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ACADEMIC YEAR 2023/2024

DEPARTMENT OF CIVIL ENGINEERING

CONSTRUCTION TECHNOLOGY

Dissertation submitted in partial fulfilment of the requirements for the Award of advanced diploma

In construction technology.

Presented by:

KALISA Rayan: 202150016

Under the guidance of:

Eng. MUKESHIMANA Annoncee

Kigali, September 2024

DECLARATION

I do hereby declare that the work presented in this dissertation is my own contribution to the best of my knowledge. The same work has never been submitted to any other University or Institution. I, therefore declare that this work is my own for the partial fulfillment of the award of advanced diploma in construction technology at ULK Polytechnic

Institute.

The name of candidate: KALISA Rayan.…………………

Signature of the candidate: ………………………………………….

Date of submission: …………………………………………………

APPROVAL

This is to certify this dissertation work entitled “Assessing the potential use of sawdust ash and cement as soil stabilizer in road construction. Case study: Musanze sector (2015-2023)” is an original student conducted by KALISA Rayan under my supervision and guidance.

Supervisor’s name Eng. MUKESHIMANA Annoncee

Signature …………….………………

Date ………/……………/………

Head of Department: Eng. Nkiranuye Bonaventure

Signature: ……………………

Date ………/……………/………

DEDICATION

To my beloved family and friends,

This project is dedicated to you, whose unwavering support, encouragement, and love have been my guiding light throughout this journey. Your belief in my potential has inspired me to push beyond my limits and strive for excellence. To my family, thank you for your endless patience and sacrifices. You have instilled in me the values of perseverance and resilience. To my friends, your camaraderie and shared laughter have made even the toughest moments enjoyable.

This accomplishment is as much yours as it is mine, and I am forever grateful for the unique ways each of you has contributed to my growth.

With heartfelt appreciation.

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May God bless you all!!!

ABSTRACT

Recycling application in road maintenance and rehabilitation is of target concern for many developing countries as they focus on minimizing the cost due to budget constraint allocated to the sector of road infrastructure, as well as to give response to environmental concern in a way of reducing the disposal or land fill because pavement rehabilitation and reconstruction give big amount of quantities of Reclaimed Asphalt Pavement (Jie, 2011). Moreover, in a world where more and more focus are being made on resources especially materials, the use of locally pavement materials such as sawdust ash and cement has been thought also to offer the suitable solution to the stabilization of RAP. The use of sawdust ash and cement for stabilizing the reclaimed asphalt has manifested a strong bond between them due to their similarity in terms of cementitious behavior to provide the performance to the mix for the surface course application. This study provides different results and performance of the RAP materials associated with sawdust ash to improve for pavement through their effect within the mixture. The study will help in improving the performance of the pavement by utilizing the sawdust ash and cement in asphalt mixture, and evaluate the behavior of it through marshal test, a part from the pavement performance also this study will contribute to the environmental impact by minimizing the disposal of waste materials. This study evaluates the effect of sawdust ash as the filler replacement by 100%; 70%; 50%; 30% and 0% in the asphalt mix and reclaimed aggregate that showed the good performance in terms of flow and stability test conducted

in laboratory as ordinary filler retained on sieve 75μm. The results obtained lied between the range of 8.5 as maximum at 5% bitumen and 3.5mm for the flow, the results are in acceptable recommendation according to (TMH14,1985). The processes that the research focus on, is the effect of sawdust and cement in the asphalt composed of aggregates and bitumen in terms of flow and stability for the mix.
Keywords: Reclaimed Asphalt Pavement, sawdust ash, stabilization, stability, flow and filler.

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LIST OF ACRONYMS AND ABBREVIATIONS

ULK	Kigali Independent University
UPI	ULK Polytechnic Institute
HOD	Head of Department
AASHTO	American association of state highway and transportation officials
AFCAP	Africa Community Access partnership
ADF	African development fund
AC	Asphalt cement
AIV	Aggregate
@	At
AAV	Aggregate abrasion value
ASTM	American society of testing material
BACMI	Britain roads at the start of 20th century
BS	British standard
BSM	Bitumen stabilized material
CBR	California bearing ration
Cm	Centimeter
CST	College of science and technology
CIPR	Cold in place recycling
CO2	Carbon dioxyde
DOTs	Department of transportation officials
EPA	Environmental Protection Agency
ESAL	Equivalent standard axle load
FDR	Full depth reclamation
FHWA	Federal Highways
HMA	Hot mix asphalt
IRI	International roughness index
KMH	Kanombe Military Hospital
LCA	Life cycle assessment

LCCA	Life cycle cost analysis
MgO	Magnesium
OPC	Ordinary Portland cement
PCC	Portland cement concrete
PSI	Present serviceability index
RAS	Reclaimed asphalt shingles
RAP	Reclaimed asphalt pavement
SDA	Sawdust Ash
SA	South Africa
USA	United State of America

CHAPTER I: GENERAL INTRODUCTION

1.1. Introduction to the study

This chapter highlights the background of the study, statement of the problem, purpose of the study, objective of the study, research questions, research hypotheses, scope of the study, significance of the study and lastly the structure of the study.

1.2. Background of the study

Road construction involves the design, building, and maintenance of roads, highways, motorways, and other transportation infrastructure. The conventional road construction use the expensive materials such as virgin aggregates, bitumen, emulsion, foam processed from the industry to reduce the project expenses, the use of locally available material and reuse of materials were applied, many countries have been using RAP for highway construction. Asphalt has been used as the construction material from the earliest days of civilization applied in ship construction as waterproofing material, its use in road project are recent (Dolacek-Alduk et al., 2020). The first roads were constructed for animals to be used for the farmers their features were only the markers to avoid marshes and other hospitable land and earlier the paved roads made of bricks and stones were reserved to the urban areas these roads seem to be started in Middle East with binders a bonding material (Bosco Niyomukiza & Yasir, 2023).

An existing typical example is the processional road in Babylon that was constructed 620BC. The bituminous mixtures also rose to be utilized in road construction from dry stone developed by two pioneers Telfold and macadam. These inventors introduced individually dry bound mixture for pavements which were sprayed with a sealing tar blend to bind the aggregates together and provide a medium with a good water proofing properties but the traffic load caused by motor vehicle noticed the weaknesses in their performance (Hunter, 1994). As the research went, the researchers found the other asphalt mixtures which gave impermeable surfacing that would not produce dust and resist to permanent deformation (Guidance, 2021).

And the damage and deterioration of the roads become limited, though the road deterioration have started to be worsened the solution were the rehabilitation to maintain the roads at their original state many defects appear and require a huge amount of resources including money it is in that regard that this study shows that the use of sawdust ash, bitumen and cement in the asphalt mixture is also a solution for pavement construction that can lead to the successful achievement of good performance of the surface layer toward sustainability of roads infrastructure. Stabilization of RAP with bitumen associated with partially sawdust, cement has been thought to be successful to prove the usefulness of the reuse of pavement materials (Abbas Khan, Omar Hamdi Jasim, 2020).

Regarding the situation of some road in the country rehabilitation by using the RAP stabilized is the effective method cost reduction and environmental friendly, considering the reuse of asphalt and aggregate and stabilizing with sawdust ash as new stabilizing material due to its pozollanic properties it has showed the presence of calcium oxide (CaO) the cementitious indicator of 10% (Bosco Niyomukiza & Yasir, 2023). This study is important for a road network of Rwanda to contribute to the sustainability and remedies to the rehabilitation cost effective. The condition of a road should be assessed in order to know the extent of the failure for action. When pavement reaches its end of life, it may remain in place and be reused as part of supporting structure for new pavement, recycled or removed and land filled. Each has economic and environmental cost, as do the more visible stages of the pavement life cycle (e.g. Material module, initial pavement construction and use phase.).Therefore and end of life activities can affect sustainability factors such as wastes generation and disposition air and water quality and materials use they must be considered in life cycle assessment (LCA) (Abbas Khan, Omar Hamdi Jasim, 2020).

Sawdust is one such by-product from Timber industries and Wood cutting factories. Sawdust by itself has little cementitious value but in the presence of moisture it reacts chemically and forms cementitious compounds and attributes to the improvement of strength and compressibility characteristics of soils. So in order to achieve both the need of improving the geotechnical properties of clays and also to make use of the industrial wastes, the present experimental study has been taken up. The Saw dust was collected from local Saw mill in Industrial area, Kheora Rajouri @Rs 2 per Kg. Saw dust is actually by-products of sawmills generated by sawing timber. It is the loose particles or wood chippings obtained by sawing wood into useable sizes. After collection, clean saw dust not having much bark and so not much organic content was air dried and burnt (Chitte, 2018). The Saw dust ash (SDA) was then sieved through 600 micron sieves to remove the lumps, gravels, unburnt particles and other materials which are deleterious to soil. The Sawdust ash passing through 600 microns sieve was used for the laboratory work.

Sawdust is one of the principal wastes produced from timber industries. Huge quantity of sawdust is generated across the world because of the rapid growth of population. Disposal of such wastes in open areas and landfills is not an effective solution. Only in USA, around 3 million tons of sawdust is produced annually. Moreover, it is reported that if this waste is not managed properly it can possess serious health and environmental problems. For developing countries, utilization of such wastes is a challenge as they do not have sufficient downstream industries. As such for developing countries utilization of such wastes is limited to steam generation for kiln driers in large sawmills which results in improper disposal of bulk quantity of this waste causing environmental and ecological havoc (Boyce et al., 2018). In Nigeria, most of these wastes are available in large quantity in the form of heaps and mostly burnt off causing environmental pollution as reported by Rominiyi et al. (2024). Literature review suggests that proper utilization of this waste is essential to reduce its detrimental effects on environment and the problem is more severe in developing countries.

Some properties of concrete with sawdust ash (SDA) as a replacement for ordinary Portland cement (OPC) are investigated. The compressive strength of specimens with replacement levels ranging from 10 to 30% cured for periods of 3–90 days showed a decreasing strength with higher ash content. The 28-day split tensile strength of SDA concrete specimens showed a similar trend. The SDA concrete was observed to gain rapid strength at later ages, indicating a pozzolanic activity of the ash. Although only concrete with a 10% replacement level attained the 20 N/mm2 designed strength at 28 days, test results indicate that SDA concrete can attain the same order of strength as conventional concrete at longer curing periods (Bosco Niyomukiza & Yasir, 2023).

A cement is a binder, a chemical substance used for construction that sets, hardens, and adheres to other materials to bind them together. Cement is considered most effective stabilizers among the aforementioned stabilizers in terms of its effectiveness in providing higher strength, reduced water absorption and increased density. Cement is seldom used on its own, but rather to bind sand and gravel (aggregate) together. Cement mixed with fine aggregate produces mortar for masonry, or with sand and gravel, produces concrete. Concrete is the most widely used material in existence and is behind only water as the planet's most-consumed resource. Cements used in construction are usually inorganic, often lime or calcium silicate based, which can be characterized as hydraulic or the less common non-hydraulic, depending on the ability of the cement to set in the presence of water (see hydraulic and non-hydraulic lime plaster) (Khode, 2019).

1.3. Problem statement

Road networks in Rwanda play a major role in socio economic development of the country, and the infrastructure in the domain of transportation is keeping increasing what is to be proud of, the road sector strive to find a solution by identifying the optimal resources such as materials labor and money. This study is finding a solution by utilizing the reused materials stabilized with other locally available material such as sawdust ash to improve the performance of the mixture toward the pavement surface. Now road Networks in Rwanda consist of National road, District roads class I, district road class II, mainly unpaved and district feeder road. The roads once constructed the government strive to keep the roads in good condition to meet their life span, analysis period and design period depend on the class of road (Abbas Khan, Omar Hamdi Jasim, 2020).

