ADDIS ABABA SCIENCE AND TECHNOLOGY UNIVERSITY

PERFORMANCE EVALUATION OF BITUMINOUS MIX USING TANNERY SLUDGE AS PARTIAL REPLACEMENT OF FINE AGGREGATE

BY

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APPROVAL PAGE

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DECLARATION

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ABSTRACT

Pavements are expected to perform better as increased volume of traffic, increased loads and increased variations in daily or seasonal temperature. Bituminous mixes most commonly used all over the world in flexible pavement. It consists of asphalt or bitumen (used as a binder) and aggregate which has been mixed together lay down in layers and then compacted. In this research the performance of bituminous mix using tannery sludge as partial replacement of fine aggregate has been evaluated since tannery sludge has become a serious problem especially in the urban areas and the disposal of this wastes cause environmental pollution. Marshall Specimens of bituminous Mix with and without tannery sludge has been prepared as per the standard procedure. The study area for this research is in Addis Ababa with moderate temperature. The penetration grading PG for the study area is 80/100. Methodology of using tannery sludge in bituminous mixes at 2%, 4%, 6% and 10% and compared with no addition of tannery sludge and presented the various tests performed on aggregates and bitumen at 0.5% increment. Laboratory test in the first phase with the production of Marshall compacted specimens has been done to investigate the changes on Marshall Properties with and without Tannery Sludge. The test result for Stability and flow at 2%, 4%, 6% and 10% partially replaced tannery sludge meet specification set by Era standard, At 2 % partially replaced fine aggregate with tannery sludge shows good result for Voids in Mineral Aggregate meets the specification set by Era and At 2% partially replaced fine aggregate with tannery sludge and void filled with bitumen in critical condition meets the specification set by Era Standard Specification. Percent Air void is beyond Era Standard specification range as the tannery sludge content increase and maximum air void occur at 10% tannery sludge replaced fine aggregate.

***Keywords*:**

Marshal Mix Design, Tannery sludge, Moisture susceptibility, Bitumen, Hot Mix Asphalt, Stripping.

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LIST OF ABBREVATIONS

ERA	Ethiopian Road Authority
AACRA	Addis Ababa City Roads Authority
AASHTO	American Association of State Highway and Transportation Officials
G_{mb}	Bulk specific gravity of compacted mixture
G_{mm}	Theoretical maximum specific gravity of loose mixture
G_{sb}	Bulk specific gravity of total aggregate
Ps	Aggregate content, percent by total weight of mix
P_b	Total asphalt binder content, % by mix mass
V_b	Total asphalt binder content, % by total mix volume
P_b	Total asphalt binder content, % by mix mass
M_b	Mass of binder in specimen
M_s	Mass of aggregate in specimen
G_b	Specific gravity of the asphalt binder
AC	Asphalt Content
ACV	Aggregate Crushing Value
ASTM	America Society for Testing and Materials
HMA	Hot Mix Asphalt
LAA	Los Angles Abrasion
MDD	Maximum Dry Density
OBC	Optimum Bitumen Content

OFC	Optimum Filler Content
OMC	Optimum Moisture Content
PG	Penetration Grade
SSD	Saturated Surface Dry
SG	Specific Gravity
Va	Percent Air Void
VFB	Voids Filled with Bitumen
VMA	Voids in the Mineral Aggregate

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CHAPTER ONE

INTRODUCTION

1.1 Background of the study

Asphalt concrete is composed of basically two components, aggregates and asphalt binder. Aggregates are hard, inert materials such as sand, gravel, crushed stone, slag, or rock dust and based on their particle size they are classified in to three coarse aggregate, fine aggregate and filler. Aggregates constitute total of 90 to 95 percent of the mixture by weight. Whereas asphalt binder is a dark, cement-like material produced by the non-destructive distillation of crude oil during petroleum refining, to which aggregates are added. It is the most expensive and economically variable material in the Hot-Mix Asphalt (HMA). It has been used for centuries for the purpose of waterproofing and as an adhesive. Nowadays, in the road construction industry, asphalt binder is mainly used as an intermediate and surface layers of flexible pavement to provide tensile strength to resist distortion, protect the asphalt pavement structure and subgrade from moisture, and provide a smooth, skid-resistant riding surface that withstands wear from traffic[1]. Asphalt concretes are widely used in pavements. Due to increase in vehicles in recent years the road surfaces have been exposed to high traffic resulting in deformation of pavements due to excessive stress. Permanent deformation happens when pavement does not have sufficient stability, improper compaction and insufficient Pavement strength. The performance of pavement is determined by the properties of bitumen. Bitumen is a visco elastic material with suitable mechanical and rheological properties for water proofing and protective covering for roofs and roads, because of its good adhesion properties of aggregates. Ethiopia is one of the leading countries that have the largest livestock populations in the world providing a strong raw material base for the leather industry. Its livestock population is estimated at 50 million cattle, 25 million sheep and 23 million goats. About 80% of all hides and skins entering the formal market come from rural areas where they are collected by private traders. The remaining 20% are derived from slaughtering facilities found in major town and cities. About 15.5 million pieces of sheep and goat skins and 1.2 million pieces of cattle hides are supplied to the tanneries per annum [2]. Leather industry is one of the pollutant industries and if there is no proper way of treating the waste from the industry it has harmful effect. Causing serious environmental and public health problems in particular in urban centers. It is obvious that the effect will further extend to rural areas as well. Tannery sludge is a solid waste generated from tannery industry. Both the solid waste from leather production processes and the sludge from tannery wastewater treatment as well as gas and odor pollutions emitted into the atmosphere. In Ethiopia also there is a concern on the waste of the tanneries.

The industrial establishments sustain economic development of the country and it has been constrained for they were not designed and operated in sustainable manner most of tanneries do not have treatment facilities and environmental management systems, as a result they simply discharge their wastes into the environment. Tannery process relies on hides and skins transformation to the leather. It involves a complex combination of mechanical and chemical processes which are divided into three fundamental sub-processes: preparatory stages, tanning and crusting. Then hides and skins pass through many operations, which form solid waste and are a source of wastewater with a highly pollutant concentration. Moreover, tanning activities are also associated with disagreeable odors emission as an effect of protein decomposition and the presence of sulphides, ammonia and other volatile organic compounds [3].

The predominant tanning method is based on chromium salts; specifically trivalent chromium salts are the most widely-used chemicals in tanneries. Of the total amount of chromium applied during the tanning process, about 60% is consumed during the processing of raw materials (animal skin). Residual chromium remains in the tanning bath and is subsequently discharged into the wastewater. Dissolved chromium and other spent chemicals present in the wastewater, are mainly removed by chemical precipitation before the wastewater is allowed to enter the biological treatment process. Precipitation is induced through pH adjustment usually by lime and the addition of inorganic coagulants. The precipitated chromium along with other co-precipitated organic compounds is discharged as sludge. Tannery sludge contains trivalent chromium, organic matter, proteins, fats, and salts such as chlorides, sulfates and carbonates. Concentrations of trivalent chromium and organic compounds in the tannery sludge are considerably high and it cannot be accepted even at landfills for hazardous wastes, which in turn signalizes the demand for its stabilization.

1.2 Statement of the Problem

Most of Ethiopian roads are flexible pavement type which are considered as cheap compared to the rigid pavement but still expensive for a developing country. The increase in road construction cost has been common in Ethiopia and many projects are being delayed or denied because of limited budget and asphalt binder is known for its enormous contribution of the construction cost for flexible pavements.

