	**17.90%**			

4) Test result of compaction density for RG material

Test no	1	2	3	4
Water added	200 ml	380ml	470ml	650ml
Mass of sample taken for test	4500gm	4500gm	4500gm	
Mass of wet soil+mass of mould	10817.6	11349.6	11110.5	11077.1
Mass of mould	6176.2	6176.2	6176.2	6176.2
Mass of wet soil(gm)	4641.4	5173.4	4934.3	4900.9
Volume of mould	2124	2124	2124	2124
Bulk density	2.18	2.43	2.32	2.30
MOISTURE CONTENT DETERMINATION				
Trial no	1	2	3	4
Container code	A2	A4	G31	3L
Mass of container	7.6	17.2	16.7	19.3
Mass of wet soil+container	95.6	99.5	105.3	146.5
mass of dry soil +container	90.3	96.8	100.2	96.6
Mass of moisture	5.3	2.7	5.1	49.9

Mass of dry soil	82.7	69.6	83.5	77.3
Moisture content	6.4	9.62	6.10	6.4
Dry density(E/(100+l)*100	2.05	2.21	2.18	2.16



5) CBR test result for RG material

Number of blows	65 blow	30 blow	10 blow
Mould ID	N13	N5	M8
Mass of mould	6938.1	6940.1	6997.6
Mass of mould+wet soil	11796.1	11522.6	11116.5
Mass of wet soil(gm)	4858	4582.5	4118.9
Mould volume	2124	2124	2124
Wet density	**2.29**	**2.16**	**1.94**
Dry density	**2.21**	**2.07**	**1.85**

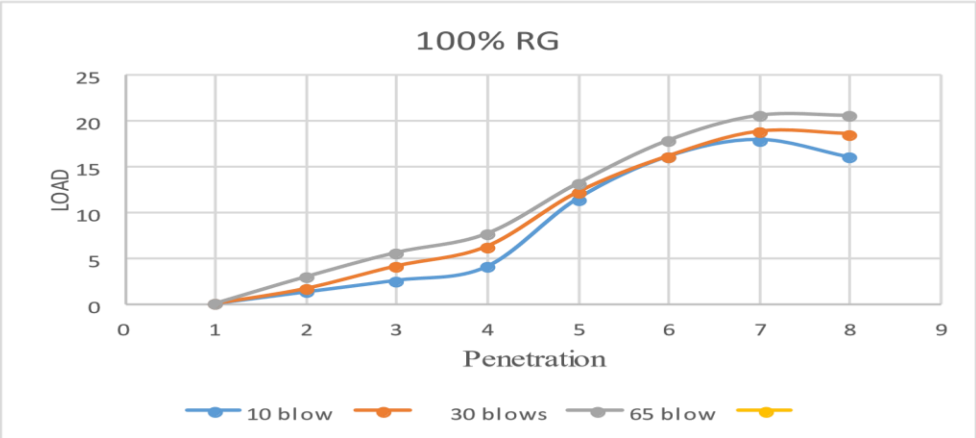
MOISTURE CONTENT DETERMINATION						
Number of blows	65		30		10	
	Before soak	After soaked	Before soak	After soaked	Before soak	After soaked
Container code	65		FT		A4	
Mass of container	37.42		17.62		16.99	
Mass of wet soil +container(gm)	147.97		107.06		75.16	
Mass of dry soil+container(gm)	144.35		103.37		72.36	
Mass of water(gm)	3.62		3.69		2.8	
Mass of dry soil(gm)	106.93		85.75		55.37	
Moisture content	3.38		4.30		5.05	
Average moisture content						

Penetration Data After 96-hours

	10 blows		30 blows		65 blow	
Penetration	load	CBR value	Load	CBR value	load	CBR value
0.641	1.258		1.627		2.898	
1.271	2.518		4.079		5.543	

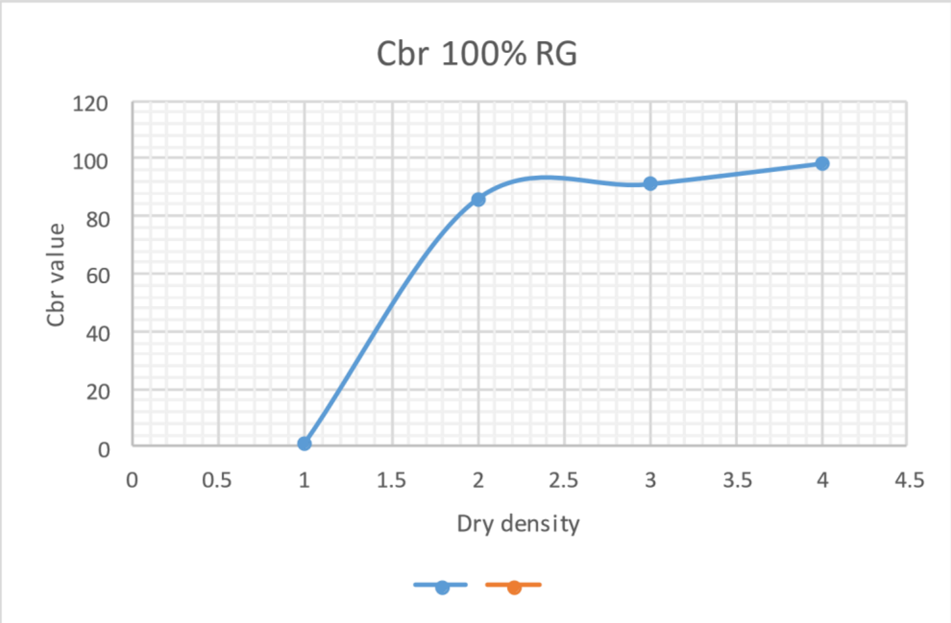
1.91	3.985		6.196		7.586	
2.543	11.344	**85.16**	12.072	**90.63**	13.025	**97.78**
3.813	15.957		16.025		17.719	
5.081	17.813	**89.065**	18.719	**93.59**	20.448	**102.24**
7.62	15.917		18.478		20.456	

Standard Load at 2.54 =13.32 KN and Standard Load at 5.08 =20 K



modified MDD	2.21		
98%MMDD	2.16		
No of blow	10	30	65
CBR Values(%)	**85.16**	**90.63**	**97.78**
Dry density(g/cc)	1.85	2.07	2.2
CBR @98%MMDD	90.63		
Swell in %	1.45	1.48	1.50