The total road network in Rwanda covers 37,898km, and this number includes paved, non-paved, classified and unclassified roads with road density 1.69km/km2. (RTDA, 2019), report on road investment based on the type of road network and the total distance in kilometer, the density is one of the greatest in Africa. This shows the intervention that the government of Rwanda is dealing with, to preserve the road network by maintenance and rehabilitation, which however goes with the budget increase therefore to deal with budget constraint as well as environmental protection, the use of locally available material is a solution (Pheng & Hou, 2019).

Expansive soils are highly plastic clays with a significant mineral composition of montmorillonite and illite. They tend to swell when moistened and soften or shrink and develop cracks as they dry. The expansive nature of these soils has led to significant damage to buildings and infrastructure. For example, in the United States alone, expansive soils annually cause destruction exceeding 15 billion dollars. Due to the potential for property loss, it is essential to stabilize expansive soil before using it in the construction of buildings and roads (Bosco Niyomukiza & Yasir, 2023).

In addition, the existing soil at a particular location may not be suitable for the construction due to poor bearing capacity and higher compressibility or even sometimes excessive swelling in case of expansive soils. The improvement of soil at a site is indispensable due to rising cost of the land, and there is huge demand for high-rise buildings. There is a need to concentrate on improving properties of soils using cost-effective practices like treating with industrial wastes those having cementitious value. In this study, materials like Saw Dust Ash (SDA) and cement are used to improve geotechnical properties of a soil (Shawl et al., 2017).

However, within the context of Rwanda, limited research has been conducted to explore the feasibility and advantages of incorporating cost-effective agricultural waste materials, like sawdust ash, into construction practices. It is in this context that the current research aims to investigate the effects of utilizing sawdust ash as a stabilizing agent for expansive soils. This endeavor encompasses a comprehensive evaluation of the chemical properties of sawdust ash and a thorough analysis of the engineering properties of both stabilized and non-stabilized soils. By doing so, this study seeks to contribute valuable insights to sustainable construction practices and promote ecofriendly solutions tailored to the specific needs of Rwanda's construction industry.

1.4. Objective of the study

1.4.1. Main objective

The general objective of this project to assess the potential use of sawdust ash and cement as soil stabilizer in road construction. Case study: Musanze sector (2015-2023).

1.4.2. Specific objectives

This project's specific objectives were as follows:

a) To identify the physical properties of sawdust ash and cement.

b) To assess the potential use of sawdust ash and cement to stabilize expansive soil before using it in the roads construction.

c) To determine the penetration grade of bitumen using penetration test.

d) To determine the particle size distribution of the coarse and fine aggregates using sieve analysis.

e) To determine the resistance of aggregate to a sudden shock using mechanical test.

f) To determine the behaviour of sawdust ash mixed with asphalt using Bitumen extraction test results.

g) To indicate that asphalt mixed with SDA and cement have better stability as the ordinary filler usin marshal test.

1.5. Research questions

Based on the project's serviceability and functionality, answers to the following research questions will be offered in order to fulfil the above particular objectives.

a) What are the physical properties of sawdust ash and cement respectively?

b) What are the the potential use of sawdust ash and cement to stabilize expansive soil before using it in the roads construction ?

1.6. Scope of study

This study will be delimited in terms of space, time, content and domain. Geographically, this study will be limited to Musanze sector, because the researcher believes that he will get relevant information concerning the topic. In addition, the study covers a time scope from 2015 to 2023, this time scope of eighty years is adequate to help the researcher to answer research questions, achieve specific objectives and come up with suitable conclusion. In terms of domain, this research will be delimited in domain of construction technology. In terms of content, this research will assess the potential use of sawdust ash and cement as soil stabilizer in road construction. This study is limited to the application of, cement and sawdust ash in the mixture to assess its behaviour through marshal stability and flow of the mixture.

1.7. Significance of the study

This section deals with motives which pushed the researcher to choose and be interested in this topic. The study will be important to the researcher, to ULK Polytechnic Institute and to the Rwandan society in general also Government, and to the other researchers. This study will help to shift from theory to practice; above all, it will contribute to the successful completion of advanced diploma in construction technology. Thereafter it will help to improve the knowledge and skills of researcher about the potential use of sawdust ash and cement as soil stabilizer in road construction. This study gives a clear picture of chemicals and physical properties of sawdust ash and cement respectively and the potential use of sawdust ash and cement to stabilize expansive soil before using it in the roads construction. The findings and recommendations of the researcher will help in road construction.

1.8. Structure of the research

This work consists of five chapters. Chapter one is the general introduction and it includes background of the study, problem statement, purpose of the study, the objectives of the study, research questions, scope of the study, significance of the study and lastly the organisation of the study. The second chapter was the literature review, which was about the general understanding of the reviews of other researchers with the related studies. The third chapter was the research methodology and it focused on the methods and materials to be used in achieving the objectives of the study. The fourth chapter was the results and discussions and it was the most important one because it showed the presentation of the results acquired. The fifth one, which was the last chapter covered the conclusion and recommendations with respect to the predefined objectives.

CHAPTER II: LITERATURE REVIEW

2.1. Introduction

A literature review in any field is essential as it offers a comprehensive overview and recapitulation on the given scholarship from past to present, giving the reader a sense of focus as to which direction your new research is headed. This involves with various reviews of textbook, newspapers, websites and other documents which present theories that are related to the topic. This chapter broadly aims to review the existing literature to arrive at conceptual understanding and this chapter contains the definitions of key words and terms used in this research and theories applicable to the study.

2.2. Definition of the key concept

2.2.1. Construction

Construction is a general term meaning the art and science of forming objects, systems, or organizations. It comes from the Latin word construction (from com- "together" and struere" to pile up") and Old French construction (Bosco Niyomukiza & Yasir, 2023). To 'construct' is a verb: the act of building, and the noun is construction: how something is built or the nature of its structure (Masengesho et al., 2021). The construction industry plays an important role in the economy, and the activities of the industry are also vital to the achievement of national socio-economic development goals of providing shelter, infrastructure and employment.

The role of construction in the national economy has been addressed by a number of researchers. According to Khan (2024), the construction sector and construction activities are considered to be one of the major sources of economic growth, development and economic activities. Construction and engineering services industry play an important role in the economic uplift and development of the country. The construction industry is also a prime source of employment generation offering job opportunities to millions of unskilled, semi-skilled and skilled work force.

2.2.2. Construction industry

Construction industry refers to the industrial branch of manufacturing and trade related to building, repairing, renovating, and maintaining infrastructures. The construction industry is a vast and multifaceted sector that encompasses the planning, design, financing, construction, renovation, and maintenance of buildings, infrastructure, and various civil engineering projects.According to UKCG (2022), “the construction industry is a driver of growth in other sectors due to its heavy
reliance on an extended and varied supply chain”. All other sectors of the economy like manufacturing, agriculture, entertainment, transportation, education, health, sports, etc. depend on construction industry as well as the construction industry relying on them for

performance. The construction industry has ability to impact on other sectors because of its nature of being infrastructure provider. There is no sector that does not depend on physical infrastructure produce by the construction industry for its production (Abbas Khan, Omar Hamdi Jasim, 2020).

Oladinrin, Ogunsemi and Aje (2017) stated that “the construction industry plays an important role in the economy, and the activities of the industry are also vital to the achievement of national socio-economic development goals of providing shelter, infrastructure and employment. It is clear that construction activities affect nearly every aspect of the economy”. BIS Secretary of State Vince Cable, in September 2019, announced a review of key strategic sectors to the UK's growth and competitiveness. Construction was one of them.

2.2.3. Road construction

Road construction involves the design, building, and maintenance of roads, highways, motorways, and other transportation infrastructure. The aim is to create durable, safe, and efficient routes for vehicular and pedestrian. In its simplest form, road construction involves installing asphalt, concrete or other materials to create a smooth surface for vehicles (Juremalani, 2021).

2.2.4. Sawdust

Sawdust is one of the principal wastes produced from timber industries. Sawdust (or wood dust) is a by-product or waste product of woodworking operations such as sawing, sanding, milling and routing. It is composed of very small chips of wood. These operations can be performed by woodworking machinery, portable power tools or by use of hand tools. Sawdust is a dry wood material consisting of cellulose, lignin, hemicelluloses, and 5-10% other materials. Sawdust (or wood dust) is a by-product or waste product of woodworking operations such as sawing, sanding, milling, planning, and routing. Sawdust is a by-product or waste product of woodworking operations such as sawing, sanding, milling, planning, and routing (Shawl et al., 2017).

2.2.5. Stabilization

Stabilization is process of fundamentally changing the chemical properties of soft soils by adding stabilizers or binders, either in wet or dry conditions to increase the strength and stiffness of the originally weak soils (Bosco Niyomukiza & Yasir, 2023).

2.2.6. Cement

A cement is a binder, a chemical substance used for construction that sets, hardens, and adheres to other materials to bind them together. Cement is a fine and soft powder that is used as a conglomerate because it hardens after being in contact with water. Cement is defined as a binding agent that is used to bind various construction materials. Given its adhesive and cohesive properties, it is an essential ingredient of concrete and mortar. Cement is mixed with water to form a paste that binds aggregates like sand or crushed rocks. Calcium, silicon, iron and aluminums compounds are closely ground to form a fine powdered product – cement.

2.3. History of road construction and the Development of road pavement

Road pavements passed different stages in their developments since the start of the 20th century (Sahu & Student, 2020). The introduction of standards for pavement construction along with the introduction of mechanical means of producing and laying materials helped develop the modern road network (Abbas Khan, Omar Hamdi Jasim, 2020). The increase traffic, rise in construction cost and environmental impacts have led to the introduction of performance specification and development of mixtures which reduce environmental impacts (EPA Ireland, 2020). This part describes some of the developments in road pavement construction over the last century.

2.4. Asphalt pavements

First used in Paris in 1854, they were made from natural rock asphalts (David and Byrine, 2021). The rock was limestone impregnated with binder (traditionally called bitumen) (David et al., 2024) .The material was imported into Britain and used in London in 1870 and persisted until 1930‘s The asphalt institute, (2017). It was very expensive material and was consequently utilized at prestigious sites only (Nicholls, 2022).

2.5 Concrete road

The first concrete roads were laid in Edinburgh 1865; it was a dry mix concrete with very little water in it and was compacted by steamroller, they proved to be unsuccessful, breaking up due to frost action, and were abandoned (Sherwood, 2019). Improved materials and laying techniques saw their reintroduction in 1920, it was clear that the motor car was here to stay and something had to be done about the state of the road (Don Caster College, 2021). The road board set up to increase the tax of fuel in order to raise funds for roads improvement 1909, the amount credited to the road improvement was raised up to $1.6millions per head of population

In 1919 the road board was absorbed into the newly created ministry of transport .there are followed a period of high activity and the road network was increasingly surfaced tarred mixtures of various forms until the Wall Street crash in 1929 (BACMI, 2022).

2.6. Typical stabilizers

Different recycled materials were used for the road construction projects and have been assessed to be efficient (Smith et al., 2023). Some of the materials are more traditionally used in practice such as RAP and fly ash, while others are more unique to the specified reconstruction work those are:

2.6.1 Coal fly ash

Fly ash is a fine- grained, powdery produced from burning pulverized coal in a coal fired boiler at electrical generation plant (RMRC, 2020) .Fly ash for road construction applications is classified as either Class F or class C those two classes of fly ash are defined in ASTM C618: 1.Class F fly ash, and 2. Class C fly ash. Fly ash that is produced from the burning of anthracite or bituminous coal is typically pozzolanic and is referred to as a Class C fly ash if it meets the chemical composition and physical requirements specified in ASTM C618 that they contains less than 10 percent calcium lime (CaO)or more than 10 percent lime(CaO) content, and class F fly ash with pozzolanic properties ,glassy silica ,and alumina requires a cementing agent such as Portland cement ,quick lime or hydrated lime in the presence of water to react and produce cementitious compound. Thus, class C fly ash will harden and get strength over tome in the presence of water

(Osinubi and Joseph, 2022).