For over a century, flexible pavement has been constructed using Asphalt concrete mixes across the world. However, a major problem still exists involving premature distresses and pavement failures; among these failures are fatigue cracking, rutting, and potholes. The main concern related to pavement design is material characterization. For constructing road with superior quality, the highway material should meet the quality requirement, good resistance and longer life. Asphalt binder has been a common and the core problem that results in premature pavement failures in Ethiopia. Ethiopia being in tropical climate receives seasonal and a significant amount of sun light and rainfall within the year. Besides climatic factor such as temperature and moisture, high traffic impact stresses also have profound effect on the durability of Hot Mix Asphalt pavements against stripping failures. Beside the Pavement strength, resistance to water and better performance there is a great concern on the economy and environment. According to recent studies, there has been a rise in the amount of tannery sludge being generated daily by factories. Experiments have been carried out whether this waste can be reused productively. For Every 100 tons of leather 2.5-3.5 tons of waste generate and widely wasted in the name of landfill which ultimately pollutes the soil as well as ground water owing to its chromium content. Such chrome shavings can be utilized as partially replaced fine aggregates in bituminous mix for road construction, the disposal problem of Chrome Shaving will be solved and improve the road network of the country for its smooth economic and social development.

1.3 Objectives of the research

1.3.1 General Objectives

- Performance Evaluation of bituminous mix using tannery sludge as partial replacement of fine aggregate.

1.3.2 Specific Objectives

- To investigate the changes on Marshall Properties with and without Tannery Sludge.
- To determine the percentage of Optimum Bitumen Content and Tannery Sludge as a Partial Replacement.
- To determine Cost- benefit analysis.

Research Question?

1. What is the effect of adding tannery sludge on HMA?
2. What is the maximum percent of tannery sludge that shows a better Marshal Properties ?

1.3 Significant of Study

- It may help to solve serious environmental and public health problems particularly in urban centers.
- It may help to minimize highway construction cost by using tannery sludge as partial replacement of fine aggregate.
- It may help to improve the pavement service life.

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1.4 Scope and Limitations

Exposure of the sludge to higher temperature may result in loss of some volatile materials and also there is a possibility of decomposition. The dosage of warm mix additive should be limited based on the earlier studies, as over dosage of it may lower the viscosity of binder. Performance Strength of the pavement is not checked practically. The sludge obtained from different animal hide may have different properties in terms of partially replacing fine aggregate.

1.5 Organization

Chapter one defines the overall importance of the problem areas and provides an introduction into what the research is all about, chapter two deals with literatures on basic pavement concepts and pavement materials and past studies and works on pavements using tannery sludge as a construction material. Chapter three describes Material and Methodology work that has been done with detailed procedures, Chapter four deals with result and discussion chapter five deals with Conclusions and recommendations derived from experimental results.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

Pavement consists of more than one layer of different material supported by a layer called sub grade. Generally pavement is of three types; rigid pavement, flexible pavement and composite pavement. A rigid pavement is constructed with Portland cement concrete (PCC) and aggregates, If the subgrade soil is poor and erodible, then it is advisable to use a base layer. However, if the soil has good engineering properties and drains well, a base layer need not be used. The top layer (wearing surface) is the Portland cement concrete slab [4]. Flexible pavement Asphalt concrete pavement, also referred to as flexible pavement, is a mixture of sand, aggregate, a filler material, and asphalt cement combined in a controlled process, placed, and compacted. The filler material can range from quarry crushing dust and asphalt-plant bag house fines to wood fibers (cellulose). There are many additives that can be used in asphalt concrete mixes to encourage thicker cement coatings, more elastic mixes, stiffer mixes, and less temperature-sensitive mixes .Flexible pavements are designed to bend and rebound with the subgrade.

The design concept is to place sufficient layers of base and intermediate courses of pavement so as to control the strains in the subgrade so that no permanent deflections result. Loading of an asphalt pavement requires the stiffest layers to be placed at the surface with successively weaker layers down to the subgrade. The types and thicknesses of sub base materials placed above the subgrade should be selected with consideration of the strength of the subgrade [5].

Flexible pavements maintain contact with and distribute loads to the prepared roadbed. Flexible pavements Consist of layer(s) formed by one or more lifts of HMA and/or aggregate base placed above the prepared Roadbed soil called the subgrade. The subgrade is the foundation layer, which consists of the existing soil or Borrow material compacted to a specified density. the pavement layers are generally divided into a Surface course, intermediate or binder course, and a base course. The surface, binder, and base courses are typically different in composition and are placed in separate construction operations. The pavement layers for two common methods, full depth HMA and HMA over aggregate base of HMA construction [6].

2.2 Asphalt Concrete

Mixes in which traffic stresses are transmitted mainly through an aggregate structure which has a continuous particle size distribution. This is by far the most common type of HMA used in tropical countries. The material has a continuous distribution of aggregate particle sizes which is often designed to follow closely the Fuller curve to give the maximum particle density after compaction but adjusted slightly to make room for sufficient bitumen. However, such a dense structure makes AC sensitive to errors in composition and the effect of this becomes more critical as traffic loads increase.

2.3 Modes of Failure of HMA Surfacing

Loss of Surfacing Aggregate, or Fretting

This is often associated with the scrubbing action of vehicle tires and may develop because of;

- Improper aggregate particle size distribution, segregation or inadequate compaction. These can result in a permeable surface leading to rapid embrittlement of the bitumen and stones breaking away from the surfacing layer;
- Use small amount of bitumen content makes the mixture less durable;
- The general embrittlement of the bitumen near the end of the design life of the wearing course;
- (‘Stripping’ resulting from ingress of water and poor adhesion between the bitumen and aggregate particles [7].

Fatigue Cracking

Fatigue cracking is a major structural distress or failure that leads to a reduction in the serviceability of asphalt concrete pavement and defined by hveem as the phenomenon of fracture under repetitive load having a maximum value generally less than the tensile strength of the material [8].

The fatigue life of an asphalt concrete mixture is influenced by many factors. Several key mix properties such as asphalt type, asphalt content and air void content are well known to influence fatigue [9].

Low-Temperature Cracking

Low-temperature cracking is a failure type caused by low pavement temperatures rather than by applied traffic loads even though traffic loads likely do play a role. Thermal cracking is characterized by intermittent transverse cracks.

Permanent Deformation (Rutting)

Permanent deformation in HMA is caused by consolidation or lateral movement of the HMA under traffic. Shear failure (lateral movement) of the HMA courses generally occurs in the top 100 mm of the pavement surface. Rutting results from the accumulation of small amounts of unrecoverable strain as a result of repeated loads applied to the pavement. Rutting can occur as a result of problems with the subgrade, unbound base course, or HMA.

Moisture Susceptibility

Environmental factors such as temperature and moisture can have a profound effect on the durability of HMA pavements. When critical environmental conditions are coupled with poor Materials and traffic, premature failure may result from stripping of the asphalt binder from the Aggregate particles.

There are three mechanisms by which moisture can degrade the integrity of a hot mix asphalt matrix:

1. Loss of cohesion or strength of the asphalt film that may be due to several mechanisms;

2. Failure of the adhesion or bond between the aggregate and asphalt, and

3. Degradation or fracture of individual aggregate particles when subjected to freezing [10].

Moisture damage to bituminous mixes is a serious problem use of antistripping agents routinely to reduce the sensitivity of mixes to moisture damage [11].