6) Test result of CBR and swell for RG material

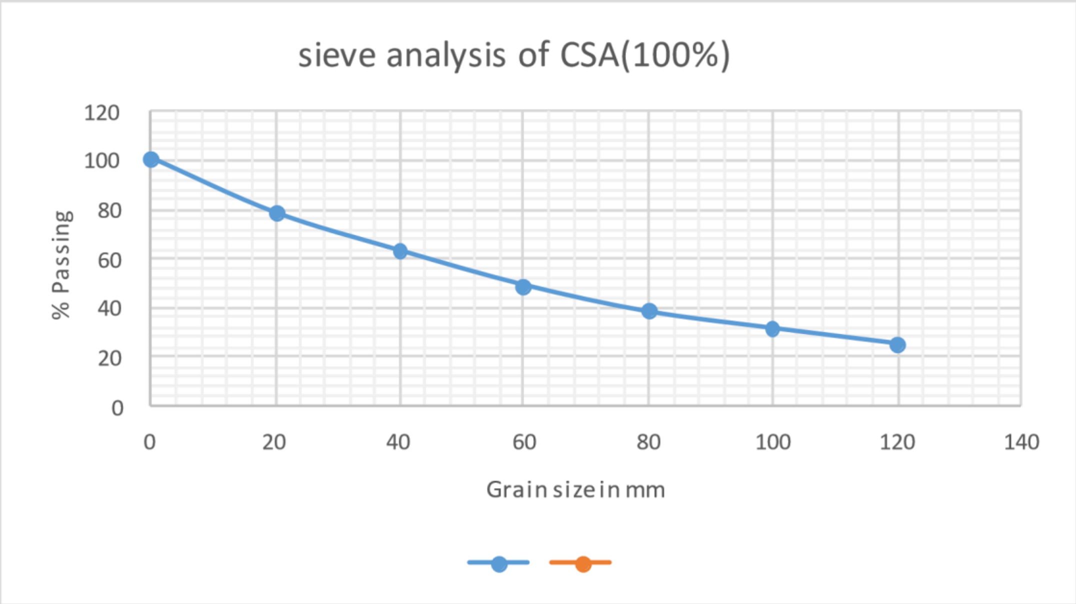


APPENDIX 2

TEST RESULTS OF CSA

1) Gradation test result for CSA material

Sieve size	Wt retained in each sieve(gm)	Percent retained	Cumulative percent retained	Percent passing	Cumulative percent passing	ERA specification	
						Upper Limit	Lower Limit
37.5	0	0	0	100	100	100	100
26.5	2210.1	22.10	22.10	77.9	77.9	100	80
19.5	1529.5	15.29	37.39	84.71	62.61	80	60
13.2/12.5	1398.1	13.98	51.37	86.02	48.63		
9.5	1077.1	10.77	62.14	89.23	37.86	60	40
4.75	669	6.69	68.83	93.31	31.17	40	25
2.36	619	6.19	75.02	93.81	24.98	30	15
1.7	349.5	3.49	78.51	96.51	21.49		
1.18	322.9	3.22	81.73	96.78	18.27		
0.500	320.5	3.20	84.93	96.8	15.07	19	7
0.425	312.3	3.12	88.05	96.88	11.95		
0.030	306.9	3.06	91.11	96.94	8.89		
0.150	299.4	2.99	94.1	97.01	5.9		
0.075	293.5	2.93	97.03	97.07	2.97	12	5
Pan	292.2						



2) Plastic limit and liquid limit test result for CSA

Description	Plastic limit			Liquid limit		
Variable	1	2	3	1	2	3
Can code	Tp1	Tp2	Tp3	Tll	L2	Q
Mass of empty can(gm)	6.44	15.99	16.94	17.05	14.6	20.65
Mass of can +wet soil	19.84	26.12	31.28	34.15	35.6	40.75
Mass of can+dry soil	16.72	24.34	29.22	30.54	32.65	36.62
Mass of dry soil	9.28	8.35	12.28	13.49	18.05	15.97
Mass of water	3.12	1.78	2.06	3.61	2.95	4.13
Water content(%)	15.38	21.31	16.77	26.76	16.34	25.86
Avg,pl and Ll	17.82			22.98		

3)FLAKINESS INDEX TEST RESULT FOR CSA

Sieve size	Wt retained on each sieve	Percent retained	Gauge range	Wt of sample the passes gauge
50mm	0	0	0	0
37.5	0	0	0	0
28	612.4			19.3

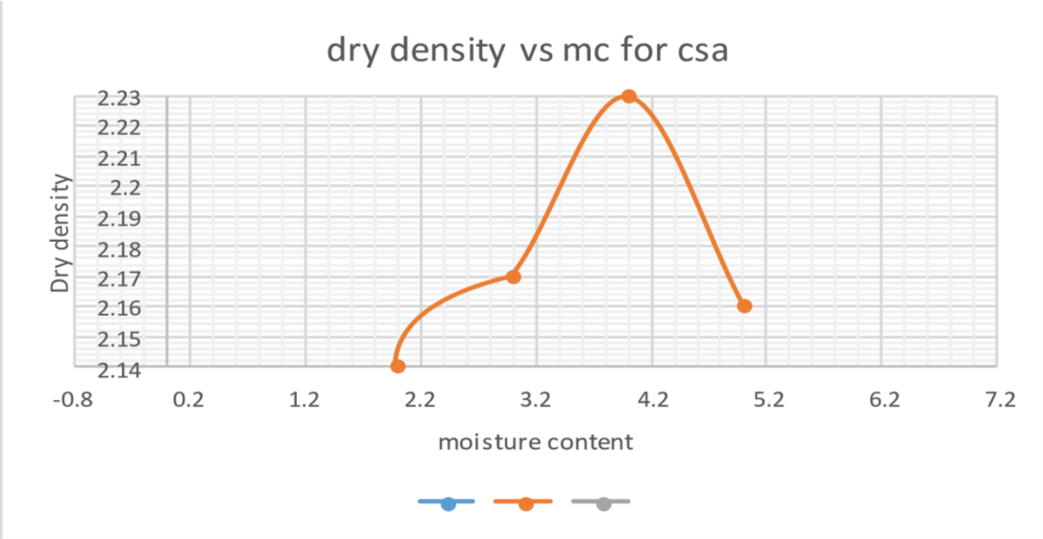
20	575.6			114.7
14	619.7			233.7
10	335.1			40.9
6.3	58.1			3
Total	2201.1			411.6
FI		18.99 %		

4) Test result of compaction density for CSA material

Test no	1	2	3	4
Water added	200ml	380ml	470ml	650ml
Mass of sample taken for test	4500gm	4500gm	4500gm	
Mass of wet soil+mass of mould	10744.0	10809.6	1094205	10786.2
Mass of mould	6176.2	6176.2	6176.2	6176.2
Mass of wet soil(gm)	4567.8	4633.4	4766.2	4610
Volume of mould	2124	2124	2124	2124
Bulk density	2.15	2.18	2.24	2.17

Moisture content determination

Trial no	1	2	3	4
Container code	G63	P2c	CS-3	CSA-4
Mass of container	25.36	17.5	32.6	34.84
Mass of wet soil+container	293.7	172	341.2	295.07
mass of dry soil +container	281.08	164.41	322.29	277.5
Mass of moisture	12.62	7.59	18.91	17.57
Mass of dry soil	255.72	146.91	289.69	242.66
Moisture content	4.93	5.16	6.52	7.2
Dry density(E/(100+I)*100	2.14	2.17	2.23	2.16



5) CBR test result for RG material

Number of blows	65 blows	30 blows	10 blows
Mould ID	s-1-0	SN	S-1-5
Mass of mould	6951.95	6925.1	6993.9
Mass of mould+wet soil	12219.55	12141.1	11836.8
Mass of wet soil(gm)	5267.6	5216	4842.9
Volume of mould	**2124**	**2124**	**2124**
Bulk density	**2.48**	**2.45**	**2.28**
Dry density	**2.32**	**2.21**	**2.19**

moisture content determination(csa)