The two classes are pozzolanic, meaning that when finely divided and in the presence of water, the fly ash will combine with calcium hydroxide to form cementitious compound (ACCAA, 2023). However Class C fly ash has self-cementitious cementing properties (i.e. ability to harden and gain strength in the presence of water alone) that make Class C a more valuable and common fly ash in road pavement construction.

According to the American coal ash association (ACAA), Fly ash has been used in road and highway projects since the early 1950's (ACAA, 2023). Fly ash is often used for cement replacement in concrete and less commonly as fill stabilization in base material (Edil, 2023).In 2014 ,approximately 13.1 million tons of fly ash were used in concrete production (ACAA,2015).

Benefits of fly ash PCC unrelated to environment or economics include higher ultimate strength, improved workability, reduced bleeding reduced permeability and more. However disadvantages of fly ash substitution may include possible reduction in durability and reduced earl strength (ACCAA, 2023). In base courses, fly ash and lime can be combined with aggregate to improve the quality of the road layer. Although not as common a practice, studies have suggested many benefits of fly ash –improved base courses including increased strength and extended service life of the roadway (Wen et al., 2011).

2.6.2 Reclaimed Asphalt Pavement

2.6.2.1. Origin

Reclaimed asphalt pavement (RAP) is the term given to removed and or reprocessed pavement materials containing asphalt and aggregates. These materials are generated when asphalts pavements are removed for reconstruction, resurfacing, or to obtain access to buried utilities (Osinubi and Joseph, 2022). When properly crushed and screened, RAP consist of high quality, well graded aggregate coated by asphalt cement (Gardner, 2021). Asphalt pavement is generally removed either by milling or full depth-removal by using the specified machine called milling machine which can remove up to 300mm thickness. Full depth removal involves ripping and breaking the pavement using a rhino horn on a buldozzer and or pneumatic pavement breakers. In most instances, the broken material is picked up and loaded into haul tracks and front end loader and transported to a central facility for processing. At this this facility, the RAP is processed using a series of operation, including clushing and screening (herman, 2024).

2.6.2.2 Reclaimed Concrete Asphalt

RCA also known as reclaimed concrete material ,consist of high quality ,well graded aggregates bonded by hardened cementitious paste (Chesnee, 2021). RCA is generated from the demolition (Prestressed Cement Concrete (PCC) in not only roads, but in other concrete structures. After demolition and excation, the RCA is typically either hauled to a stockpiling facility (i.e. aggregate suplier) landfilled, or reused on site. At the stockpiling facility or at the site the RCA is crushed to the desired gradation and reinforcing steel is removed such that it can serve as a high quality base or subbase material (edil et al., 2021). However the removal of some mesh reinforcement is difficult consequently decrease the quality of the RCA. The lower- quality RCA can be used as subgrade or fill material. the FHWA ,(2008) also discussed the effect of the presence of cementitious paste such as texture ,specific gravity and water absorption ,compared to the typical aggregate in the concrete.

here the form of stabilization according to Austroads are cement and cementitious blends where by cement products cover a wide range of property , the following explanation regard the cementitious products.

2.6.2.3. Portland Cement

Cement is the chief ingredient in cement paste, the binding agent in Portland Cement Concrete (PCC) .it is an hydraulic cement that, when combined with water, harden into a solid mass .mixed with aggregate matrix it forms PCC. As a material Portland cement has been used long time ago there is 175 years, and from an empirical perspective, its behavior is well understood. Chemically, however, Portland cement is a complex substance whose mechanisms and interactions have yet to be fully defined. ASTM C 125 and the Portland cement association (PCA) provide the following precise definition

(Steven, 2023).

1. Hydraulic cement: an organic material or mixture of inorganic materials that sets and develops strength by chemical reaction with water by formation of hydrates and is capable of doing so under water.

2. Portland cement: hydraulic cement composed primarily of hydraulic calcium silicates.

2.7. Physical and Chemical properties

Portland cements can be characterized by their chemical composition. The basic chemical composition are shown in the Table below according to (Mindess and Young, 2021).

Table 1: Chemical composition of Portland cement

Chemical name	Chemical formula	Shorthand notation	%by weight
Tricalcium cilicate	$3CaO \times SiO_2$	C_3S	50
Dicalcium cilicate	$2CaO \times SiO_2$	C_2S	25
Tricalcium aluminate	$3CaO \times Al_2O_3$	C_3A	12
Tetracalcium Aluminoferrite	$4CaO \times Al_2O_3 \times Fe_2O_3$	C_4AF	

8

Gypsum

$CaSO_4 \times H_2O$

CSH2

3.5

2.7.1 Physical properties of cement

As definition, cement is a binder, a substance used in construction industry with a huge value due to its properties of setting, hardens and adheres to other materials to bind them together. Cement is a seldom used on its own, but rather to bind sand and gravel or aggregate together. Cement mixed with fine aggregate produce mortar for masonry, or with sand and gravel produces concrete. Concrete is the largely used material in existence and is behind only water as the most useful in the world of construction of various infrastructures (Williams, 2017).

Cement used in construction are characterized by their physical properties. Some important parameters control the quality of cement therefore the physical properties of good cement are based on: fineness of cement ,soundness ,consistency ,strength ,setting time ,heat of hydration ,loss of ignition ,balk density and specific gravity . The Figure 5 below illustrate the schematic properties of cement both physical and chemical based on the parameters cited previously.

Figure 1: Physical and chemical properties of cement

• Fineness of cement

The size of the particles of the cement is its fineness. The required fineness of good cement is achieved through grinding the clinker in the last step of cement production process. As hydration rate of cement is directly related to the cement particle size, fineness of cement is very important.

• Soundness of cement

Soundness refers to the ability of cement to not shrink upon hardening. Good quality cement retains its volume after setting without delayed expansion, which is caused by excessive free lime and magnesia.

• Consistency of cement

Consistency of cement paste is its ability to flow .it is measured by Vicat Test . it is measured as follows : The plunger of the apparatus is brought down to touch the top surface of the cement. The plunger will penetrate the cement up to a certain depth depending on the consistency. Cement is said to have a normal consistency when the plunger penetrates 10¡À1 mm.

• Strength of cement

Three types of strength of cement are measured compressive, tensile and flexural. Various factors affect the strength such as water-cement ratio, cement-fine aggregate ratio, curing conditions, size and shape of a specimen, the manner of molding and mixing, loading conditions and age.

Compressive Strength: It is the most common strength test. A test specimen (50mm) is taken and subjected to a compressive load until failure. The loading sequence must be within 20 seconds and 80 seconds.

Tensile strength: Though this test used to be common during the early years of cement production, now it does not offer any useful information about the properties of cement.

Flexural strength: This is actually a measure of tensile strength in bending. The test is performed in a 40 x40 x 160 mm cement mortar beam, which is loaded at its center point until failure.

• Setting time of cement

Cement sets and hardens when water is added. This setting time can vary depending on multiple factors, such as fineness of cement, cement-water ratio, chemical content, and admixtures. Cement used in construction should have an initial setting time that is not too low and a final setting time not too high. Hence, two setting times are measured:

Initial set: When the paste begins to stiffen noticeably (typically occurs within 30-45 minutes)

Final set: When the cement hardens, being able to sustain some load (occurs below 10 hours)

• Heat of hydration

When water is added to cement, the reaction that takes place is called hydration. Hydration generates heat, which can affect the quality of the cement and also be beneficial in maintaining curing temperature during cold weather.

On the other hand, when heat generation is high, especially in large structures, it may cause undesired stress.

The heat of hydration is affected most by C3S and C3A present in cement, and also by water cement ratio, fineness and curing temperature.

The heat of hydration of Portland cement is calculated by determining the difference between the dry and the partially hydrated cement (obtained by comparing these at 7th and 28th days).

• Bulk density

When cement is mixed with water, the water replaces areas where there would normally be air. Because of that, the bulk density of cement is not very important. Cement has a varying range of density depending on the cement composition percentage. The density of cement may be anywhere from 62 to 78 pounds per cubic foot.

• Specific gravity

Specific gravity is generally used in mixture proportioning calculations. Portland cement has a specific gravity of 3.15, but other types of cement (for example, Portland-blast-furnace-slag and Portland-Pozzolan cement) may have specific gravities of about 2.90.

2.7.2. Sawdust ash

Sawdust is a waste product of woodworking operations such as sawing, milling; planning and routing .it is composed of small chipping of wood. These operations can be performed by wood working machinery. The material are largely from woodwork industry or carpentry and then processed to become ash by burning them slowly in a container. The Figure 6 below shows the circula saw in a carpentry of Musanze sector, and the sawdust to be collected and burned for finding the appropriate ash required for the research.

Figure 2: Sawdust burned to become sawdust ash (SDA).

Sawdust ash which was obtained was sieved and large particles retained on the 600micro meter sieve were discarded while those passing the sieve were used for the work this are particle size distribution shown in the figure below.

Figure 3: Particle size distribution

Chemical composition of sawdust ash

The chemical composition of sawdust ash proved to be the pozzolanic material and can be used as cement and or in partial replacement or blended cement. Chemical composition are shown in a Table below:

Table 2: Chemical composition of Sawdust Ash (SDA)

Parameter

Alumina

($Al2O3$)

Silica

($SiO2$)

Calcium

(CaO)

iron

($Fe2O3$)

Magnesium

(MgO)

sodium

($Na2O$)

potassium

($K2O$)

%composition

9.85

62.87

10.35

4.45

4.18

0.035

1.17

Source: ASTM C 618 Standard

The composition of $SiO_2+Al_2O_3+Fe_2O_3$ is about 77.17% according to IS. 3812:2003 the SDA behave as Pozzolana material.

2.8. Pavement deterioration

Pavement deterioration is the process by which distress (defects) develop in the pavement under the combined effects of traffic loading and environmental conditions. (Norman, 2021).

2.8.1. Types of road defect

Road defect are different due to their causes, paved road may be structurally deteriorate or functionally deteriorates (Hoban et al., 2024). These two major types of deterioration are divided into sub types which are:

cracking is a load associated structural failure .the failure can be due to weakness in the surface ,base or subgrade knowing that the pavement structure of road in Rwanda is composed of three layers ,the illustrated pavement structure be a thin wearing course according to the Figure 6 illustrated below.

Figure 4: Pavement structure

Cracking may be longitudinal, transverse, block or crocodile therefore longitudinal cracking are cracks that are parallel to the pavements centerline or laydown deflection. (Brett , 2019).Whereas transverse cracking these type of cracks are not restricted to the wheel paths and may occur because of poor construction techniques (e.g. Asphalt overlay construction joint) settlement of embankments or active clay subgrades. These are line cracks running longitudinally along the pavement .they are often located near the edge of the pavement (Derek, 2021). Although these cracks are not normally caused by traffic, the action of traffic and lack of maintenance can lead to crocodile cracking in the wheel path in the form of small longitudinal cracks. The Figure 7 below illustrates the severe cracks on degree 5 according to (TMH9, 2021). The deterioration of that extent requires the full depth maintenance and the road must be undergoing the rehabilitation.