2.4 Bitumen

Bitumen is a black, highly viscous and very sticky liquid or semi-solid, found in some natural deposits. It is also the by-product of fractional distillation of crude petroleum. Basically, Bitumen is composed of highly condensed polycyclic aromatic hydrocarbons, containing 95% carbon and hydrogen (± 87% carbon and ± 8% hydrogen), up to 5% sulphur, 1% nitrogen, 1% oxygen and 2000 ppm metals. Also bitumen is Mixture of about 400 - 2000 chemical components, with an average of around 600 - 800. It is the heaviest fraction of crude oil, the one with highest boiling point (525° C). Bitumen acts as binding agent for aggregates in bituminous mixes. Generally in India bitumen used in road construction of flexible pavement is of grades 60/70 or 80/100 penetration grade [12]. Bitumen is now imported cold in drum primarily from Iran and Saudi Arabia, through the port of Djibouti. Common types of imported 80/100 penetration grade the Ethiopian current affairs reports that 44 million birr of bitumen supplied to AACRA [13]. They are semisolid hydrocarbons with certain physiochemical characteristics that make them good cementing agents. They are also very viscous, and when used as a binder for aggregates in pavement construction, it is necessary to heat both the aggregates and the asphalt cement prior to mixing the two materials. For several decades, the particular grade of asphalt cement has been designated by its penetration and viscosity. The softest grade used for highway pavement construction has a penetration value of 200/300, and the hardest has a penetration value of 60/70. For some time now, however, viscosity has been used more often than penetration to grade asphalt cements [14].

2.4.1 Bitumen Characteristics

Bitumen has the following five characteristic properties.

- Adhesion

Bitumen has excellent adhesive qualities provided the conditions are favorable. However in the presence of water the adhesion does create some problems. Most of the aggregates used in road construction possess a weak negative charge on the surface. The bitumen aggregate bond is because of a weak dispersion force. Water is highly polar and hence it gets strongly attached to the aggregate displacing the bituminous coating.

- Elasticity

When one takes a thread of an asphalt binder from a sample and stretches or elongates it, it has the ability to return to a length close to its original length eventually. This property is referred to as the elastic character of bitumen.

- Plasticity

When temperatures are raised, as well as when a load is applied to bitumen, the bitumen will flow, but will not return to its original position when load is removed. This condition is referred to as plastic behavior.

- Visco-elasticity

Asphalt binder has a Viscoelastic character. Its behavior may be either viscous or elastic depending on the temperature or the load it is carrying. At higher temperatures and slow loading condition there is more flow or plastic behavior, while at a lower temperatures, bitumen tends to be stiff and elastic. At intermediate temperatures it tends to be a combination of the two.

- Aging

Aging refers to changes in the properties of asphalt binder over time, which is caused by external condition. There are two stages of a pavement's life where oxidation can occur in the field.

- Hot mixing and construction:

During the mixing and placement process the asphalt binder is exposed to elevated temperatures and a large contact area with the aggregates which can lead to rapid aging by volatilization and oxidation. The aging mechanism which includes the loss of volatiles and chemical oxidation that result from elevated mixing and placement temperatures falls under the primary process which is followed by oxidation in a secondary process during long term service.

2.4.2 Bitumen Durability

Bitumen derived from different sources of crude oil can have varying resistance to ageing and oxidation. Their characteristics can be further affected by the type of refining plant in which they are produced. The main purpose of most oil refining is to obtain the valuable distillates such as naphtha, fuel oils and heavier oils. After distillation, the bitumen residue is usually too soft to be used for paving and must be treated further. There are two methods of treatment. The first involves either air blowing (or oxidation) of the residue, typically carried out in fuel-producing refineries.

The second is blending with propane-precipitated bitumen, which is a by-product of the manufacture of lubricating oil. Depending upon the properties of the crude oil and the processing, bitumen produced in the propane-precipitation method can be more durable. This can be determined by the extended RTFOT. Financial restraints may mean that authorities must purchase bitumen at the most competitive open market rates. However, the import of more durable bitumen should be seriously considered for major projects such as international airfields and important transcontinental routes.

Bitumen durability refers to long term resistance to oxidative hardening of the material in the field. Although, in service, all bitumen harden with time through reaction in the field, excessive rate of hardening (durability) can lead to pre mature binder embrittlement and surface failure resulting in cracking and chip loss [15].

2.4.3 Pre-hardening of Bitumen

Bitumen samples should be tested in both the ‘as delivered state’ and also after pre hardening, which is intended to simulate the ageing of bitumen during storage, mixing and construction. Two test methods are used to pre-age bitumen, the Thin Film Oven Test (TFOT) and the Rolling Thin Film Oven Test (RTFOT). The RTFOT test is considered to be the best method of simulating the ageing of bitumen during the construction process. The TFOT can be used for penetration graded specifications but, where possible, the RTFOT equipment and a viscosity graded specification should be used [7].

Requirements for penetration graded bitumen

The basic requirements for penetration graded bitumen are;

- Bitumen shall be prepared by the refining of bitumen obtained from crude oil by suitable methods. The bitumen shall be homogeneous and shall not foam when heated to 175°C.
- The various grades of bitumen shall conform to the requirements.

Requirements for viscosity graded bitumen

Authorities such as AASHTO, ASTM, the Standards Association of Australia and the South African Bureau of Standards have produced specifications based on viscosity. The AASHTO and ASTM tests use capillary viscometers whilst the South African specifications utilize a rotary viscometer which is ideal for acquiring data to plot on the Bitumen Test Data Chart.

2.4.4 Bitumen Rheology

Rheology is the science that deals with the flow and deformation of matter. The rheological characteristics of bitumen at a particular temperature are determined by both the constitution (chemical composition) and the structure (physical arrangement) of the molecules in the material. Changes to the constitution, structure or both will result in a change to the rheology.

Rheology is the fundamental interdisciplinary science that is concerned with the study of the internal response of real materials to stresses. Eugene C. Bingham, a professor at Lafayette College in the USA, who was researching the properties of materials that showed both elastic properties, akin to solids, as well as flow characteristics typical of liquids, coined the term ‘rheology’ in 1929 from the Greek, as explained above. There is a body of different tests, commonly referred to as rheometry, which has been devised to quantify these properties. More often than not, they have been customized to elicit a response from a material to a specific mechanical stimulus. Rheology can be considered to be the study of materials that exhibit both solid and liquid characteristics. At rest, a solid or a liquid retains its form; under load the material deforms, when the load is removed this deformation can be either irrecoverable (viscous) or the deformation can be recoverable (elastic).

In the simplest of terms, ideal solid materials behave in an elastic manner, and the deformation is recovered when the force or load is removed, whereas liquids behave in a viscous manner, and the load is not recovered but results in a permanent deformation of the material. Between these two ideal states, materials can exhibit what is referred to as visco-elastic behavior, in which the response to stress is partially viscous and partially elastic.

2.5 Aggregate

Aggregate is the largest constituent in asphalts, typically 92–96% by mass; the type of aggregate, its mineralogy, and physical and chemical properties will have a significant impact on asphalt performance. The majority of asphalts are produced with natural crushed rock aggregate, although the trend is for ever greater use of recycled aggregate as a replacement, usually for economic or environmental reasons. Some asphalt aggregates are manufactured, typically as a by-product of other industrial processes (e.g. steel slag and blast furnace slag). Some of these aggregates have properties that are very beneficial for and have a good history of use, while others, particularly those with little or no history of use, will require greater testing and need careful consideration in asphalt design and its application.

The performance of asphalt is largely predetermined by the characteristics of its components: bitumen, aggregates and air voids. However, for this marriage to be successful, the properties of the aggregates need to be known, fully understood and adequately specified. The properties can be considered within a group of five broad classifications, namely

- geometrical properties (e.g. size, shape and particle packing)
- mechanical properties (e.g. strength and hardness)
- physical properties (e.g. particle density and water absorption)
- chemical properties (e.g. adhesion)
- Durability, weathering properties (e.g. freeze–thaw resistance).