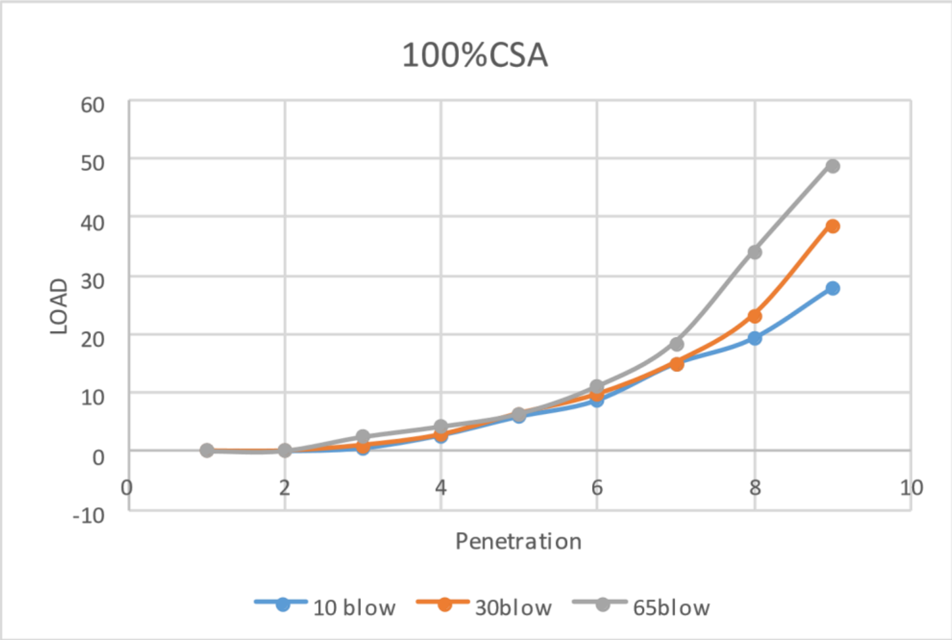
Number of blows	65		30		10	
	Before soak	After soaked	Before soak	After soaked	Before soak	After soaked
Container code	P_{10}		L_4		G_{14}	
Mass of container	17.50		7.62		19.45	
Mass of wet soil +container(gm)	143.55		115.9		125.12	

Mass of dry soil+container(gm)	135.9		105.5		121.3	
Mass of water(gm)	7.65		10.4		3.82	
Mass of dry soil(gm)	118.4		97.88		101.85	
Moisture content	6.46		10.62		3.75	

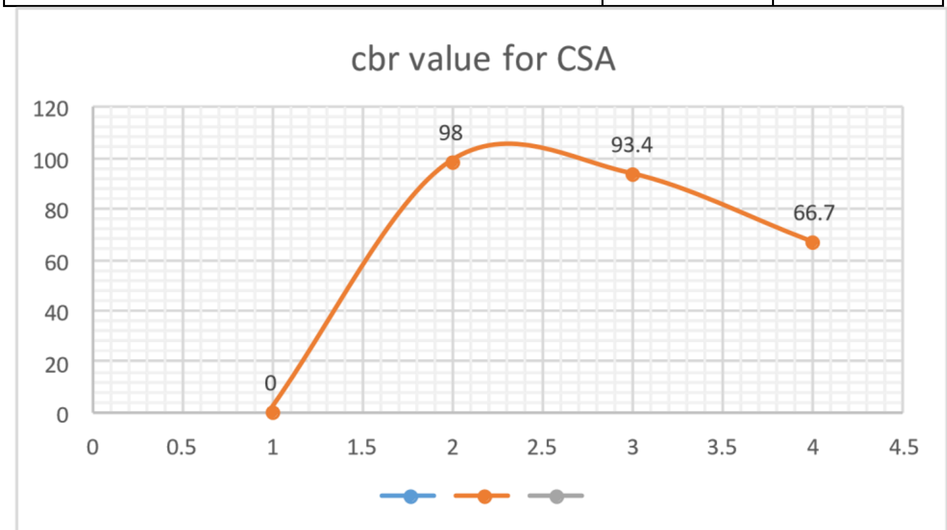
Penetration Data After 96-hours

	10 blows		30 blows		65 blow	
Penetration	load	Cbr value	Load	Cbr value	load	Cbr value
0.641	0		0		0	
1.271	0.453		0.94		2.365	
1.91	2.633		2.711		4.128	
	5.826		6.325		6.283	
2.543	8.588		9.581		10.93	
3.813	14.834	**111.45**	14.974	**112.41**	18.403	**138.160**
5.081	19.159	**95.8**	22.97	**114.85**	33.838	**169.19**
7.62	27.698		38.499		48.829	

Standard Load at 2.54 =13.32 KN and Standard Load at 5.08 =20 K



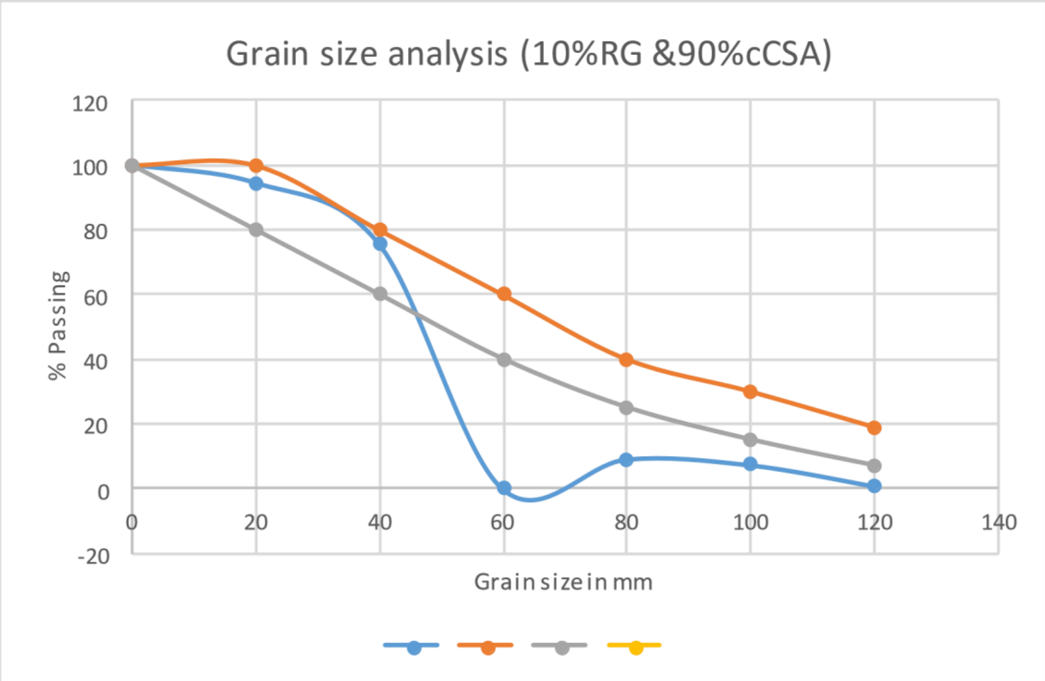
modified MMDD			2.23	
98% of MMDD			2.19	
No of blows		10	30	65
CBR values(%)		66.7	93.4	98
Dry density(g/cc)		2.32	2.21	2.19
CBR @98%MMD)			**104**	