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Figure 5: Severe crack degree five

Block cracking or stabilization crack therefore blocks are normally caused by the shrinkage of treated pavement layers, the cracks are not only confined to the wheel paths but also in the edge of the road ,there are characterized by cracks of definite block pattern and longitudinal and transverse cracks do not always meet. According to Derek P. (2021), the spacing of the cracks depends on the type of the material, the type and the quantity of stabilizing or modifying agent used; furthermore, these kinds of defects cover a large area and may occur where there is no traffic.

The cracks do not necessarily indicate significant deterioration of the pavement but a potential for deterioration. Traffic action may lead to the formation of secondary cracks which could eventually lead to severe defects. It is often difficult to distinguish between block cracks and a combination of longitudinal and transverse cracks on a particular road segment. In such case, cracks should be classified in one of two-option i.e. the more predominant type. The Figure 9 illustrates the stabilization crack/ block degree of deterioration 4 according to (TMH9 2023).

Then the Figure above which follows is showing another type of defect which is blocking cracking in severe condition that affects the serviceability, comfort due to the cracks. This kind of defect is predominant in developing countries where the structure of pavement condition is not considered much due to budget constraint allocated to the infrastructure such as roads and they opt for the alternative to the decision maker. Maintenance comes late though the increase of cost for road users, road agency .i.e. operating cost, maintenance cost respectively. The Figure below is showing the degree of deterioration rated 4.

Figure 6: Crack of degree 4 according to TMH9 (2008)

The following illustration is for defect called block crack in severe condition the Figure 9 as follows below.

Figure 7: Block crack in severe condition degree 5 according to the rating and extent of the distress (TMH9, 2008).

- Transverse cracks

Transverse crack are line cracks across the pavement. They are often a first manifestation of shrinkage in a cement stabilized base or sub-base ,but may also be a sign of active clay in the subgrade .Transverse cracks can also be a sign of a temperature associated fatigue and seasonal effect. They are normally not related to structural problems, but further deterioration of the pavement may occur with the ingress of water through the cracks. These cracks often occur at drainage structures or where services have been installed subsequent to initial construction by the pavement layers. They could indicate poor compaction of the material in the mediate vicinity of the cracks. Shrinkage cracks which often appear in an asphalt surface surfacing layer (map pattern) should not be noted as transverse cracks, but as surface cracks.

Crocodile or fatigue cracking is very often limited to the wheel path. Crocodile cracks normally occur as a result of fatigue of surfacing or base layers and are related to the inability of the pavement to carry the traffic load (Kallas, 2023). In addition, they may occur as a result traffic fatigue of dry or brittle surfacing layers in the wheel paths permitting the penetration of water into the pavement layers .in such cases there is initially no sign of rutting. Crocodile cracks also occur in isolated patches where failure is caused by poor drainage and sealed in moisture (Dong, 2017).

Initially crocodile cracking sometimes appears as fine irregular longitudinal cracks which grow progressively closer and eventually interconnect to form the familiar crocodile pattern (TMH9, 2017). These initially irregular fine cracks can be identified via visual assessment and rate the extent of the defect according to the indication of the pavement condition also TMH9 provide the way forward. Crocodile cracking also occurs as secondary cracking around primary line cracks. Higher degrees (degree >3) of crocodile crack are often accompanied by deformation. The Figure below illustrates the crocodile cracking.

The Figure below is showing the other defect accounted which is the crocodile cracks in severe condition.

Figure 8: Crocodile cracking degree 5

As conclusion paved road distress is the defect occur to the pavement structure caused by different factors such as traffic loading, climate, type of soil for subgrade, all these factors lead to the cracking resulting to the potholes finally poor riding quality. Traffic loading also affects the surface that results into deformation (smith et al., 2017).

2.8.2. Deformation

Deformation is the change in the road surface profile. This is manifested as an area of the pavement having its surface either above or below that of the original level. The following types of deformation are observed and may be assessed such as rutting and settlement or undulation.

Rutting results from compaction or shear deformation through the action of traffic and limited to the wheel paths. When the rutting is fairly wide and even shaped, the problem is normally in the lower pavement layers. When rutting is narrowed and more sharply defined, the problem normally lies within the upper pavement layers. Rutting frequently occurs together with crocodile cracking, especially for pavement structures with thin bituminous layers. (Hoban and Christopher, 2017). The Figure below shows the typical rutting example of degree five.

Figure 9: Rutting degree 5

2.8.3. Pumping

Pumping means the movement of the material constitutes the pavement underneath the slab or ejection of material from underneath the slab as a result of water pressure. The causes are the water accumulation underneath the slab. This can lead to linear cracking, corner breaks and faulting (Sparkes, 2021).

Pumping occurs when active pore pressures under traffic loading cause fine material to be pumped from within the pavement to the surface, normally through existing cracks (. Pumped out fines are visible along the cracks on the surfacing and there is usually a thin layer of fines next to the cracks which adheres to the surface layer. The figure below shows the degree of pumping distress failure according to (TMH9, 2022). Its degree of failure stand at severe state rated degree five. This is illustrated on the figure below.

Figure 10: Pumping distress degree 5

2.8.4. Potholing

Potholes mean loss of material from the base layer refer to structural failures and exclude surfacing failures (owing to loss of surfacing), the mechanism of failure is structured as the succession of traffic loading, leading to cracks and then fatigue of the surface material and finally pothole all the results of poor riding quality (AASHTO, 2023). The Figure shows the pothole of severe state rated degree five. The surface is seriously deteriorated the result of bad riding quality, due to its severe state the intervention is needed in terms of rehabilitation.

The evaluation of this kind of defect is based on visual inspection as an important aspect to understanding the condition index of pavement, maintenance and rehabilitation needs and priorities at network level for pavement management system (PMS).The visual distress is described by recording: the type, degree and the extent of occurrence (TMH9, 2024).

The condition index is the indication of the pavement distress and is showed within the spectrum of qualitative measure as Very Good, Good, Fair, Poor and Very poor rated from 1, 2, 3,4and 5 respectively. The figure below shows the pothole of degree 5.

Figure 11: Potholes due to disintegration

Shows the failure occurred over a large areas and or secondary defects have developed owing to the failures (diameter >300mm) concentration of significant failures the indication of its rating of degree five.

2.9. Functional features

The functional requirements of a road reflect the service it provides to the road user .they are predominantly those that govern the comfort, safety and speed of travel refers to level of service, the level of service is said when there is an improved service for the resources available, i.e. when the road capacity is improved and it is showing the best operating condition (Rajshahi, 2019). The various functional features to be regarded are the riding quality, skid resistance, surface drainage, and condition of the shoulders as well as edge breaking (Abulizi, 2017).

2.9.1. Riding quality

The riding quality of a pavement is defined as the general extent to which road users are satisfied or not satisfied for the service on their behalf are rated .Riding quality is seen in terms of ,   smoothness and comfort of driver. This is the subjective evaluation of the pavement roughness (Chandra, 2022). Riding quality is described in the table below.

Table 3: International Roughness Index

Degrees

Description

Approxi mate IRI*

(0) very good

Ride very smooth and very comfortable no unevenness of the road profile. no rutting raveling or even patching.

<2

(1) Good

Ride smooth, and comfortable slight an evenness of the road profile, slight rutting, raveling or uneven patching.

3

(2) fair

Ride smooth and slightly uncomfortable intermittent moderate unevenness of the road profile, moderate rutting, raveling or uneven patching.

3.5

(3) poor

Ride poor and uncomfortable ,frequent moderate unevenness of the road profile frequent rutting raveling and uneven patching ,comfortable driving speed below speed limit .

4.5

(4) very poor

Ride very poor and very uncomfortable extensive severe unevenness of the road profile, extensive rutting, raveling uneven patching, and comfortable driving speed much lower than speed limit, road unsafe due to severe unevenness.

>6

Source World Bank, 1986

IRI is average rectified slope (ratio of accumulated suspension motion to distance travelled at 80 km/h). As it is said above, 0 =perfect 4=Damaged. IRI is calculated following the formula equ.1 below. AASHTO PSI is also a measure of riding quality (Present Service Index) was subjective rating between 0-5. 0 =very bad condition, 5= excellent performance, 2.5= maintenance required. Performance criteria recommended for the assessment for riding quality is illustrated in the Table below where also the present serviceability index is also showed.

Table 4: Standard riding quality

Road category	Riding quality			
	PSI		IRI	
	X	Y	X	Y
A	3.0	2.5	2.9	3.5
B	2.5	2.0	3.5	4.2
C	2.0	1.5	4.2	5.1

Riding quality is one of measure of functional requirements of a paved road, such as the measure of roughness or bumping as well as present serviceability index (PSI). These parameters are measured or assessed to show the behavior of the paved skid resistance such as surface texture and friction. Some evaluation techniques of riding quality are based on AASHTO and IRI.

AASHTO, PSI is a measure basing on the axle load like considering single axles and tandem axles, the damage are different due to imposed traffic loads and type of vehicle. PSI was subjective to quality measures rating between 0 and 5. Whereby 0 =very bad condition, 5=excellent performance and 2.5=maintenance required (The Highway Capacity Manual, 2000).

International Roughness Index (IRI) is average rectified slope means ratio of accumulated suspension motion to distance travelled at 80 km/hr. and is rated from 0 to 5 where by 0=perfect, 5=damaged. However, zero roughness is considered apparent practically, zero it is not used. The practical IRI lies between 2 and 3.5 for our road class B .The equation is

$IRI = 7.436 - 4.132 \times \ln (PSI)$ Eq.1

2.10. Materials for soil stabilization

2.10.1. Sawdust ash and ordinary Portland cement (OPC)

As we are striving to use locally available materials in road construction especially in rehabilitation, the use of sawdust ash and OPC as partial replacement is of more advantage because cement is widely noted to be most expensive constituent in the mixture example of Concrete (Ramzi et al., 2002).

According to (Bosco Niyomukiza & Yasir, 2023), pozzolana is a siliceous or a siliceous aluminous material which contains little or cementitious value but in finely divided form and in the form and in the presence of moisture or water ,chemically reacts with calcium of moisture at ordinary temperature to form compound possessing cementitious properties . Such material includes sawdust ash due to the similar properties observed during experiment.

Saw dust is an organic waste resulting from the mechanical milling or processing of timber (wood) into various shapes and sizes. Saw dust ash has not found a known use or application as highway materials but have been used as partial replacement for cement in the making of bricks and concrete and had been found to contain pozzolanic properties in concrete (Shawl et al., 2017). This statement is similar to be the significant observation when it is used in road rehabilitation as stabilizer replacing cement.

2.10.2. Reclaimed asphaltic concrete (RAC).

Reclaimed asphalt pavement is a term allocated to the removed or reprocessed pavement materials containing asphalt and aggregate and these are not to neglect because they are used again in the formation of a new road pavement (Mousa, 2021). Asphalt concrete consists of a mixture of fine, course according to the grading specification to form a mixture of bituminous material such as emulsion or foamed. The RAP are generated when asphalts are removed for reconstruction, resurfacing or to obtain access to buried utilities. When crushed and screened reclaimed asphalts consist of high quality, well-graded aggregate coated by asphalt cement according to FHWA user guidelines for byproduct and secondary use Materials in pavement construction (Harold, 2023).