Some of these properties (i.e. those for geometric requirements, e.g. grading, size, shape and cleanliness (clay and silt content)) are partly controlled, and are a function of the aggregate processing, while others (e.g. physical, mechanical and chemical properties) are an inherent characteristic of the aggregate unaltered by quarry processing [16].

Aggregate used for asphalt mixture are typically comprised of crushed rock, gravel, sand, or mineral filler occasionally, product from other industries, including foundry sand, blast furnace slag, and glass may be recycled into asphalt pavement as an aggregate. Aggregates are selected and classified according to size and other properties for specific asphalt mix design and pavement end–use specification [17]. Roughness of surface texture of fine aggregates increased Marshall and Hveem stability values for asphaltic concrete at optimum asphalt. They also found that increased roughness of surface texture of the fine aggregate fractions increased the minimum percentage of voids in the mineral aggregate and increased the optimum asphalt content [18].

Size and Grading

The maximum size of an aggregate designates the smallest sieve through which 100 percent of the material will pass. The nominal maximum size is the largest sieve upon which any of the aggregate material retained. Maximum size and aggregate grading are invariably controlled by specification and may describe as dense graded, open graded, one sized, coarse graded and gap graded.

Cleanliness

Aggregate cleanliness may often be determined by visual inspection. Some aggregates contain certain foreign or deleterious substances that make them undesirable for asphalt paving mixtures unless the amount of foreign matter is reduced.

Toughness

Aggregate are subjected to additional crushing and abrasive wear during manufacture, placing and compaction of asphalt paving mixes aggregate are also subjected to an abrasion traffic loads and exhibit, to a certain degree, an ability to resist crushing, degradation and disintegration [19].

Particle Index (Shape and Texture)

Particle index is an overall measure of aggregate particle shape and texture. Aggregates with rough textures, such as crushed limestone or gravel, tend to form stronger bonds with asphalt cement and increases the strength and asphalt cement demand of a mix. On the other hand, aggregates with smooth textures, such as river gravels and sands, tend to form weaker bonds with asphalt cement which leads to reduced strength and decreased asphalt cement demand. However, smooth aggregate surface textures may provide more workability.

Affinity for Asphalt

An aggregate's affinity for asphalt cement is its propensity to attract and retain attached to asphalt cement. Asphalt cement must coat the aggregate, stick to the aggregate, and resist stripping of the asphalt film in the presence of water. Though there are several theories surrounding the chemical interactions that take place in stripping. It is important to recognize that some aggregates appear to have a greater affinity for water than for asphalt cement. These hydrophilic (water-loving) aggregates have a tendency to get stripped (asphalt film gets detached from the aggregate) with exposure to water. Siliceous aggregates such as quartzite and some granite are examples of hydrophilic aggregates. On the other hand, hydrophobic (water-hating) aggregates have a greater affinity for asphalt cement. Limestone and dolomite are examples of hydrophobic aggregates.

Absorption

Absorption is a measure of an aggregate's porosity. While porosity is generally associated with the absorption of water, a porous aggregate also tends to absorb asphalt cement. Porous aggregates have a greater asphalt cement demand and require additional asphalt cement for a comparable mix. Therefore, highly porous aggregates are generally not used for HMA unless the aggregates possess certain desirable qualities that outweigh the cost of additional asphalt cement. Blast furnace slag and other synthetic aggregates are examples of lightweight, wear resistant aggregates that are used in spite of their high Porosity [20].

2.5.1 Effect of Aggregate Characteristics

The physical characteristics of the aggregate surface have been shown to be somewhat related to the occurrence of stripping in asphalt pavements. The surface texture of an aggregate affects its coat ability, making it easier to coat a smooth aggregate surface than a rough one [21].

A general hypothesis has been that acidic aggregates are hydrophobic. Surface texture of the aggregate affects its ability to be properly coated, and a good initial coating is necessary to prevent stripping. The bond energy was far greater for the calcareous aggregates than for the siliceous. These results agreed well with mechanical mixture testing. They point out clearly the importance of the interaction of the physical and the chemical bond. Besides the importance of a good mechanical bond promoted by an amenable surface texture, the effects of crushing of the aggregate are very interesting. One might expect that a freshly crushed aggregate surface would have a greater free energy than an uncrushed aggregate surface. This is because broken bonds due to fracture should substantially increase the internal energy even though having something of a counter effect on randomness (entropy increase) [22].

2.5.2 Effect of Aggregate Properties on stripping

A number of aggregate properties affect the adhesive bond between asphalt and aggregate: size and shape of aggregate, pore volume and size, surface area, chemical constituents at the surface, acidity and alkalinity, adsorption size surface density, and surface charge or polarity.

Pore Volume and Surface Area

Five aggregates (granite, dolomite, chert gravel, quartz, gravel, and limestone) tested for pore volume, surface area, average pore size, and percentage coating after boiling. A low pore volume or surface area suggests a smooth, crystalline surface with low surface roughness. On the basis of purely mechanical considerations that is, the requirement for large areas of interfacial contact and surface roughness to have good adhesion and interlock-the low pore volume and surface area of granite should imply the existence of low adhesive bond strength with the asphalt cement and high moisture susceptibility When an aggregate is being coated with asphalt, the aggregate selectively adsorbs some components of the asphalt, such as the more polar species of the asphalt, and hydrogen bonds or salt links are formed.

PH of Contacting Water

Adhesion between asphalt cement and aggregate in the presence of water became weakened when the pH of the buffer solution was increased from 7.0 to 9.0. Changes in the pH of the water had significant effects on stripping. Stripping became more severe as the pH value increased from 2.0 to 7.0 for the granite aggregate and from 3.0 to 13.0 for the crushed chert gravel. This result indicates that significant change in the pH of water in contact with the aggregate surface could cause stripping to occur.

Surface Potential

Interfacial activity between asphalt cement and the aggregate surface is fundamentally important in assessing stripping potential. The functional groups of asphalt that are adsorbed on the aggregate surface come mainly from the acid fraction of the asphalt. Aggregates with water present are negatively charged, and as a result, a repulsive force develops between the negatively charged aggregate surface and the negatively charged asphalt surface at the interface [23].

2.5.3 Aggregate Gradation

Aggregate characteristics impressively affect the performance of asphalt pavements. Gradation is one of the important characteristics of aggregates affecting permanent deformation of hot mix asphalt. Permanent deformation (i.e. rutting) of asphalt pavements is one of major types of distress modes experienced in the service life of pavements [24].

Brown and Cross indicated that aggregate properties have little effect on rutting when voids are less than 2.5%. For percentage of voids greater than 2.5, Brown and Cross claimed that, it is the fine aggregate angularity and not the gradation that has a significant influence on rutting resistance [25].

A study was performed to investigate the effect of variations in the gradation of aggregates on the properties of asphalt concrete mixes. The gradation variation tested represented the extremes for a typical construction project. The specific objectives of the study were to determine the effect of gradation variation on

1. Creep behavior as a measure of rutting resistance;
2. Split tensile strength as an indicator of fatigue resistance potential;
3. Marshall Mix properties (stability, flow, air voids, and voids in mineral aggregate) as a measure of mix acceptability; and
4. Resilient modulus as the parameter controlling the AASHTO thickness design structural layer coefficient [26].