APPENDEX 3 TEST RESULTS OF 10%RG and 90%CSA

1) Gradation test result for 10%rg and 90%csa material

Sieve size	Wt retained in each sieve(gm)	Percent retained	Cumulative percent retained	Percent passing	Cumulative % passing	ERA specification	
						Upper Limit	Lower Limit
37.5	0	0	0	100	100	100	100
26.5	557.7	5.577	5.57	94.42	94.43	100	80
19.5	1877.47	18.77	24.34	81.23	75.66	80	60
13.2/12.5	4022.2	40.22	64.56	59.78			
9.5	529.3	5.29	69.85	94.71	30.15	60	40
4.75	2114.5	21.14	90.99	78.86	9.01	40	25
2.36	174.1	1.74	92.73	98.26	7.27	30	15
0.500	650	6.5	99.23	93.5	0.777	19	7
0.075	74.73	0.74	99.97	99.26	0.77	12	5



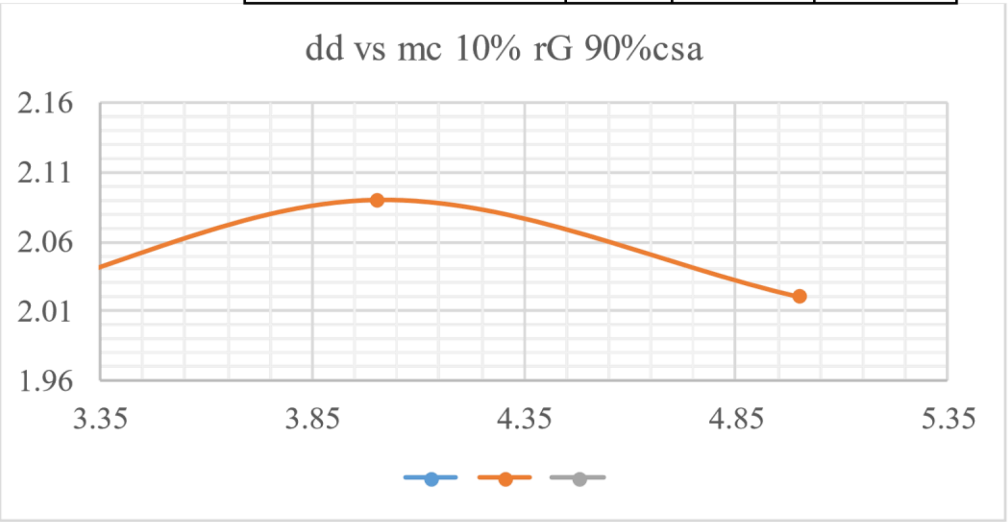
Test no	1	2	3	4
Water added	200ml	380ml	290Ml	110ml
Mass of sample taken for test	4500gm	4500gm	4500gm	4500 gm
Mass of wet soil+mass of mould	10526.4	10642.6	10900.5	10623
Mass of mould	6176.2	6176.2	6176.2	6176.2
Mass of wet soil(gm)	4350.2	4466.2	4724.5	4446.8
Volume of mould	2124	2124	2124	2124
Bulk density	2.05	2.10	2.22	2.09

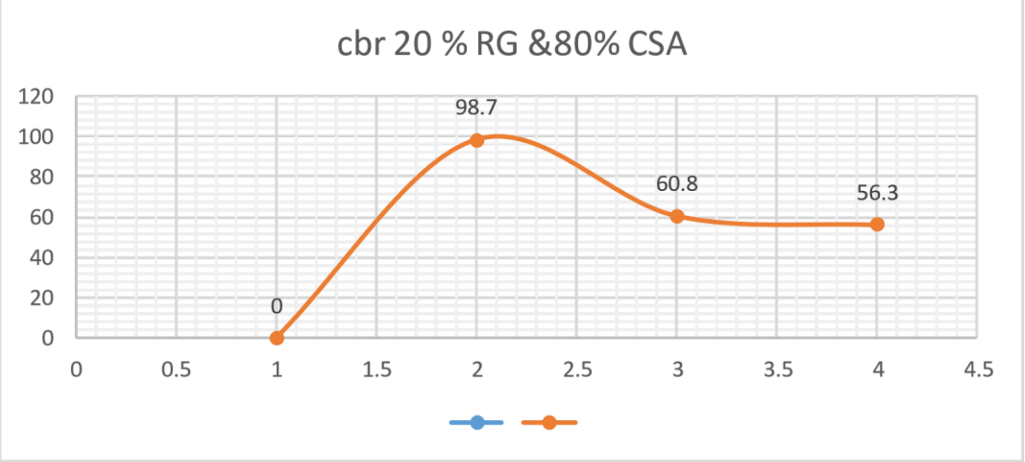
Moisture content determination

Trial no	1	2	3	4
Container code				
Mass of container	17.60	17.47	34.74	37.38
Mass of wet soil+container	185.62	189.03	277.28	240.77
mass of dry soil +container	178.64	181.99	263.28	234.17
Mass of moisture	6.98	7.04	14	6.6

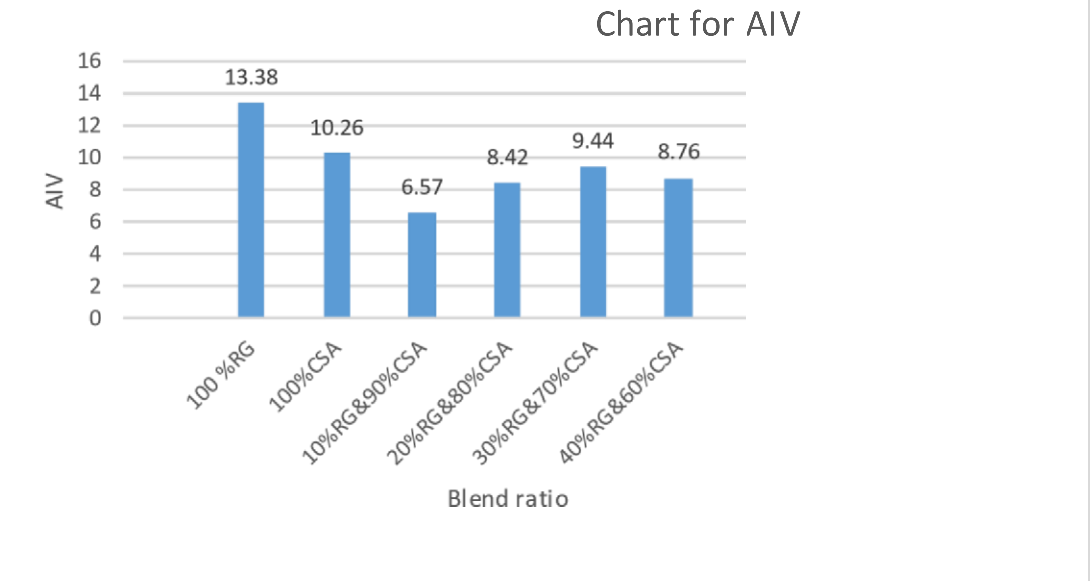
Mass of dry soil	161.04	164.52	228.54	196.79
Moisture content	4.33	4.27	6.12	3.35
Dry density(E/(100+l)*100	1.96	2.01	2.09	2.02

modified MMDD		2.09	
98%MMDD		2.04	
No of blows	10	30	65
cbr value(%)	50.3	52.8	93
Dry density	2.05	2.18	2.16
CBR @98%MMDD		93	