2.10.3. Cement

A cement is a binder, a substance that sets and hardens and can bind other materials together. It principal constituents for constructional purpose are compounds of Ca (calcareous) and Al + Si (argillaceous). Chemical Composition of Cement are Lime: 63%, Silica: 22%, Alumina: 06%, Iron oxide: 03% and Gypsum: 01 to 04%. The cements have property of setting and hardening under water, by virtue of certain chemical reaction with it and are called ‘hydraulic cements’. It is the variety of artificial cement. It is called Portland cement because on hardening (setting) its colour resembles to rocks near Portland in England (Abbas Khan, Omar Hamdi Jasim, 2020). “An extremely finely ground product by calcinising together , at above 1500oC , an intimate and properly proportioned mixture of argillaceous (clay) and calcareous (lime) raw materials, without the addition of anything subsequent to calcination , excepting the retarder gypsum” (Abbas Khan, Omar Hamdi Jasim, 2020).

CHAPTER III. RESEARCH METHODOLOGY

3.1. Introduction

This section described the procedures that will be followed in conducting the study. The techniques of obtaining data were also explained. The study area, population, sampling techniques, sample size, data collection instruments, data collection procedures and data analysis methods were discussed in details.

3.2. Description of the study area.

This study was conducted in Musanze Sector which is one of the 15 administrative sectors of Musanze district in the Northern Province of Rwanda. The geographical coordinates of Musanze sector are: 1°29'59.42"S, 29°38'5.89"E. This sector is composed with 6 cells including Cyabagarura, Garuka, Kabazungu, Nyarubuye I, Rwambogo and Cyabagarura. This sector has 47,720 Population [2022]; 1,451/km² Population Density and 32.90 km2 area.

Figure 12: Administrative map of Musanze sector, Musanze district

3.3. Materials

The current study employed expansive soil and sawdust ash (SDA). A thorough description of these materials is presented as follows:

3.3.1. Expansive soil

Soil sample was obtained from Musanze sector.

3.3.2. Sawdust ash

The sawdust utilized in this study was sourced from a local carpentry workshop in Musanze sector.

3.3.3. Cement

A cement is a binder, a chemical substance used for construction that sets, hardens, and adheres to other materials to bind them together. Cement is seldom used on its own, but rather to bind sand and gravel (aggregate) together. In this study, researcher will use Twiga Cement 42.5 N model.

Table 5: Materials characteristics

Bitumen properties

Penetration at 250c dmm

79

Penetration index

-0.5

Temperature

30

Normally reclaimed asphalt pavement (RAP) is the term given to removed and or/reprocessed pavement materials containing asphalt and aggregates. These materials are usually generated from milling, pavement removal and waste taken from existing paved road (Kallas, 1994).

The RAP used was brought in University of Rwanda, College of science and technology laboratory especially highway laboratory to be tested: first the test of bitumen extraction was performed .This test consists of separating the aged bitumen from aggregate, and remains with the mixture of coarse aggregate, fine aggregate and sand dust. Grading analysis was performed then to make the mixture, smaller sample size for grading analysis in accordance to ASTM C 702. The RAP was air dried before use for the test. Then the other physical and mechanical properties were analyzed through laboratory test such as Aggregate Impact Value Test, Los Angeles Abrasion value Test, Flakiness Index Test and

Elongation Index Test.

Saw dust – sawdust was obtained from the carpentry Workshop University of Rwanda –college of science and technology then burned to convert into ash to be utilized in this research. The ash was passed through a sieve No .200 with 0.075 mm aperture before use for the study. The figure 15 below illustrates the sample obtained after burning the sawdust to become SDA.

Figure 13: Sawdust ash sample and crushed stone dust

Saw dust ash is a good partial replacement of cement in stabilization as it shows to contain pozzolanic properties in concrete, the reason to be used in recycled asphalt concrete for highway rehabilitation and maintenance (Praveen, 2015). Cement and sawdust ash were used as mineral filler to perform the marshal test to analyze the performance of the mixture flow and stability. The 79 penetration grade bitumen was chosen for the research.

3.4. Methods used in this study

This research evaluates the performance of RAP stabilized with the sawdust ash and cement as partially replacement of active filler in the mixture (AC). This was achieved by preparing the samples including RAP aggregates by bitumen extraction a three samples A, B and C the extraction was done by centrifuge method by using the dichlomethane liquid reactant in form of solution poured in the reclaimed asphalt pavement (RAP), the aggregates of 552 grams were first extracted and ready to be sieved for gradation from 12.5 up 0.075mm.the bitumen properties were also determined as seen in table 6 in order to know the stiffness of the binder later in the analysis of the penetration , softening points as they are important.

Separate the bitumen from aggregates and preparation of bitumen and heat it at 190Oc and at different percentage 4; 5; 5.5 and 6 thoroughly mixed with different grade size of aggregates ,and the different percentage of sawdust partially replacement of the active filler i.e crushed stone dust 0 ;30;50;70;100 percent then subjected to marshal test apparatus to determine the behavior of the mixture in terms of flow and stability ,air voids VMA . These tests are performed before the aggregates tests have been performed such as sieve, aggregate impact, flakiness and elongation for the purpose of knowing the texture and the strength and durability of the aggregates material in the mixture.

Aggregate physical and mechanical test performed procedures:

3.4.1. Sieve analysis

The test was performed to determine the particle size distribution of the coarse and fine aggregates. This is done by sieving the aggregates on different sieves as standardized and then passes aggregates through them and thus collects different sized particles left over different sieves.

Apparatus:

• A set of sieve of different sizes

• Balance with an accuracy to 0.1g

• Oven

The sample for sieving should be prepared from the larger sample either by quartering or by means of a sample divider.

Procedure:

 The test sample is washed to remove all impurities.

 The test sample is dried to a constant weight at a temperature of 110±5oc and weighed.

 The sample is sieved by using a set of sieves

 On completion of sieving, the material on each sieve is weighed

 Cumulative weight passing through each sieve is calculated as a percentage of the total sample weight.

The sample for sieving should be prepared from the larger sample either by quartering or by means of a sample divider.

Procedure:

 The test sample is washed to remove all impurities.

 The test sample is dried to a constant weight at a temperature of 110±5oc and weighed.

- The sample is sieved by using a set of sieves
- On completion of sieving, the material on each sieve is weighed
- Cumulative weight passing through each sieve is calculated as a percentage of the total sample weight
- Fineness modulus is obtained by adding cumulative percentage of aggregate retained at each sieve and dividing the sum by 100. Calculation and reporting

The results shall be calculated and reported as the cumulative percentage by weight of the total sample then the percentage by weight of the total sample passing through one sieve and retained on the next smaller sieve, to the nearest 0.1 percent.

The results of sieve analysis must be recorded on a semi log graph with particle size as abscissa (log scale) and the percentage smaller than the specified diameter as ordinate. The Figure 16 shows the sieve analysis graph.

Figure 14: Sieve analysis log- graph

3.4.2. Aggregate impact value (AIV)

3.4.2.1 Theory

Impact value of an aggregate is the percentage loss of particles passing 2.36mm sieve by the application or load by means of 15 blows of standard hammer and drop, under specified test condition. The aggregate impact value gives a relative measure of resistance of an aggregate to sudden shock or impact, which in some aggregate differs from their resistance to the slowly applied compressive load.

The property of a material to resist impact is known as toughness (Fleck and smith, 1984). Due to movement of vehicles on the road the aggregates are subjected to impact resulting in their breaking down into smaller pieces. The aggregates should therefore have sufficient toughness to resist their disintegration due to impact. This characteristic is measured by impact value test. The aggregate impact value is a measure of resistance to sudden impact or shock, which may differ from its resistance to gradually applied compressive load (Taylor, 1985).

Aim:

(i) To determine the impact value of the road aggregates;

(ii) To assess their suitability in road construction on the basis of impact value.

Apparatus

The apparatus as per IS: 2386 (Part IV) – 1963 consists of:

(i) A testing machine weighing 45 to 60 kg and having a metal base with a painted lower surface of not less than 30 cm in diameter. It is supported on level and plane concrete floor of minimum 45 cm thickness. The machine should also have provisions for fixing its base.

(ii) A cylindrical steel cup of internal diameter 102 mm, depth 50 mm and minimum thickness 6.3 mm.

(iii) A metal hammer weighing 13.5 to 14.0 kg the lower end being cylindrical in shape, 50 mm long, 100.0 mm in diameter, with a 2 mm chamfer at the lower edge and case hardened. The hammer should slide freely between vertical guides and be concentric with the cup. Free fall of hammer should be within 380±5 mm.

(iv) A cylindrical metal measure having internal diameter 75 mm and depth 50 mm for measuring aggregates.

(v) Tamping rod 10 mm in diameter and 230 mm long, rounded at one end.

(vi) A balance of capacity not less than 500g, readable and accurate up to 0.1 g.

Procedure

The test sample consists of aggregates sized 10.0 mm 12.5 mm. Aggregates may be dried by heating at 100-110° C for a period of 4 hours and cooled.

(i) Sieve the material through 12.5 mm and 10.0mm IS sieves. The aggregates

Passing through 12.5mm sieve and retained on 10.0mm sieve comprises the test material.

(ii) Pour the aggregates to fill about just 1/3 rd depth of measuring cylinder.

(iii) Compact the material by giving 25 gentle blows with the rounded end of the tamping rod.

(iv) Add two more layers in similar manner, so that cylinder is full.

(v) Strike off the surplus aggregates.

(vi) Determine the net weight of the aggregates to the nearest gram (W).

(vii) Bring the impact machine to rest without wedging or packing up on the level plate, block or floor, so that it is rigid and the hammer guide columns are vertical.

(viii) Fix the cup firmly in position on the base of machine and place whole of the test sample in it and compact by giving 25 gentle strokes with tamping rod.

(ix) Raise the hammer until its lower face is 380 mm above the surface of aggregate sample inthe cup and allow it to fall freely on the aggregate sample. Give 15 such blows at an interval of not less than one second between successive falls.

(x) Remove the crushed aggregate from the cup and sieve it through 2.36 mm IS sieves until no further significant amount passes in one minute. Weigh the fraction passing the sieve to an accuracy of 1 gm. Also, weigh the fraction retained in the sieve.

Compute the aggregate impact value. The mean of two observations, rounded to nearest whole number is reported as the Aggregate Impact Value.

Observation:

Total weight of dry sample (W1) in grams

Weight of portion passing 2.36 mm sieve (W2) in grams

Aggregate impact value is shown in the equation 1 below in terms of percentage

Eq.1

The mean of two samples are considered and there are recommended value following the classification of aggregate using the Aggregate Impact Value (AIV).The Table 6 below is showing the recommended value of AIV. The classification and the values are considered in order make a decision making in regard to the strength of aggregate chosen for road construction .in fact this values help to carry out the standardize report whereby the results may be accepted or rejected .

The quality of aggregate will pray a big role in asphalt mixture that it simulate the behavior of the surface course one of the important layer that carry the most of the load imposed. Such as traffic load the load is transmitted through surface course to be distribute to other respective layers base, subbase and subgrade (AASHTO, 1993).Table 6 below shows the recommended values for Aggregate Impact Value.

Table 6: Recommended value of AIV

Aggregate impact value	Classification
>10 %	Exceptional strong
10-20%	Strong
20-30 %	Satisfactory for road surfacing
<35%	Weak

-

3.4.3. Flakiness index test

This method is based on the classification of aggregate particles as flaky when have a thickness (smaller dimension) of less than 0.6 of their nominal size, this size being taken as the mean of the limiting sieve apertures used for determining the size fraction in which the particle occurs (IS2386.part I ,1963).

The flakiness index of aggregate sample is found by separating the flaky particles and expressing their mass as a percentage of the sample tested.

The taste is not applicable to material passing a 6.3mm BS test sieve.