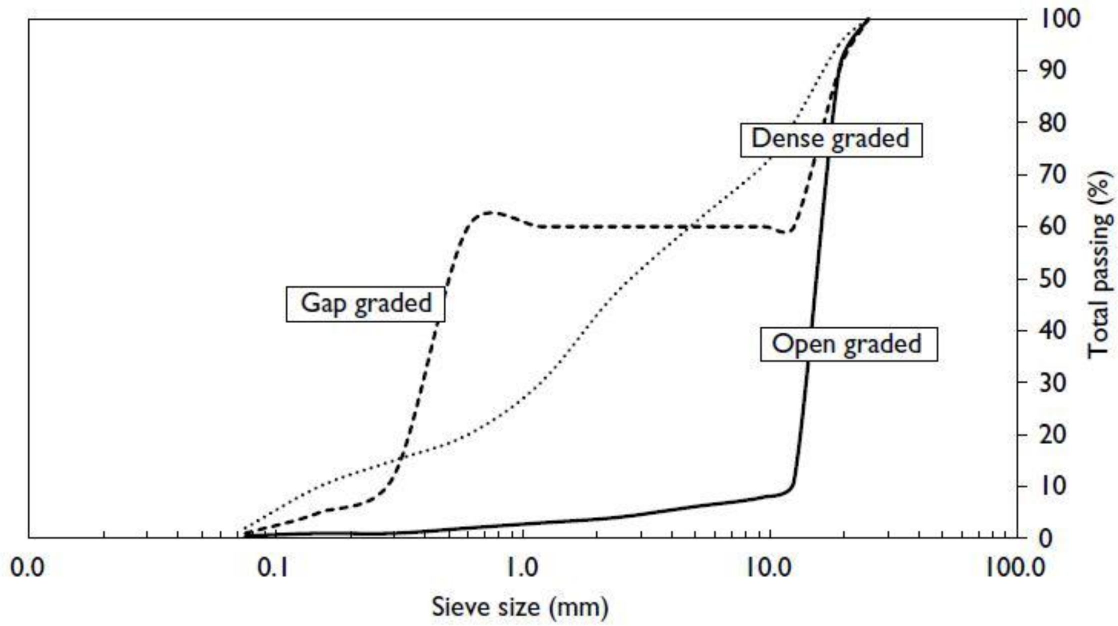


Figure 2-1 Aggregate Grading [27]

Aggregate gradation graphs can either be semi-log chart as shown in Figure 2-2 or 0.45 power chart. The 0.45 power chart was developed in 1962 by the United States Bureau of Public Roads that uses an arithmetic scale of the sieve size rose to the 0.45 power.

The chart was developed on the assumption that the best aggregate grading for asphalt mixture is the one that gives the densest particle packing. The maximum density gradation is a line drawn from the maximum aggregate size through the origin as shown in Figure 2-2 below.

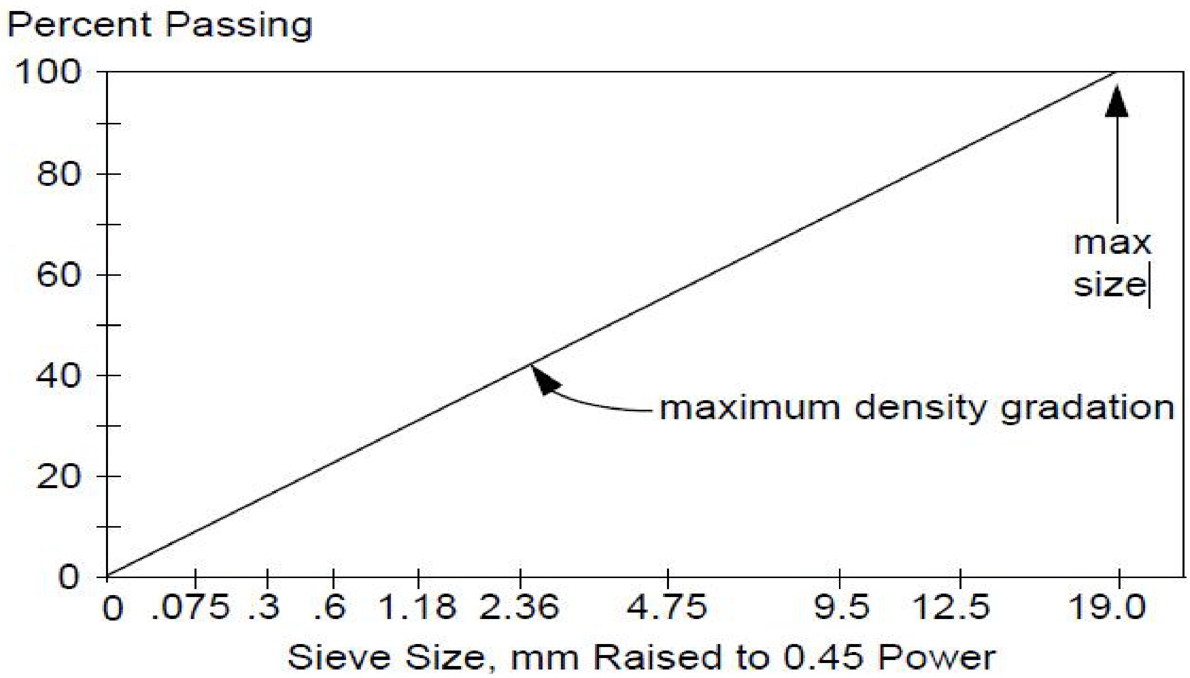


Figure 2-2 0.45 Power Chart [28]

2.6 Factors Affecting Bitumen–Aggregate Adhesion

Many factors influence the bitumen–aggregate bond; the importance of aggregate mineralogical composition has been recognized for many years Failure of the aggregate–bitumen bond is commonly referred to as 'stripping'. One of the main factors is the type of aggregate. This has a considerable influence on bitumen adhesion due to differences in the degree of affinity for bitumen. The vast majority of aggregates are classified as 'hydrophilic' (water loving) or 'oleophobic' (oil hating). Aggregates with high silicon oxide content (e.g. quartz and granite (i.e. acidic rocks)) are generally more difficult to coat with bitumen than are basic rocks such as basalt and limestone.

The majority of adhesive failures have been associated with siliceous aggregates such as granites, rhyolites, quartzites, cherts, etc. The fact that satisfactory performance is achieved with these same aggregates and that failures occur using aggregates that have good resistance to stripping emphasizes the complexity of bitumen–aggregate adhesion, and raises the possibility that other factors may play a role in the failure. Other factors affecting the initial adhesion and subsequent bond are the surface texture of the aggregate, the presence of dust on the aggregate and, to a lesser extent, the degree of acidity of the water in contact with the interface. It is generally agreed that rougher aggregate surfaces have better adhesion characteristics. However, a balance is required between wetting of the aggregate (smooth surfaces being more easily wetted) and rougher surfaces, which hold the bitumen more tenaciously once wetting has been achieved. Physio-mechanical adsorption of bitumen into the aggregate depends on several factors, including the total volume of permeable pore space, the size of the pore openings, and the viscosity and surface tension (surface energy) of the bitumen [16].

2.6.1 Mechanism of Stripping

The bonding between asphalt and aggregate is of special importance because it is the primary characteristic that Influences the integrity of the pavement. This bonding must be established at the initial stages of contact between the asphalt and the aggregate and must endure during the lifetime. Stripping
in asphalt pavement results from the failure of the asphalt aggregate adhesion bond due to the presence of water [29].

Several mechanisms contributing to stripping have been identified. These mechanisms include detachment, displacement, emulsification, pore pressure, film rupture, etc.

Detachment

Detachment is the separation of an asphalt film from an aggregate surface by a thin layer of water, with no obvious break in the asphalt film. Where stripping by detachment has occurred, the asphalt film can be peeled cleanly from the aggregate, indicating a complete loss of adhesion. The theory of interracial energy provides the rationale for explaining the detachment mechanism.