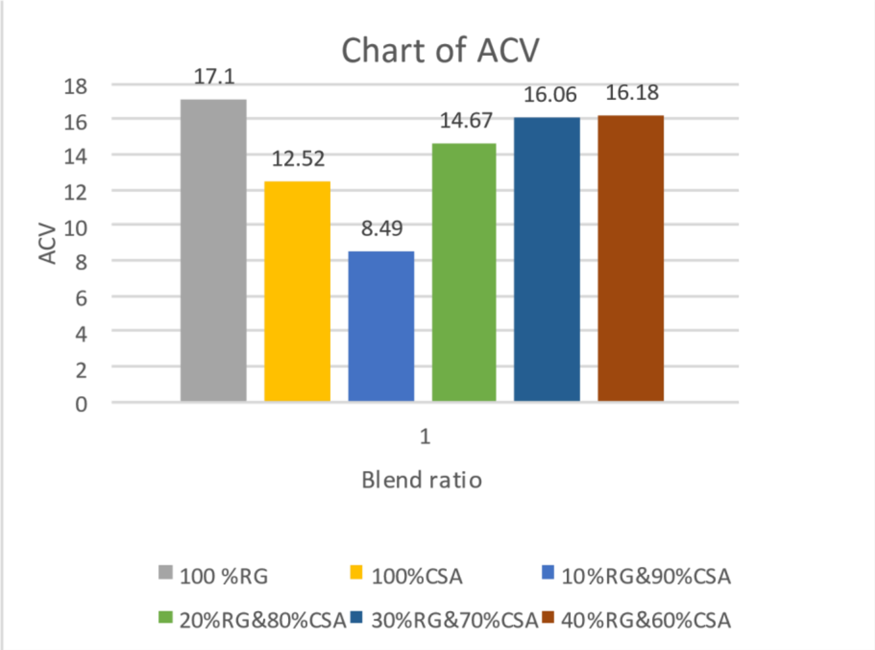


Type of sample	Total mass(W1)	Mass of pass through sieve size 2.36mm(W2)	Impact value W2/W1*100
100 %RG	560.5	75	13.38
100%CSA	580.7gm	59.6gm	10.26
10%RG&90%CSA	629.8	41.4	6.57
20%RG&80%CSA	600.3	50.6	8.42
30%RG&70%CSA	588	55.6	9.44
40%RG&60%CSA	590.11	51.7	8.76

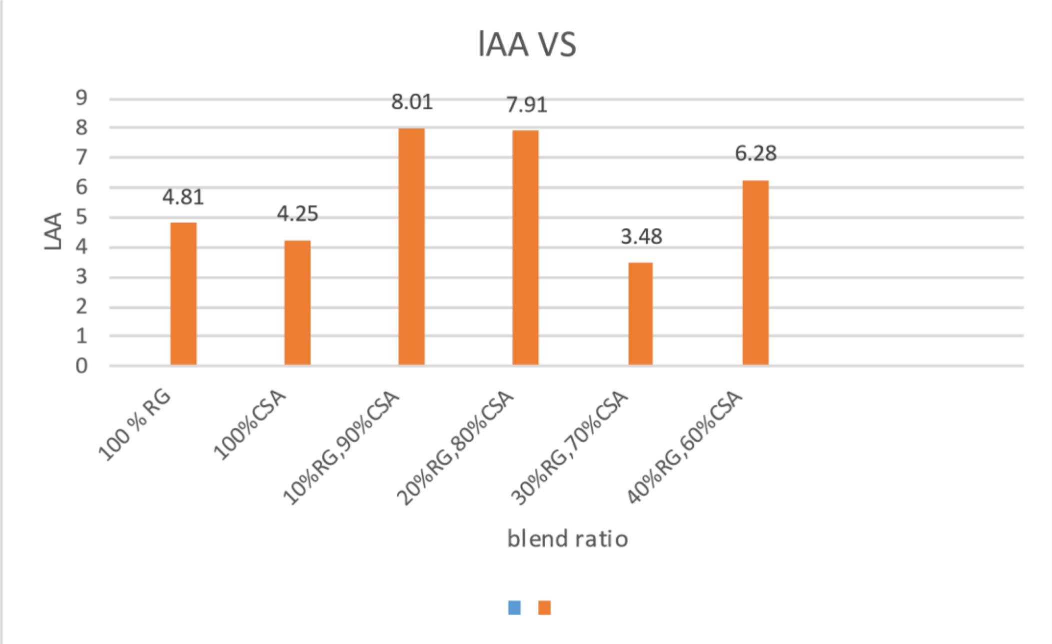


Type of sample	Total mass(W1)	Mass of pass through sieve size 2.36mm(W2)	Crushing value W2/W1*100
100 %RG	2745.2	472.7	17.1
100%CSA	2997.8	375.5	12.52
10%RG&90%CSA	2974.2	252.5	8.49
20%RG&80%CSA	2890.8	824.2	14.67

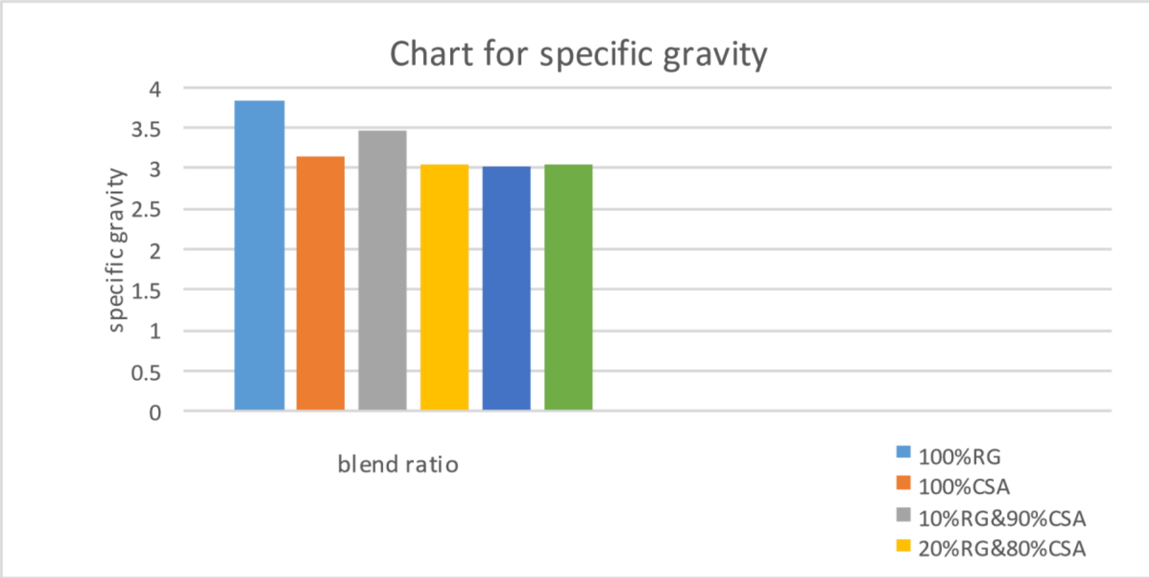
30%RG&70%CSA	2804.5	450.5	16.06
40%RG&60%CSA	2746.5	444.4	16.180