- Apparatus

A metal thickness gauge or special sieves having elongated apertures. The width of the apertures and thickness of the sheet used in the gauge or sieve shall be as specified. The figure17 shows the elongation and flakiness apparatus used to carry out the test of shape, texture of aggregate chosen to be used for the mixture in asphalt pavement. The performance is measure in terms of surface texture, i.e riding quality, international roughness index. When make asphalt mixture also intend to find the state of the surface with regard to the deformation and rutting explained by the two parameters such as stability and flow so the shape of aggregate will determine the bond, the adherence between the bitumen and the aggregate, the result of good performance of the surface layer structure. The flexible pavement has the quality of resisting water penetration into the structure due to its bond between bitumen and aggregates with specified shapes that is important in structural pavement design (Theyse, 2000).The Figure 17 shows the apparatus used to measure the flakiness and elongation in the laboratory.

Figure 17: Elongation and Flakiness apparatus

Thickness and length of gauge as BS test sieve is shown in the following Table 7 below.

Table 7: Thickness and length according to BS test sieve

Aggregate size fraction BS test sieve nominal aperture size

Thickness of gauge width of slots

Length gauge Gap pin between.

Minimum mass for subdivision

100%

passing(mm)

100%

retained(mm)

Mm

Mm

Kg

63.0

50.0

33.9±0.3

50.0

37.5

26.3±0.3

78.7±0.3

35

37.5

28.0

19.7±0.3

59.9±0.3

15

28.0

20.0

14.4±0.15

43.2±03

5

20.0

14.0

10.2±015

30.6±0.3

2

14.0

10.0

7.2±0.1

21.6±0.3

1

10.0

6.30

4.9±0.1

14.7±0.2

0.5

A balance with the accuracy of 0.1 % of the mass of the sample is used.

Procedure

 Carrying out a sieve analysis as indicated on the above table

 Discard all aggregate retained on the 63.0mm BS sieve and all aggregate passing

 6.3mm BS test sieve.

 Weight each of the individual size fractions retained on the sieves other than the 63.0mm BS test sieve and store them on separate trays sizes marked on the trays.

 From the sums of the masses (M1) calculate the individual percentage retained on each of the various sieves. Discard any fraction of which the mass is 5% or less of the mass (W1).record the mass remaining (M2) .Gauge each fraction by on the following procedures:

 Combine and weigh all particles passing the gauges or special sieves (M3).

The equation 2 is shown below for the calculation of flakiness index.

• Calculation

Eq.2

3.4.4. Elongation index test

This test is based on the classification of aggregates particles as elongated when they have a length (greater dimension of more 1.8 of their nominal size being taken as the mean of the limiting aperture used for determining the size fraction in which the particles occurs (Bouquet,2006).

The elongation of particles and expressing their mass as a percentage of the mass of the sample tested. The test is not applicable to material passing 6.3mm BS sieve or retained on a 6.3mm BS sieve.

Apparatus:

• A metal length with gauge length

• BS test sieves

• A balance to 0.1% of the mass to be tested

Procedure:

- Carry out a sieve analysis using the sieves
- Discard all aggregate retained on a 6.3mm BS sieve and all aggregates passing a 50.0mm BS sieve.
- Weigh and store each individual size-fraction retained on the other sieves in separate trays with their sizes marked on the tray.
- From the sum of the masses of fractions in trays (M1) calculate individual percentages retained of each the various sieves. Discard any fraction whose mass is 5% or less of mass (M2)
- Gauge each fraction as follows;
- Select the length gauge appropriate to the size fraction under test and gauge each particle separately by hand.
- Elongated particles are those whose greatest dimension prevents them from passing through the gauge.

Combine and weigh all elongated particles (M3)

Calculation of elongation index is calculated in the equation that follows in equation 2 below

Eq.3

Where by the M1 and M2 are discussed above.

3.4.5. Bitumen tests

3.4.5.1. Bitumen extraction test method

The Figure 15 below is the sample of reclaimed asphalt in the laboratory to be used for the extraction of bitumen in order to determine the bitumen content. These are the samples obtained from KMH (Kanombe Military Hospital) a section of road rehabilitated using in place recycling technology with sand base. By NPD-COTRACO.

Figure 15: Reclaimed asphalt pavement sample

The process of extracting is done by centrifugal method where the aggregate should be separated with bitumen using the reactant called dichlomethane, is a liquid poured into the mass and in the equipment and close, after the equipment is put on and the materials inside are revolved and increase gradually to a maximum of 3600 rpm. The Figure 16 below is the sample after extraction in the equipment.

Figure 16: Sample after extraction in the equipment

This test was performed in the asphalt and bitumen laboratory in College of Science and Technology (CST), University of Rwanda .Its purpose was to determine the bitumen content in the reclaimed asphalt pavement brought for the research, and then RAP were to be as the original aggregate to be used in the marshal test and the mineral filler (crushed stone dust) were replaced by the sawdust ash and cement by 0;30;50;70 and100 percent in order to balance between the density of sawdust ash that has lighter density of 1.18 . The figure 20 below shows the RAP in the container.

Figure 17: sample of RAP after extraction

Test procedure

Fill the dichlomethane as dissolvent into the cup up to the sample top (as thoroughly soaked). The dichlomethane was separated the aggregate and bitumen. Now place the filter paper and cover the sample in the centrifuge apparatus .Now place the container at the outlet of the centrifuge to collect the extracted sample.

This test is important because the various pavement properties such as durability, compatibility and resistance to various defects and failure such as Raveling, Rutting, bleeding depend upon the content of the bitumen present in the aggregate. The Table 8 below illustrates the observation and calculation sample of bitumen extraction.

Table 8: Observation and calculation

SN

OBSERVATION

SAMPLE 1

SAMPLE2

SAMPLE 3

1

Weight before extraction

W1

2

Weight of filter paper before extraction B

3

Weight after extraction

W2

4

Weight of filter paper after extraction D

5

Weight of filler collected in filter paper(B-D)=W3

The formula to calculate the percentage of binder content is given by

Eq.3

3.4.5.2. Penetration test

Penetration test is done to determine the penetration grade of bitumen in order to assess the consistency of the bitumen regarding their performance on the particular climate of the specified region (Bala, 2007).

The principle is that, the penetration of a bituminous material is the distance in tenth of a millimeter that a standard needle would penetrate vertically into a sample of the material under standard conditions of temperature, load and time.

Apparatus

• Penetrometer with a standard needle

• Three sample cup about 55 mm diameter and 35 deep each

• Water bath

• Thermometer 0 to 440c graduation 0.2 0c

Sample preparation

Bitumen should be just sufficient to fill the container to a depth of at least 15mm in excess of the expected penetration.

Procedure

1. Soften the bitumen above the softening point (between 75 and 100 0c). Stir it thoroughly to remove air bubbles and water.
2. Pour it into container to a depth of at least 15 mm in excess of the expected penetration
3. Cool it at an atmospheric temperature of 15 to 30 0c for one hour and half. Then place it in a transfer dish in the water bath at 250c +0.10c for one hour and a half.
4. Keep the container on the stand of the penetration apparatus
5. Adjust the needle to make a contact with the surface of the sample.
6. Adjust the dial reading to zero
7. With the help of the timer ,release the needle for exactly for 5 seconds
8. Record the dial reading

9. Repeat the above procedure three times

The value of penetration reported should be the mean of not less than three determinations expressed in tenths of mm.

3.4.6. Marshal stability and flow test procedure

This test is designed to determine the ability of the asphalt mixture to withstand the deformation defect due to the load caused by the wheel truck (ASTM D6927, 1985).

Procedure

The sample should be of 1200 gr of the dry aggregates (RAP) extracted from bitumen, coarse aggregate, fine aggregates, filler and the percentage bitumen of 4, 4.5; 5; 5.5 and 6 percent respectively. The aggregate should be heated to 1600c. The heated aggregate was placed in a pan and mixed thoroughly. A crater was formed in the aggregate and the 79 penetration grade bitumen heated to 1600c was added. The aggregate and the bitumen were mixed thoroughly until the RAP aggregates were well coated ,then thoroughly cleaned sample mold assembly and the compaction hammer was heated to 1600c.

A filter paper was placed in the bottom of the mold and the mixture was placed in the mold and trimmed with a spatula around the perimeter. The collar was removed and the surface of the mix was smoothened with a trowel to a slightly rounded shape. Temperature of the mixture immediately prior to compaction was maintained at 1500c in the oven. The collar was replaced, and the mold assembly was placed on the compaction pedestal in the mold holder, and the top of the specimen was given 65 blows. The baseplate and the collar were removed and the sample was inverted and the mold reassembled. The inverted face was also given 65 blows. After compaction, the baseplate was removed and the mold containing the specimen was immersed in cool water for two minutes .The specimen was removed from the mold by the means of sample extractor and a suitable jack and flame arrangement .The specimen was placed on a smooth, flat surface and allowed to cool at room temperature for 24 hours.

3.4.7. Density determination

The specimen was weighed in air and in clean water at a room temperature, the percent density or percent compaction is the ratio of the actual Ga of the compacted bituminous mixture specimen to the theoretical maximum specific gravity of the combined aggregates and asphalt contained in the specimen expressed as a percentage, density is calculated as follows in Kg/m3 The calculation of density is calculated as taking the mass of briquet (A) divide by the difference of saturated surface dry (B) and the mass of briquet in water (C) .

eq.1

3.4.8. Specific gravity

Specific gravity will be determined for every single component of the asphaltic mixture such as coarse aggregate, fine aggregate, cement and sawdust ash (SDA) these last are filler as well as the specific gravity of stone dust as the control sample as the ordinary filler in the mix.

Specific gravity procedure

The specific gravity is computed as the ratio of the weight in air of a given volume of soil particles at a stated temperature to the weight in air of an equal volume of distilled water at the same temperature.

- Coarse aggregate specific gravity is needed to determine weight- to -volume relationships and to calculate various volume related quantities such as Voids in Mineral Aggregate (VMA), and Voids Filled by Asphalt (VFA), and also is normally used in construction ranges from 2.5 to 3.0 with an average value of about 2.68, specific gravity is an indication of strength means that material having higher specific gravity is generally considered as having higher strength.
- Cement will also have to be tested for specific gravity as it is going to be assessed in terms of mixture proportion to know the behavior of the material in water. The specific gravity of Portland cement is generally around 3.15 while the specific gravity of Portland-blast furnace slag and Portland –pozzolan cements may have specific gravities near 2.90 (PCA ,1988).
- Sawdust ash

Sawdust ash has a specific gravity of 1.18 and PH 9.5, dry extract by mass of 40%

3.4.9. Stability and flow determination

The sample was brought to test temperature by immersing in water bath for 20 to 40 minutes .The sample was properly put into the test breaking head .The upper segment of the breaking head was placed on the specimen and the complete assembly was placed in the position on the testing equipment. The flow and stability are read automatically on the machine after that the load was released then the stability and flow were to be recorded on the start of breaking of the specimen, the marshal stability machine with the specimen in place is shown in Figure 18 below.