Displacement

Stripping by displacement results from the penetration of water to the aggregate surface through a break in the asphalt film. The break can be caused by incomplete coating of the aggregate initially or by film rupture. Because the asphalt film at these locations is generally thinner and under tension, rupture of the asphalt film is probably at the sharp edges and corners of angular aggregate pieces as a result of traffic loading.

Spontaneous _Emulsification

In spontaneous emulsification, water and asphalt combine to form an inverted emulsion, where asphalt represents the continuous phase and water represents the discontinuous phase. The formation of such an emulsion leads to stripping and is further aggravated by the presence of emulsifiers such as mineral clays and some asphalt additives.

Pore Pressure

Pore pressure has been suggested as a mechanism of stripping in high void mixes where water may circulate freely through interconnected voids. Upon densification of the mix from traffic loading, water may become trapped in impermeable voids that previously permitted water circulation. Further traffic may induce high excess pore pressures in the trapped water causing stripping of the asphalt film from the aggregate [30].

Hydraulic Scouring

Hydraulic scouring is a mechanism of stripping that is applicable only to surface courses. Stripping
Due to hydraulic scouring results from the action of vehicle tires on a saturated Pavement surface. This causes water to be pressed down into the pavement in front of the tire and immediately sucked away from the pavement behind the tire. This compression tension cycle is believed to contribute to the stripping of the asphalt film from the aggregate [31].

Film Rapture

The rupture of the film coating the aggregate particles is most likely to occur at the sharp corners of the aggregate where the binder film is thinnest. Rupture may be mitigated by the stresses induced by the dynamic and kneading action of traffic. Once the binder is ruptured, water may easily displace bitumen on the aggregate surface [32].

PH Instability Mechanism

Stabilization of the pH sensitivity at the asphalt aggregate interface would minimize the potential for bond breakage provide strong bonds and enhance reduce stripping [33].

2.6.2 Cause of Stripping

Some of the aggregates are inherently susceptible to stripping. However, there are also other external factors and in-place properties that lead to the deterioration of the HMA. Some of the other factors for the moisture induced stripping of the HMA.

Inadequate Pavement Drainage

Inadequate surfaces or subsurface produce water or moisture vapor, which is the necessary catalyst to induce stripping. There have been case histories where stripping was not a general phenomenon Occurring on the entire project site but only in areas that were over-saturated with water due to inadequate drainage.
Water can enter the HMA pavement in many ways. It can enter as surface runoff from cracks and other openings.

Physical Properties of Aggregates

Physical properties of aggregates are important to study as they participate in the process of stripping. Aggregates surface texture, aggregate porosity and pore structures are also known to affect stripping.
It was reported that decreasing the aggregate size and increase in mastic asphalt would increase the stripping potential of hot mixes asphalt with dense gradation.

Inadequate Compaction

Most agencies specify air content in the HMA mat of about 8% during construction, which is further compacted by traffic to about 4-5%. Studies indicate that when the air content is about 4-5%, the pores are not interconnected, and thus almost impervious to water. However, if good compaction control is not exercised, the pavement would have higher air content, leading to the ingress of water, causing moisture damage to the pavement. Also, if the pavement remains pervious to water for a long period of time, moisture damage can also be caused due to the hydrostatic pore pressure caused by traffic.

Excessive Dust Coating on the Aggregate

The presence of dust and clay coating on the aggregate can inhibit the intimate contact between the binder film and the aggregate, thereby forming channels for penetrating water. The binder coats the dust coating and is not in contact with the aggregate surface. Some very clayey material may cause stripping by emulsifying the binder in the presence of water.

Action of the Traffic

After any rain shower, the water in the pavement is pressed into the underlying layer by truck tires .This causes tremendous hydrostatic stresses, leading to the breaking of the bond between the binder and the aggregate. This is especially severe in the case of open graded friction courses due to the high air content. Traffic stresses can also directly rupture thin bitumen films, especially around sharp aggregate corners.

Inadequate Drying of Aggregates

When the aggregate is coated with binder, a dry aggregate surface will better adhere to the binder than a wet surface. As the hot binder is introduced to the wet aggregate surface, the moisture on the surface of the aggregate vaporizes and does not allow the binder to coat the aggregate well.

Weak Aggregates

If weak and friable aggregates are used in the mix, degradation takes place during rolling and later under heavy traffic loads. Degradation and delamination exposes new uncoated aggregate surfaces that can absorb moisture and initiate stripping problems [34].

2.6.3 Factor affecting Stripping

Factors responsible for inducing premature stripping include

- Water in, or on, the Dried Aggregate - High water absorption and/or adsorption makes drying more difficult, and fine aggregates dry preferentially which may leave some moisture in the coarse aggregate, particularly under the partial vacuum conditions of the dryer/drum.
- Aggregate Type – 'Siliceous' aggregates more prone to stripping than 'carbonate' aggregates.
- Aggregate Surface Texture – 'Smooth' surface texture less resistant to bitumen stripping than rough surface texture.
- Dust-Coated Aggregate - bitumen does not adhere properly and dust creates film defects.
- Stockpile Age - Some newly crushed aggregates exhibit poor resistance to bitumen cement stripping.
- Spontaneous Emulsification – Anti-stripping agents can become stripping agents under certain conditions.
- Bitumen Cement Properties - The chemical and physical properties of each bitumen cement are unique, and can dramatically influence the stripping behavior of a bitumen mix.
- Hot-Mix Design, Production and Placement - High in-place air voids, for instance, can promote water movement.
- Free Water Availability to bitumen Pavement Structure.

2.6.4 Methods to Prevent Stripping

The best way to prevent stripping will be to test the mixture in the laboratory and to use an aggregate/binder combination that does not strip. However, this will not always be possible due to many reasons such as, lack of suitable aggregates, increased costs in the transportation of certain aggregates, political constraints, etc. Even in spite of having the mix not be susceptible to moisture in the laboratory, there is not much certainty that the mix will behave the same in the field.

Different types of aggregate pre-treatments have also shown to improve the moisture susceptibility of the mix. Some of the pre-treatments include pre-heating the aggregate to evaporate the moisture, weathering, washing to remove surface dirt, crushing, etc. It has also been shown that aggregates coated with asphalt or other recycled materials are better at resisting the moisture damage in the HMA than are virgin materials [35].

Measurement of indirect tensile strength under specific conditions of moisture soaking and immersion correlate well with stripping area of aggregates to an extent of 90-100%. The addition of 0.5 % dehydrogenated tallow di methyl amine in bitumen to prevent stripping in presence of detrimental salt ion [36]. The impact of bitumen and aggregate composition on stripping in bituminous mixtures using four bitumen and four aggregates. It was found that mixtures made with lower penetration grade bitumen exhibit higher tensile strength in dry and wet conditions [37].

2.7 Tannery Waste

According to the results of the survey on the generation and treatment of solid wastes, carried out by the Greek Statistical Institute, the quantity of industrial wastes generated in 2010 amounted to 70,433,000 tones approximately, of which about 292,000 tones are hazardous wastes, representing 0.5% of the total amount and 26 kg of hazardous wastes per inhabitant. In Greece, 58,520,000 tons of solid wastes were disposed or deposited in designated sites or landfills, 6,415,000 tones were used for embankment and fill applications, 5,308,000 tones were recycled or used for energy and substance recovery, 126,150 tones were incinerated for energy recovery and 21,300 tones were simply incinerated. However, there are considerable amounts of solid wastes temporarily stored in areas next to industrial sites, as well as illegally disposed of in several other sites, thus posing serious environmental risks. Consequently, there is a demand for an efficient process that can allow the disposal of the produced solid wastes using an environmentally sound and low cost method [38].