Sample type	**Total mass in gram(A)**	**Mass retained on 1.70mm sieve and washed(B)**	**A-B=C**	**LAA Value C/A*100%**
100 % RG	**5000**	4759.4	240.6	4.81
100%CSA	**5000**	4787.2	212.8	4.25
10%RG,90%CSA	**5000**	4599.4	400.6	8.01
20%RG,80%CSA	**5000**	4604.5	395.5	7.91
30%RG,70%CSA	**5000**	4826	174	3.48
40%RG,60%CSA	**5000**	4685.9	314.1	6.28

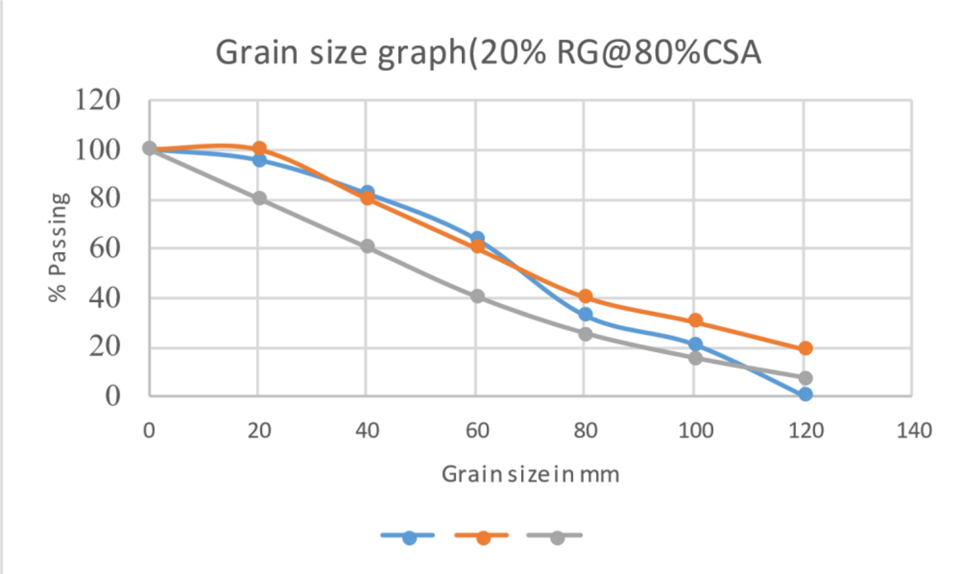


Sample type	Wt of sample taken	Wt of sample in water	Wt of surface dry sample	Wt of oven dry sample	Bulk specific gravity	Ssd	% absoption
100%RG	2000	1489.3	2015	2000	3.80	3.80	0.75
100%CSA	2000	1369.9	2008	1985	3.11	3.13	1.15
10%RG&90%CSA	2000	1430.5	2006	1984	3.44	3.47	1.10
20%RG&80%CSA	2000	1350	2003	1983	3.03	3.06	1.00
30%RG&90%CSA	2000	1345	2011	1998	3.00	3.00	0.65
40%RG&60%CSA	2000	1368	2015	1955	3.02	3.09	3.06



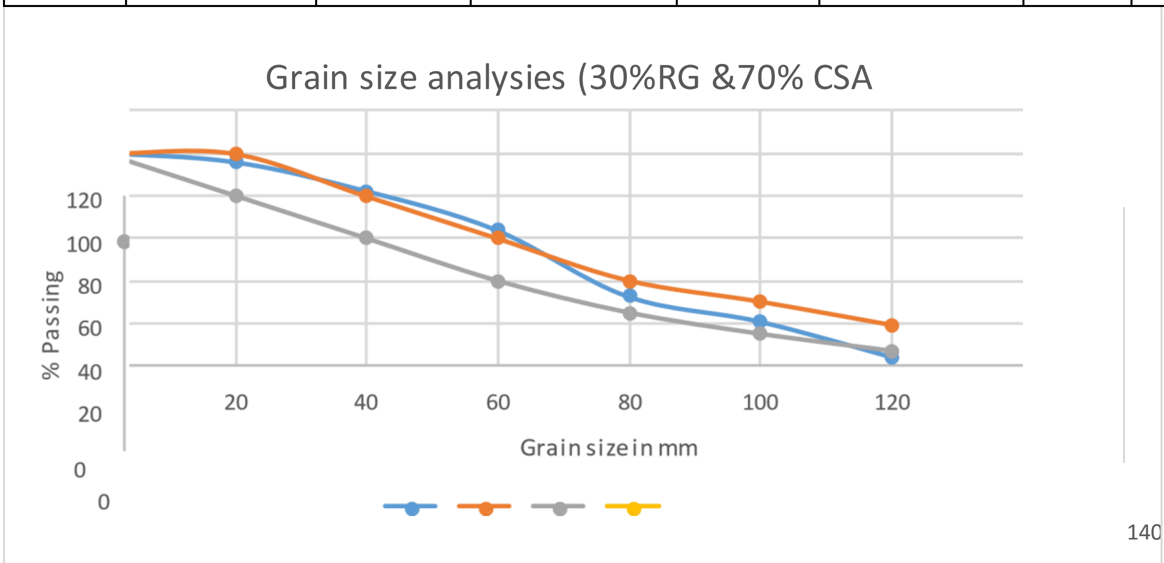
gradation test for 20% RG &80% CSA

Sieve size	Wt retained in each sieve(gm)	Percent retained	Cumulative percent retained	Percent passing	Cumulative % passing	ERA specification	
						Upper Limit	Lower Limit
37.5	0	0	0	100	100	100	100
26.5	436.7	4.36	4.36	95.64	95.64	100	80
19.5	1363.45	13.63	17.99	86.37	82.01	80	60
13.2/12.5	1012.2	10.12	28.11	89.88			
9.5	819.3	8.29	36.4	91.71	63.6	60	40
4.75	3114.5	31.14	67.54	68.86	32.46	40	25
2.36	1174.1	11.74	79.28	88.26	20.72	30	15
0.500	1660	16.5	95.78	83.5	4.22	19	7
0.075	419.75	4.19	99.97	95.81	0.03	12	5