Figure 18: Marshall Stability testing machine

All experiments procedures are carried out in accordance to the standards specifications ASTM C618 -92a, 1994. Various proportions of sawdust ash (SDA) passing through sieve No. 200 and in equal proportion with cement were stabilized with various RAP aggregates (the appropriate peak proportions was however determined during the preliminary mix design tests). The RAP used was crushed using LOS Abrasion from its state to smaller particle sizes ,passed through a 28mm aperture sieve was air dried and sieved after they are mixed with bitumen in percent, up to 6 percent as bitumen percentage, 20 samples with 450 gr. of the fines to be in a different proportion as seen below:

Sample 1: 4%; 5%; 5.5; 6% bitumen with 100 percent SDA as filler

Sample 2: 4%; 5% 5.5%.; 6% bitumen with 70 percent SDA as filler

Sample 3: 4%; 5%, 5.5%;6% bitumen with 50 percent SDA as filler

Sample 4: 4%; 5%; 5.5%; 6% bitumen with 30 percent SDA as filler

Sample 5: 4%; 5%; 5.5%; 6% bitumen with 0 percent SDA as filler and 100 percent crushed stone dust (CSD)

The masses required were also determined to ease the calculation of bulk specific gravity and other parameter

The core was organized as follows to determine the specific gravity of each sample at the optimum binder of 5%. The table 9 below following the formula eq.1

Table 9: Specific gravity

CHAPTER IV: RESULTS AND DISCUSSION

4.1. Bitumen extraction test results

In this study the use of sawdust ash stabilization on the reclaimed asphalt pavement (RAP), to assess the behavior of the sawdust ash in the asphalt mix composed of different percentage replacement of the crushed stone dust as filler (CSD) have been investigated and studied via experimental driven data. The results of three samples from laboratory are presented through the tables and figures respectively. Example below is the presentation of results of first experiment in form of table that is Table 10. This test is performed according to EN 12697-1 Sample A

Table 10: Bitumen extraction results sample A

A	Weight of asphalt in gr.	552.0
B	Weight of empty Aluminum cup in gr.	258.0
C	Weight of aluminum cup with filler in gr.	288.6

D

Weight of aggregate recovered on sieve in gr.

483.0

E

Weight of filler recovered in gr.(C-B)

30.6

F

TOTAL weight of aggregates in gr.(D+E)

513.6

G

Weight of bitumen extracted in gr.(A-F)

38.4

Bitumen content ((G/F) * 100

7.5

The percentage of bitumen content present in the first sample of 552gr pavement is 7.5 Percent bitumen in old asphalt concrete at the section Kanombe Military Hospital (KMH).

Particles size distribution: particle size distribution or sieve analysis of coarse –grained particles (sand and gravel fraction) was carried out in order to group the particles into separate ranges of sizes and to determine the relative proportion by mass of each size range. To achieve this sample/stabilized sample was passed through successively smaller mesh sizes. The weight of asphalt concrete crushed sample retained on each sieve was calculated. Furthermore the particle size distribution was compared through results obtained with virgin aggregate and sand base of the road in a case study KMH.

As we have discussed for the experiment above of knowing the bitumen content in the sample A the following sample B is also to determine its bitumen content through extraction the variables are to be three to provide the good results as the experiment results shows in the Table 11 below.

Table 11: Bitumen extraction results sample B

A	Weight of asphalt in gr.	652.0
B	Weight of empty aluminium cup in gr.	258.0
C	Weight of aluminum cup with filler in gr.	288.6
D	Weight of aggregate recovered on sieve in gr.	583.0
E	Weight of filler recovered in gr.(C-B)	30.6
F	TOTAL weight of aggregates in gr.(D+E)	613.6
G	Weight of bitumen extracted in gr.(A-F)	39.0
	Bitumen content ((G/F)*100)	6.3

The following Table 11 is also discussing the results of bitumen extraction sample C where by the results are quite similar to the first and second extraction bitumen percentage due to the design procedure done before the analysis period and design period this determine the life cycle , maintenance and rehabilitation strategy of the country through pavement condition and time. The results are of great importance because the RAP to be used are not enough impregnated by the bitumen though recycling is simple and viable to be sustainable during the execution period in regard of rehabilitation and maintenance.

The Table 12 below shows the bitumen extraction for the samples C extracted during the test and the bitumen content of 4.7

Table 12: Bitumen extraction sample C

A	Weight of asphalt in gr.	582.0
B	Weight of empty aluminium cup in gr.	258.0
C	Weight of aluminum cup with filler in gr.	288.6
D	Weight of aggregate recovered on sieve in gr.	525.3
E	Weight of filler recovered in gr.(C-B)	30.6
F	TOTAL weight of aggregates in gr.(D+E)	555.6

G	Weight of bitumen extracted in gr.(A-F)	26.4
	Bitumen content ((G/F) * 100	4.7

The summary below is the average bitumen percentage of the KMH road by recycling sand base application executed by NPD –COTRACO where the average is understandable and the RAP can be useful in terms of gradation as the objective of extraction. The summary of the results shows the compilation of the samples from A, B and C where the results are 7.4; 6.2 and 4.7 respectively. The average shows give 6.2 percentage bitumen content in the sample obtained from the field by milling

The summary of the results are illustrated in the Table 13 below

Table 13: Summary

Samples	A	B	C
%bitumen	7.4	6.2	4.7
Average	6.2		

Considering the percentage of bitumen varying according to the location of sample extracted, sample was extracted in center line of the rehabilitated road KMH and sample B at the verge of shoulder and the third sample shows less bitumen content. The extraction of the binder was to help in the gradation process to facilitate the sieve and the gradation help in the mixture. The reclaimed asphalt pavement will show good quality of being reused in as the material in the 8 asphalt mixture. The Figure 19 below present the results of bitumen content distribution for7 different three first

Figure 19: Bitumen content distribution

The Figure 20 below shows the average percentage of the bitumen extracted for three samples

Showing how the average is behaving, the bitumen content found show that the aggregate were coated enough first sample.

Figure 20: Average bitumen content in percentage

4.1.1 Aggregate testing results

Aggregate testing of RAP extracted of bitumen has been conducted in laboratory including physical test such as particle size distribution. This is a fundamental property, which governs how an aggregate will perform in the mixture.

The aggregates tests include sieve analysis where by the gradation will be examined, percentage passing is of great importance, because the durability of an aggregate it's a measure of its ability to resist deterioration in service and so retain its original grading ,shape and physico mechanical properties during the service of the road.

The good mixture with bitumen and well graded particles contribute to the strength of the pavement which shows the resistance to the deterioration at early age due to traffic loading, and environmental effect such as climate, rain water which penetrate within the bond.

4.1.1.1. Sieve analysis for sample A

This experiment is performed according to EN 933-1 specification and the sample A are obtained from aggregate separated by using bitumen extraction test sample A as well, the sample A is weighing 483 grams. The Table 13 below show the gradation of the aggregates that even there are of reusing purpose they show the well graded sample to be used without any other supplement of aggregate as it is shown for the purpose of asphalt mixture the presence of coarse and fine aggregate required.

Table 14: Sieve analysis data

Sieve (mm)	Cumulative retained (g)	%passing
20	0.0	100.0
16	0.0	100.0
14	0.0	

100.0

12.5

3.0

99.4

10

34.0

93.4

8

68.0

86.8

6.3

126.0

75.5

4

266.0

48.2

2

336.0

34.6

1

372.0

27.6

0.5

407.0

20.8

0.315

432.0

15.9

0.25

443.0

13.7

0.08

483.0

6.0

The Figure 21 that follows shows the result in terms of log-graph it goes with the first sample of aggregate 483grams. The graph is showing the well graded sample as it is given in the previous table of gradation of the first sample A

Graph of particle size distribution sample A

Figure 21: Sieve analysis graph A

As we have three samples previously now the sieve analysis is done to the second sample of aggregate extracted from bitumen by the extraction method as it was done by centrifuge, the Table 15 below shows also the gradation of RAP aggregates those are showing the well graded as we can see on the log graph after word.

Table 15: Sieve analysis data B

Sieve (mm)

Cumulative retained (g)

%passing

20

0.0

100.0

16

0.0

100.0

14

0.0

100.0

12.5

3.0

98.9

10

34.0

89.9

8

68.0

81.0

6.3

126.0

69.6

4

266.0

46.8

2

336.0

33.8

1

372.0

28.8

0.5

407.0

22.6

0.315

432.0

13.5

0.25

443.0

7.4

0.08

483.0

4.8

The Figure 22 below is the log-graph of the second sample respectively as it done methodologically from first sample, the result are shown in terms of sieve analysis graph this graph is showing the well graded aggregate to be used in the mix of asphalt as it is the objective of this research which is to determine marshal stability and flow of the mix by replacing the crushed stone dust as filler (CSD), by sawdust ash and cement as filler material.

Graph of particle size distribution B

Figure 22: Sieve analysis graph B

The experiment that is following is to find also the sample number three, sample C to determine its gradation by separating the reused aggregate, the sample C also show the well graded behavior and it is well to be used in the mix. The Table 16 illustrates the sieve analysis for the aggregate extracted sample

Table 16: Sieve analysis for the aggregate extracted sample

Sieve (mm)	Cumulative retained (g)	%passing
20	0.0	100.0
16	0.0	100.0
14	0.0	100.0
12.5	3.0	100.0
10	34.0	94.7
8	68.0	86.7
6.3	126.0	

76.8

4

266.0

53.3

2

336.0

37.2

1

372.0

28.5

0.5

407.0

17.8

0.315

432.0

14.9

0.25

443.0

8.3

0.08

483.0

5.3

Sieve analysis graph according to EN 933-1 (passing in %) sample C is shown in Figure 23 below also well graded sample.

Figure 23: Sieve analysis graph C

Discussion summary of gradation

The previous chapter shows the gradation of RAP particles after extracting the bitumen, the results shows that all three samples take A, B and C were well graded particles. The sign that the rehabilitation of the pave road will reuse the aggregate in place, which will be reclaimed, and stabilized with cement and saw dust as filler i.e crushed stone dust.

4.1.2 Aggregate particle shape

In both natural and crushed rock aggregate the particles within a particular size fraction have a range of shapes .the shape reflect intrinsic petrological –petrographic characteristics of the material, environmental effects plays a role in their formation and process.

BS 812:part 103: 1985 groups the aggregates particles into six shapes : rounded ,irregular, angular ,flaky, elongated and elongated or flaky.

a) Flakiness: This is restricted to aggregate coarser than 6.5 and is an expression of the weight –percentage of particles, in a minimum sample of 200 pieces, whose least dimension is 0.6 the mean dimension. The mean dimension is the arithmetic average of the side dimension of the delimiting square holed sieves.

b) Elongated: this is the weight percentage of particles whose long dimension is greater than eight times the mean dimension .measurement can be made with a standard gauge (BS 812: part 112: 1985). The table 16 shows the results found during the laboratory test.

Table 17: Flakiness index

Flakiness index

Sieve (mm)

Slot

Gauge (mm)

Number

of particles

Total weight (gr.)

Passing particles

Passing weight (gr)

Flakiness index by number

%

Flakiness index by weight %

63-70

33.9

50-37.5

26.23

37.5-28

19.65

28-20

14.4

100

1493.4

16

239.7

16

16.05

20-14

10.2

100

680.1

19

160.6

19

23.62

14-10

7.2

100

324.9

17

41.1

17

12.64

10-63

4.9

17

18

The Table 18 below is discussing the RAP used as the texture as the test for the good pavement materials the as it is shown through the results.

Table 18: Elongation index

Elongation index

Retained particle

Retained

Weight (gr)

Elongation n index by number%

Elongation index by weight %

63-70

50-37.5

37.5-28

28-20

8

43.2

8

2.89

20-14

16

176.1

16

25.9

14-10

14

142.8

14

43.94

10-63

13

14

The two Tables are describing the flakiness index and elongation index, the same condition of test, same sample, same sieve size and weight of sample.

4.2. Mechanical test

4.2.1 Aggregate impact value (AIV)

The aggregate impact value gives a relative measure of the resistance of an aggregate to sudden shock or impact, which in some aggregates differs from its resistance to a slow compressive load it is classified as the strength test.

Calculation

The ratio of the weight of fines formed to the total sample weight in each test shall be expressed as a percentage the results being recorded to the first decimal place.