The leather is made into approximate size when it is in wetted form. The size is maintained by shredding the materials. The shredded waste which is so obtained is used for the replacement of the fine aggregate.

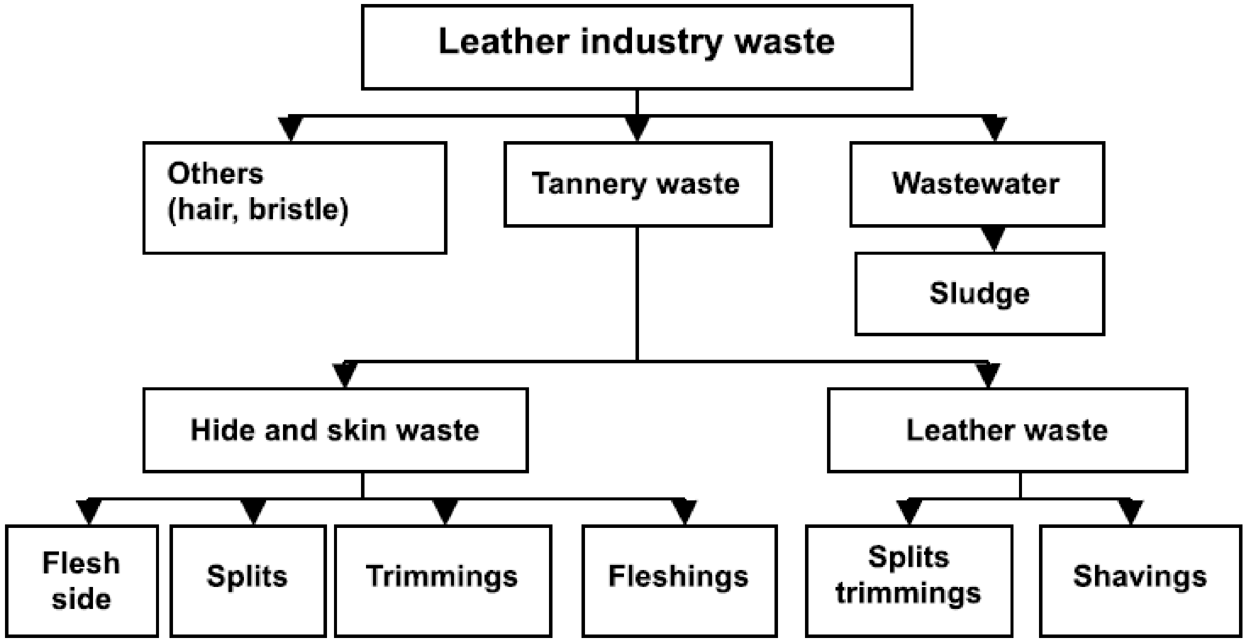


Figure 2.3 the scheme of basic tannery waste division

Table 2.1: Wastes obtained from leather industry during processing

Fleshing	50-60 %
Chrome shaving, Chrome splits and buffing dust	35-40 %
Skin trimmings	5-7 %
Hair	2-5 %

2.7.1 Environmental Impacts of Tannery Waste

The tanning industry is an especially large contributor of chromium pollution. Sustenance of tanneries, particularly of the small units, is becoming increasingly difficult due to alarming levels of environmental pollution caused by various tanning operations and practices. It is estimated that in India alone, about 2000–3000 tons of chromium escape into environment annually from the tanning industries, with chromium concentration ranging between 2000 and 5000 mg/L in the aqueous effluent, compared to the recommended permissible limit of 2 mg/L. installation of wastewater treatment plants in tanneries has considerably reduced the chromium content of such effluents. However, one of the major emerging environmental problems of the tanning industry is the disposal of chromium-contaminated sludge that is produced as a byproduct of wastewater treatment. Since scientific solid waste disposal practices are almost absent in India, large amount of chromium-contaminated sludge is regularly disposed in unlined and ill-maintained solid waste dumping grounds all over the country chromium in such disposal sites is a cause of ongoing concern [39].

2.7.2 Solidification and Stabilization

Chemical stabilization is a process in which the waste is converted to a more chemically stable or more insoluble. Solidification or cementation is a process in which the waste is converted to an insoluble rock like material by mixing with suitable material to form a solid product. Wastes with relatively high concentration of hazardous materials could be immobilized and therefore disposed as wastes with much lower pollution potential [40].

Solid Sludge

According to the data received from the studies of several researchers, approximately 200 kg of leather is manufactured from 1 tone of wet-salted hide this amount constitutes about 20% of rawhide weight. More than 600 kg of solid waste is generated during the transformation of rawhide into leather. That is to say, solid wastes containing protein and fat that constitute more than 60% of rawhide weight are disposed to the environment by leather factories without turning them to good use besides the 30-35m3 waste water disposed to environment during the processing of every 1 ton of rawhide in world leather industry, approximately 8.5 million tons of solid waste is generated during the production of 11 million tons of rawhide processed in the world Data from research shows that 80% of solid wastes are generated during pre-tanning processes, while 20% of the wastes are caused by post-tanning processes [41].

Suspended Solids

The suspended solids component of an effluent is defined as the quantity of insoluble matter contained in the wastewater. These insoluble materials cause a variety of problems when discharged from a site.

Settle able Solids

Although suspended solids analysis is the method most commonly used to assess insoluble Matter, analysis of the settle able solids content is sometimes required. The settle able solids Content is determined by leaving the shaken sample to settle and then filtering a known Volume of the semi-colloidal matter remaining in suspension. After drying and weighing, the quantity of semi-colloidal matter can be calculated.

Gross Solids

The waste components that give rise to this problem are often large pieces of leather cuttings, trimmings and gross shavings, fleshing residues, solid hair debris and remnants of paper bags. They can be easily removed by means of coarse bar screens set in the waste water flow [42].

2.8 Characteristics of Tannery Solid Waste

2.8.1 Chemical Characteristics of tannery sludge

The chemical composition and properties of solid wastes generated from beam house operations (fleshing, Trimmings, splits) depends mainly on a kind and quality of the raw material, treatment type and process conditions. The main components are proteins and fat, up to 10.5% (w/w) for both groups. Water content is high, moisture amounts up to 60%. These wastes contain small amounts of mineral substances, 2-6% (w/w). The tanned leather wastes are mainly useless splits, shavings and trimmings. These waste groups differ mostly in size and shape, the chemical composition is comparable for each. They contain 3-6% (w/w) of fat and about 15% (w/w) of mineral components, including 3.5- 4.5% (w/w) of chromium as $Cr2O3$. Sludge from wastewater treatment plants contains mostly water (up to 65% (w/w)), organic substances (30% (w/w)) and chromium (III) compounds (about 2.5% (w/w)) . Some research work on tannery sludge shows that the level of chromium content is 500 mg kg-1 and this is five folds higher than that should be present in the soil (100 mg kg-1). It has a moisture content (60.6%), pH (7.4), Organic Carbon (20%), Total kjeldhal nitrogen (1.0) and carbon to nitrogen ratio (20). Due to the low solubility of chromium, only a little (Cr) is bioavailable, which means that even when crops are grown in soils treated with sludge relatively high in Cr, phytotoxicity is rarely observed [43].

Table 2.2: Presence of Chemicals in Tannery Sludge.

Composition	Tannery Sludge (%)
MnO	0.23
CaO	26.1
Al_2O_3	0.49
SiO_2	3.52
SO_3	28.7
Cr_2O_3	3.4
TiO_2	0.4
MgO	1.7
ZnO	0.09

2.8.2 Physical Characteristics of tannery sludge

Color and Odors

Color of tannery sludge is dark brown and its measured by visual comparison of the sample.