gradation test for 30% RG &70% CSA

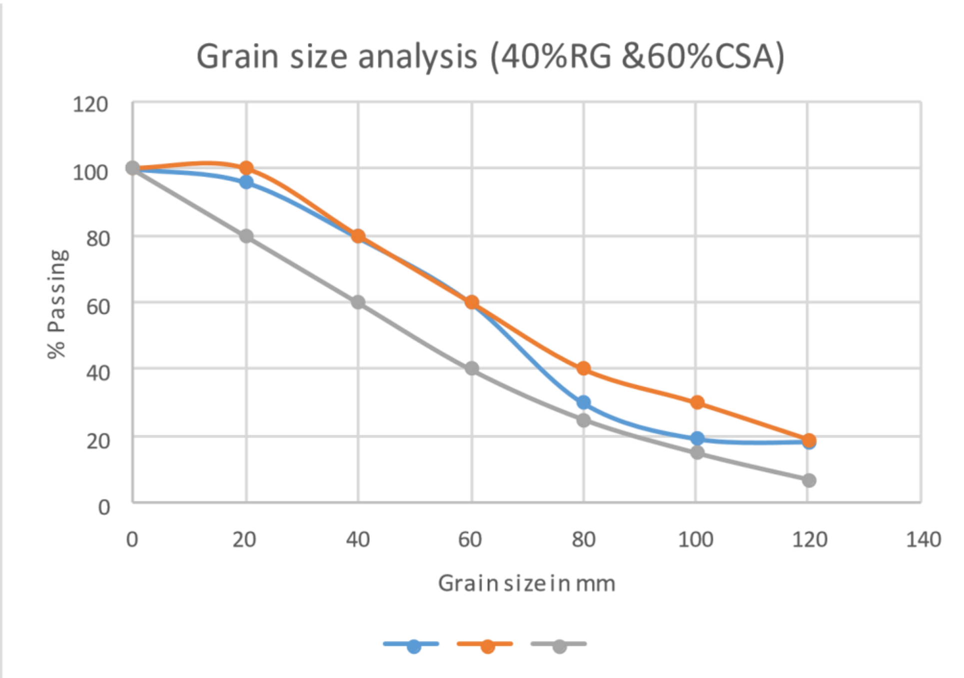
Sieve size	Wt retained in each sieve(gm)	Percent retained	Cumulative percent retained	Percent passing	Cumulative % passing	ERA specification	
						Upper Limit	Lower Limit
37.5	0	0	0	100	100	100	100
26.5	436.7	4.36	4.36	95.64	95.64	100	80
19.5	1253.45	13.53	17.89	86.47	82.11	80	60
9.5	829.3	8.29	36.3	91.71	63.7	60	40
4.75	3114.5	31.14	67.44	68.86	32.56	40	25
2.36	1174.1	11.74	79.18	88.26	20.82	30	15
0.500	2650	16.5	95.68	83.5	4.32	19	7
0.075	429.75	4.29	99.97	95.71	0.03	12	5



gradation test for 40% RG &60% CSA

Sieve size	Wt retained in each sieve(gm)	Percent retained	Cumulative percent retained	Percent passing	Cumulative % passing	ERA specification	
						Upper Limit	Lower Limit
37.5	0	0	0	100	100	100	100

26.5	400.7	4.00	4	96	96	100	80
19.5	1653.45	16.53	20.53	83.47	79.47	80	60
9.5	1950	19.5	40.03	80.5	59.97	60	40
4.75	3000.5	30.05	70.08	69.95	29.92	40	25
2.36	1074.1	10.74	80.82	89.26	19.18	30	15
0.500	1000	1	81.82	99	18.18	19	7
0.075	708.3	7.08	88.9	92.92	11.1	12	5



compaction test for 20%RG &80%CSA

Test no	1	2	3	4
Water added	110ml	290ml	470Ml	110ml
Mass of sample taken for test	4500gm	4500gm	4500gm	4500 gm

Mass of wet soil+mass of mould	10765.2	11069.5	10781.5	10723.2
Mass of mould	6176.2	6176.2	6176.2	6176.2
Mass of wet soil(gm)	4589	4893.3	4605.3	4547
Volume of mould	2124	2124	2124	2124
Bulk density	2.16	2.30	2.17	2.14

Moisture content determination

Trial no	1	2	3	4
Container code				
Mass of container	5.63	6.72	7.62	19.5
Mass of wet soil+container	71.94	76.27	96.08	69.4
mass of dry soil +container	69.49	72.05	89.81	65.83
Mass of moisture	2.45	4.22	6.27	3.57
Mass of dry soil	63.86	65.33	82.19	49.9
Moisture content	3.83	6.45	7.62	7.15
Dry density(E/(100+l)*100	2.08	2.16	2.01	1.99

test type: compaction test for 30%RG &70%CSA

Test no	1	2	3	4
Water added	180ml	270ml	360Ml	450ml
Mass of sample taken for test	4500gm	4500gm	4500gm	4500 gm
Mass of wet soil+mass of mould	10865.2	11075.5	10751.5	10620.2
Mass of mould	6176.2	6176.2	6176.2	6176.2
Mass of wet soil(gm)	4689	4899.3	4575.3	4444
Volume of mould	2124	2124	2124	2124
Bulk density	2.20	2.30	2.15	2.09

Moisture content determination

Trial no	1	2	3	4

Container code	S	T	Q	W
Mass of container	12.53	8.82	8.62	18.5
Mass of wet soil+container	81.94	86.37	106.07	89.5
mass of dry soil +container	76.39	82.05	99.81	85.83
Mass of moisture	5.55	4.32	6.26	3.67
Mass of dry soil	63.86	73.23	91.19	67.33
Moisture content	8.69	5.89	5.45	5.3
Dry density(E/(100+I)*100	2.02	2.17	2.01	1.98

test type: compaction test for 40%RG &60%CSA

Test method: standard modified proctor (56, BLOWS each layer)

Test no	1	2	3	4
Water added	180ml	270ml	360Ml	450ml
Mass of sample taken for test	4500gm	4500gm	4500gm	4500 gm
Mass of wet soil+mass of mould	10936	10965	11051.5	10640.2
Mass of mould	6176.2	6176.2	6176.2	6176.2
Mass of wet soil(gm)	4759.8	4788.8	4875.3	4464
Volume of mould	2124	2124	2124	2124
Bulk density	2.24	2.25	2.29	2.10

Moisture content determination

Trial no	1	2	3	4
Container code	D	O	P	R
Mass of container	15.33	9.62	12.62	20.5
Mass of wet soil+container	85.98	88.40	90.07	92.5
mass of dry soil +container	80.39	84.05	86.81	86.83
Mass of moisture	5.59	4.35	3.26	5.67
Mass of dry soil	65.06	74.43	74.19	66.33

Moisture content	3.39	4.84	6.54	8.59
Dry density(E/(100+l)*100	1.93	2.12	2.26	2.1

CBR test(10%RG &90%CSA)