Aggregate Impact Value = (B/A) X 100 where A is weight in gr. of a saturated surface –dry sample while B is weight in gr. Of fraction passing through 2.36 mm IS Sieve.

The below Table 18 shows the value of aggregate impact value where by it is one of the indicator of durability measure of aggregate as part of mechanical test, the value shows the good behavior of the RAP to be used in the mixture for the pavement, the Marshall test will also prove the stability and flow of the mixture late alone.

As table of results is between 10 and 20, therefore the material is strong according to the specification and recommendation for the road materials.

Table 19: Aggregate impact value (AIV)

Aggregate impact value test

Standard Method IS - 2386 (Part IV)

Test number

1

2

Weight of Cylinder + Sample(gr)

3222.4

3211.5

3

Weight of Cylinder (gr)

2617.04

2617.0

4

Total Mass of Sample(gr)

605.36

594.49

Retained Weight (gr)

484.6

489.73

Passing Weight (gr)

120.8

104.8

Aggregate Impact Value

19.9

17.6

Average aggregate Impact Value

19

4.3. Bituminous mixture test

4.3.1. Marshal test and procedure

First we take IS sieve set

- We sieve aggregates on sieves of size 12.5 mm; 10 mm;4.75 mm and 2.36 mm
- We sieve finer particle this time ,we will be using sieves of size 2.36 mm,600 μm,300 μm;150 μm;75 μm
- After sieving the total weight of aggregate is 1.2kg

The Figure 24 below shows the samples in oven ready for mix in order to perform the marshal test.

Figure 24: Sample in oven

Heating the aggregate to the temperature of 175-190 Celsius

Now we will add bitumen (4-6% by weight) heated up to 100-140 Celsius, in aggregates will mix it properly.

After mixing thoroughly, we will pour the mixture in the mold.

In the process we 65blows are utilized.

The Table 20 below shows the proportion in the mixture according to STM D (1559) the size used for the weight of aggregate and their corresponding sieve size. The results are sound and good to make a mixture.

Table 20: Sample proportion for the mixture

Weight of aggregate	Size
71.5g	12.5 mm
331.5g	10 mm
103.5g	4.7 mm
223.5g	2.6 mm

450g

Filler(SDA)+cement

1200g

Test procedure for marshal

1. Pre-heating of mold

2. Remove from the mold

Put it into hot water bath of 60 degree Celsius for 20 minutes

• Take the submerged weight after 20 min

• Fix the mold in breaking head

• Put the set up on the machine

• Adjust the screws and daily gauge

• Upper daily gauges gives stability reading

• Lower daily gauges gives flow value

• Remove the tested mold

The Table 21 below shows the standard description and requirement of the marshal test according to (ASTM Designation: D-1559) and the value of flow and stability IRC.

Table 21: Recommendation of marshal value and flow value as per IRC

S-N

Description

Requirement

1

Marshal stability (ASTM

Designation :D-1559)

Determined on marshal specimens compacted by 75blows on each end.

820 kg Minimum

2

Marshall flow (mm)

2-4

3

Percent voids in mix

3-5

4

Percent voids in mineral

aggregates(VMA)

Minimum 11-13 percent

5

Percent voids in mineral aggregates filled with bitumen (VFB)

65-75

6

Binder content ,percent by weight of

Minimum 4.5

total mix

The Figure 25 below is showing the samples in laboratory in a tray and sample in the testing machine for stability and flow.

Figure 25: The sample in a marshal stability testing machine

The table 22 shows the results found during the test with their corresponding parameter for the mix of the bitumen percentage ranging from 4 up to 6 as the optimum bitumen content utilized in the mix the filler are sawdust ash and cement in the same proportion of 50% and the ordinary filler are completely replaced.

Table 22: Values found during test

SN

%-

Bitumen

Marshal

stability value

Flow

values

Bulk

specific gravity

(Gm)

Air voids

(%Vv)

%of bitumen (Vb)

VMA

VFB

1

4

686

3.26

2.15

3.90

7.622

11.522

65.96

2

4.5

765

3.36

2.11

3.26

8.560

11.82

67.68

3

5

820

3.80

2.13

2.60

9.460

12.06

78.44

4

5.5

672

4.20

2.12

1.46

10.340

11.80

85.60

5

6

518

4.30

2.14

1.43

10.540

11.97

87.00

The graph below present the Figure 26 and it is showing the optimum bitumen as 5 percent for all proportion of the SDA for all five samples for each bitumen percentage whose stability is read against bitumen percentage. The samples cube are found in the appendix

Figure 26: Bitumen content% vs Marshal Stability value

The Figure 26 below shows the values of flow in millimeter for all the samples for different percentage of SDA as presented in the matrix of samples page 51.

Figure 27: Bitumen % vs flow values

Discussion for the marshal test

The optimum content of the bitumen in the mixture is determined and shown in the graph above .The stability test results, the results show that the stability increases with the bitumen content % up to the optimum content and thereafter decreases.

The optimum bitumen content was found to be 5%, .the stability of the mix with sawdust ash and cement in equal proportion was found to be near the one with crushed stone dust (CSD) as the ordinary filler in the mixture.

At the optimum bitumen content of 4;5; 5.5 and 6 the stability were 6.48KN, 7.65KN,and 8.20 KN respectively .it can be noticed that the effect of sawdust and cement is huge because the stability values meet the AASHTO specification that is not going less than 3.5 KN . These results are considered and indicate that the asphalt mixture with SDA and cement have better stability as the ordinary filler especially on the 5% bitumen of the total weight of sample composed of sawdust ash at 90 percent and 10 percent crushed stone dust or mineral filler.

The better stability can be attributed to improved adhesion of between the aggregates and the bitumen as well as the sawdust ash. I would like to recommend the more test like indirect tensile fatigue, four point bending etc. for further research to confirm the behavior of sawdust ash in the mixture.

The flow values of the both asphalt mixtures against bitumen content are shown in the Figure 28 bitumen %vs flow values.

Flow values are the displacement expressed in mm the results were 3.2; 3.3; 3.8 and 4.2 for the first sample composed of 100 percent SDA and then the results were varied according to the percentage of SDA present , that shows the increase with the sawdust ash as attitude toward the mixture and the behavior of sawdust ash toward the binder. This manifest here the presence of the sawdust ash and cement, the surface become slightly cementitious i.e. asphalt cement.

Stiffness of the bitumen (Sbit)

The bitumen utilized for the test in this study is for the temperature of 30 oc where is assumed to be performed in worm region. Bitumen properties have been set and they are as follows in the table 23 below

Table 23: Bitumen characteristics and conditions

Bitumen properties

Penetration at 250c dmm

79

Penetration index

-0.5

The results were as follows considering the data given above thus the following Table 8 illustrates the results of bitumen stiffness after the sawdust has been analyzed

At the penetration of 79 dmm, and also considering the temperature of between 20-30 the softening point was 48 according to the ring and ball test and also using the chart for determination of T800 and penetration index (PI).

Stiffness of the bitumen at a temperature of 30 degree Celsius the stiffness was 3.5 x106 pa which shows the effect of sawdust ash in the mix for the cube of 5percent bitumen and 70 percent SDA and 30 percent CSD. Stiffness of the mix (Smix) is in normal range it can be useful as the ordinal mineral filler in the pavement.

Here is the summary of the whole stiffness results on the table 8 below

Table 24: Stiffness of bitumen at temperature of 25 0c

Sbit (Pa) 108

Proportion of SDA in the mix and RAP

Bitumen

%

10

30

50

70

100

4

0.8

0.9

1.3

0.8

0.4

5

0.9

0.95

1.5

0.7

0.3

5.5

1.1

1.0

1.9

0.5

0.26

6

1.2

1.3

2.1

0.3

0.4

 Bitumen is temperature sensitive. That why there is a significant reduction in bitumen stiffness for both bitumen at 30oC sawdust demonstrates a change to the mix when bitumen percentage increase up to the optimum of 5 percent and as the quantity of sawdust increase the there is a significant change in the stiffness but at 50 percent.

Table 25: Stiffness of the mix

Smix (Pa) 108

Proportion of SDA in the mix and RAP

Bitumen

%

10

30

50

70

100

4

0.7

0.9

1.6

0.8

0.4

5

0.75

0.95

1.8

0.7

0.3

5.5

1.2

1.0

1.9

0.5

0.26

6

1.3

1.3

2.3

0.3

0.4

 The stiffness of the mixture is increasing as the percentage of sawdust increase but now at the fifty percent

 The stiffness of the mixture does not only depends on the bitumen stiffness but also the voids, aggregate grading, aggregate shape, texture, and degree of compaction

 The stiffness of bitumen value is lower that the stiffness of mix value. This means that the aggregate structure influences the increase in stiffness. And also at higher temperatures the contribution of the aggregate structure increases.

CHAPTER V: CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

The aim of this thesis is a study on the effect of sawdust ash in different proportion with active filler (CSD) in the asphalt mixture composed of reclaimed aggregates. The marshal test was used to assess the stability and flow of the asphalt mixture by using the sawdust ash (SDA) as the filler replacing the ordinary filler which is the crushed stone dust (CSD).The results were showed that the performance of the asphalt surface were effective as the ordinary filler application , in the asphaltic road construction and also the rehabilitation can be carried out by using recycling technology as RAP were used to be also effective in terms of usage as cost effective as virgin aggregate are expensive .

The use of RAP is better choice to be used road pavement and rehabilitation due to

• The good performance in terms of resistance to deformation

• Saw dust ash and cement can perform better for sub- base material as cementitious

• The proportion of bitumen used in the study were 4%, 5%, 5.5% and 6% were good to evaluate the stability where by the optimum bitumen content is 5% RAP with all the necessary quality control such the test of aggregate either physical and mechanical test for aggregates. When the new bitumen content is added we observe the increase of stability decrease of flow.

The tests performed were grading test i.e sieve analysis, also the mechanical test such as aggregate impact value which has proved that the RAP lies between 10 and 20 the RAP was satisfactory to sustain the loading impose by the traffic .

• The surface was to be evaluated through marshal test which showed that it can perform well through IRI as the indicator of smoothness and surface texture.

5.2 Recommendation

The use of sawdust ash and cement in same proportion as stabilizers in road construction and rehabilitation and are very much useful.

As the developing country where the materials take huge amount of expenses, the researches of using local available materials have to be taken into consideration.

The industry of road construction worldwide is an important thing in the socio-economic development therefore the investment in the sector is to be considered in the cost effective way by the strategy: planning, preparation and operation these are management of the project.

The sawdust ash and RAP usage will also address the problem of land fill i.e. problem of deposition of used waste in Rwanda example UDUKIRIRO, the sawdust obtained from carpenters will be an important solution.

I would recommend that all the sawdust waste should be well managed in terms of deposition for future works.

The same as the waste from the rehabilitation of paved road using conventional way, that waste should be reused in road pavement thus reducing the hazardous bituminous effect for the environment as well as the disposal problem stipulated previously in the text.

5.3 Areas of further studies

There still some areas in which detail study is required some of them are as follows:

 More study is needed to analyze the effect of sawdust ash on the permanent deformation of the surface

 Analysis of the characteristic of binder and its effect on the stiffness and aging

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APPENDICES

Appendices–1: RAP Collection

Appendices–2: Sawdust ash sample

Appendices–3: Binder extraction

Appendix 1: RAP

Appendix 2: Sawdust ash sample

Appendix 3: Binder extraction

Appendix 4: Sample in oven

Appendix 5: First sample after compaction

Marshal data: stability values

Air voids curve

Void filled with bitumen (VFA) curve

81

A

81

A

81

A

81

A

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EXCLUDE QUOTES	OFF
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