Number of blows	65	30	10
Mould ID	N_7	T_5	A
Mass of mould+Plate	6947.1	6989.9	6989.6
Mass of mould+wet soil	12746.6	11757.2	11512.5
Mass of wet soil(gm)	5799.5	4767.3	4522.9
Volume of mould	2124	2124	2124
Bulk density	2.73	2.24	2.12
Dry density	2.61	2.18	2.05

moisture content determination

Number of blows	65		30		10	
	Before soak	After soaked	Before soak	After soaked	Before soak	After soaked
Container code	T_2		F_3		T_5C_2	
Mass of container	6.7		6.0		17.6	
Mass of wet soil +container(gm)	45.6		58.2		131.4	
Mass of dry soil+container(gm)	43.9		57		127.7	
Mass of water(gm)	1.7		1.2		3.7	
Mass of dry soil(gm)	37.2		51		110.1	
Moisture content	4.56		2.35		3.36	

Average moisture content						

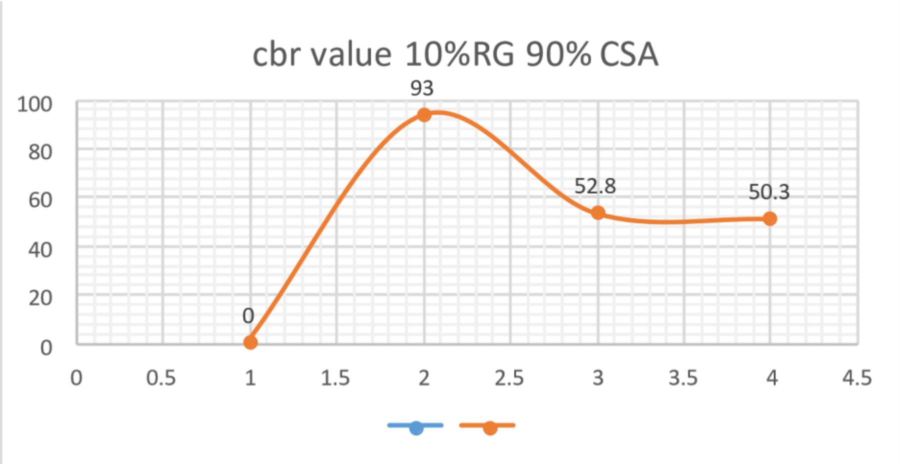
CBR test(20%RG &80%CSA)

Number of blows	65	30	10
Mould ID	T_2	N_{12}	Bn
Mass of mould+Plate	6915	6978.2	6943.1
Mass of mould+wet soil	11939	11774.6	11652.8
Mass of wet soil(gm)	5024	4796.4	4709.7
Volume of mould	2124	2124	2124
Bulk density	2.36	2.25	2.21
Dry density	2.23	2.19	2.11

moisture content determination

Number of blows	65		30		10	
	Before soak		Before soak	After soaked	Before soak	After soaked
Container code	B_3		Q		J	
Mass of container	5.5		16.45		16.99	
Mass of wet soil +container(gm)	76.2		90.57		74.93	
Mass of dry soil+container(gm)	72.6		88.6		72.5	
Mass of water(gm)	3.6		1.97		2.43	
Mass of dry soil(gm)	67.1		72.15		55.51	
Moisture content	5.36		2.73		4.37	

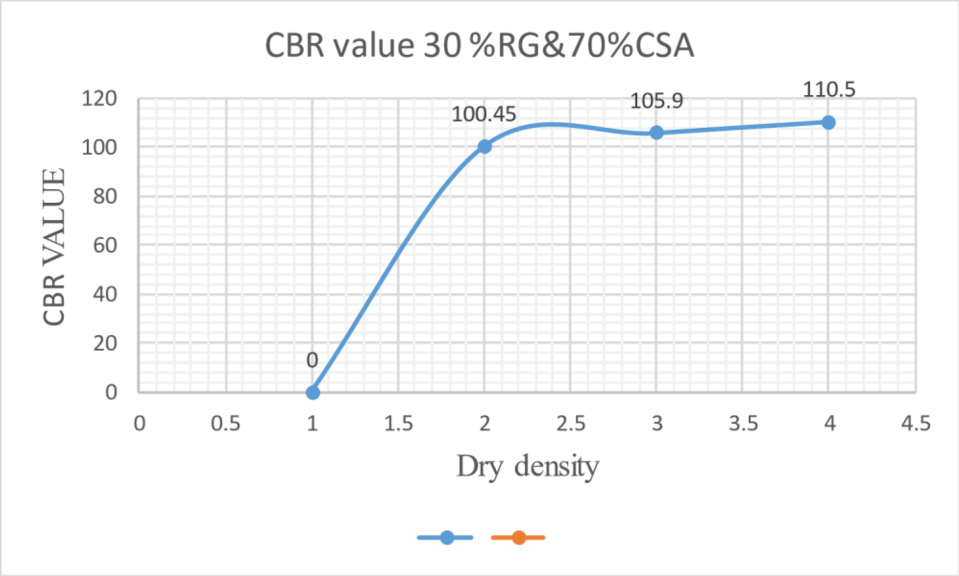
Average moisture content						
Dry density						



CBR value=93

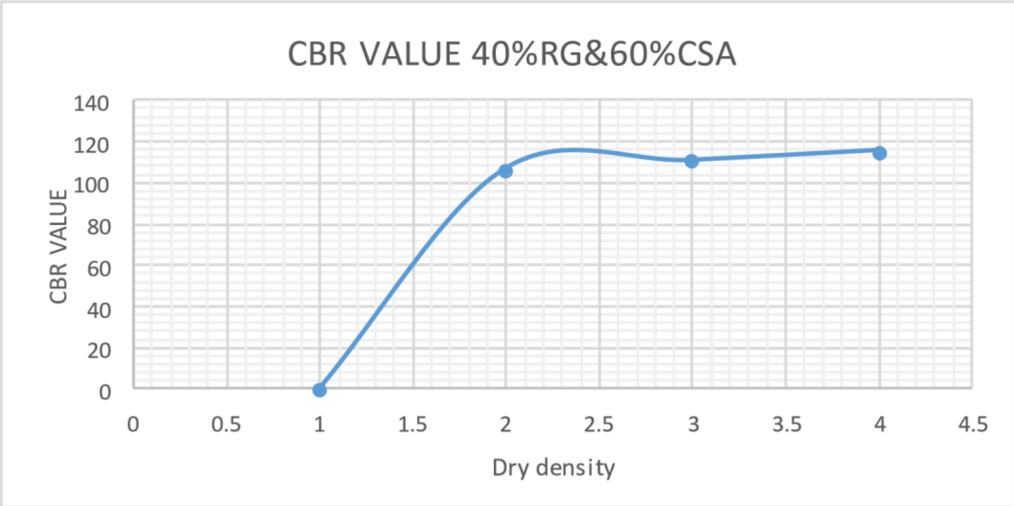
30%RG&70%CSA

modified MMDD		2.17	
98%MMDD		2.12	
No of blows	10	30	65
cbr value(%)	100.45	105.9	110.5
Dry density	2.06	2.10	2.17
CBR @98%MMDD	106		



40%RG&60%CSA

modified MMDD		2.26	
98%MMDD		2.21	
No of blows	10	30	65
cbr value(%)	106.65	110.9	115.70
Dry density	2.15	2.2	2.23
CBR @98%MMDD	111%		


CBR VALUE 40%RG&60%CSA
CBR VALUE
Dry density
140
120
100
80
60
40
20
0
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5