The Odors may result from raw hides and skins, putrefaction, and from substances including sulfides, mercaptans, and organic solvents. Prevention and control measures for odor emissions include the following:

- Promptly cure raw hides;
- Reduce the time that sludge remains in the thickener, dewater thickened sludge by centrifugation or filter press, and dry the resulting filter cake. Sludge containing less than 30 percent solids may generate especially strong odors;
- Ventilate tannery areas and control exhaust from odorous areas (e.g. where wastewater sludge is thickened and dewatered), through use of a bio filter and / or a wet scrubber with acid, alkali, or oxidant.

Dust

Dust / total particulate may be generated from various operations (e.g. storage and handling of powdery chemicals, dry shaving, buffing, dust removal machines, milling drums, and staking). Dust emissions should be controlled through use of a centralized system, employing cyclones, scrubbers, and / or bag filters, as needed [44].

2.8 Summery

Based on the literature review it's discussed on different Modes of Failure of HMA Surfacing (Fatigue Cracking. Low-Temperature Cracking. Permanent Deformation,. Moisture Susceptibility) Specifically on flexible pavement type most commonly used in Ethiopia. It's discussed on bitumen type of 80/100 used in Addis Ababa because of moderate temperature.

Beside the bitumen characteristics and durability. The aggregate (Size and Grading, Cleanliness, Toughness, Particle Index, Affinity for Asphalt), the Effect of Aggregate Characteristics and Effect of Aggregate Properties on stripping. What are the cause of stripping and methods of preventing stripping?

finally the chemical and physical characteristics of tannery sludge that is obtained from tannery industries its Environmental Impacts ,what are the hazardous and toxic chemical which is bad for human being has been reviewed.

CHAPTER THREE

MATERIAL AND METHOD

3.1 Introduction

The goal of this study is to determine the performance evaluation of bitumen mix using tannery sludge as partial replacement of fine aggregate. The effectiveness of this Partial replacement has been evaluated by comparing test results conducted on unmodified or conventional specimens. The test used in this study to compare the bitumen mix using tannery sludge as partial replacement of fine aggregate is Marshall Mix Design in addition, other performance tests were conducted on the aggregate , asphalt binder, and un-compacted specimens. All tests on aggregate, asphalt binder, loose mixtures, and compacted specimens were conducted according to respective ERA, AASHTO and ASTM testing standards.

3.2 Study Area

Addis Ababa the political capital and the most important commercial and cultural center of Ethiopia, is geographically located at the heart of the nation, $9^{o}2'$N latitude and $38^{o}45'$E longitude. Its average altitude is 2,400 meter above sea level, with the highest elevations at Entoto Hill to the north reaching 3,200 meters. This makes Addis Ababa one of the high-altitude capital cities of the world. With a total of 540 sq. km land area surrounded by mountainous landscape.

Addis Ababa has sub-tropical highland climate with a constant moderate temperature of roughly $23^{o}C$ average high and $11^{o}C$ average low throughout the year. The main rainy season, is from June to early

October, and between early March and mid-April, there is short period of rainfall. The average annual rainfall is about 1,200 mm, out of which close to 80% falls during the main rainy season. Reports show that Addis Ababa has registered around 630,440 vehicles.

Almost all the pavement constructed in the capital city is flexible pavements .Based on climate in Addis Ababa which is sub-tropical. The suitable paving grade for road construction is bitumen penetration grade of 80/100.

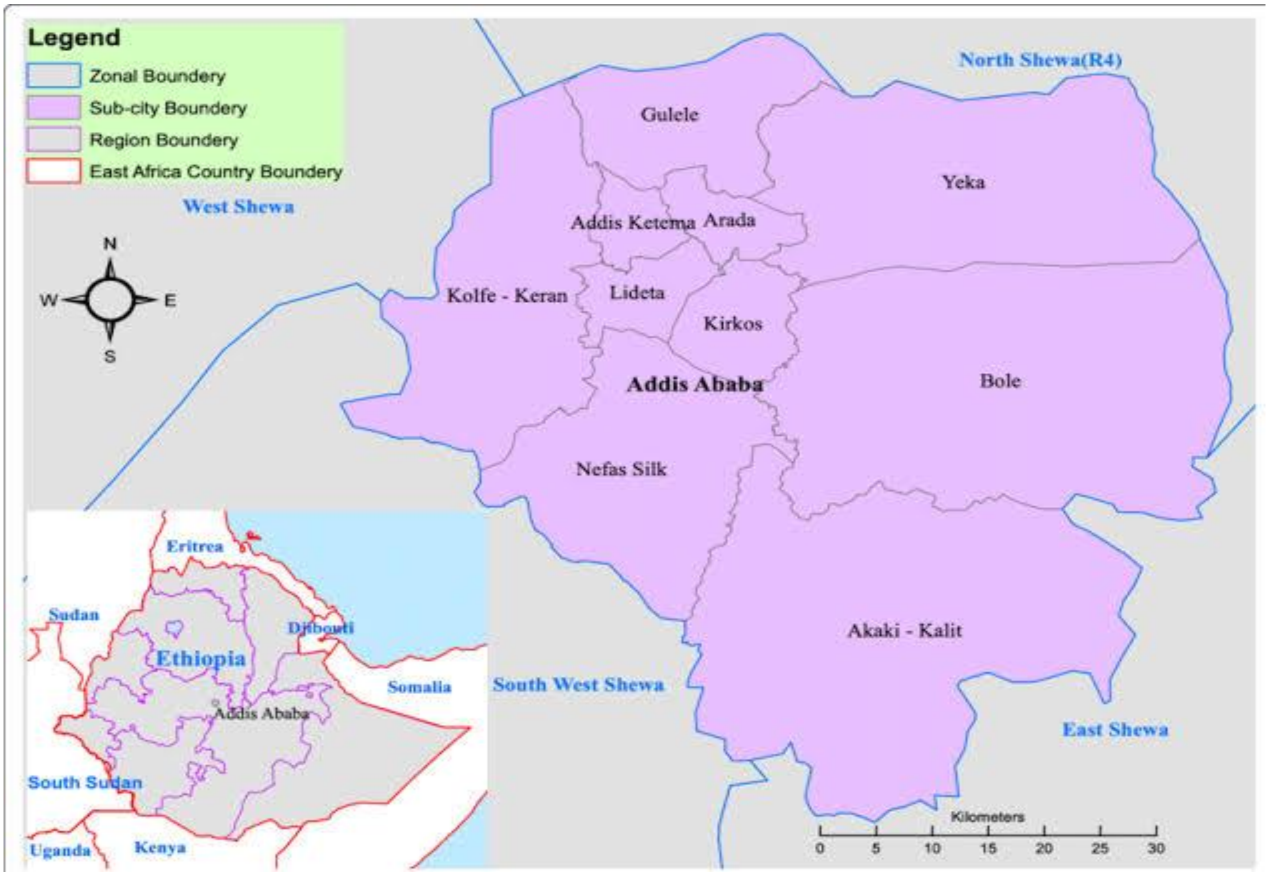


Figure 3-1: Addis Ababa city Administration Map

3.3 Sampling Size

In conducting this research the sample size shall be quantified enough to execute the necessary trials in fulfilling the Marshall property design requirements for all types. A sample of 15 HMA specimens with no tannery sludge has been prepared for this experiment as a controlled condition While the other 60 sample of specimens has been prepared by using tannery sludge as partial replacement of fine aggregate with 2% tannery sludge, 4 % tannery sludge, 6 % tannery sludge and 10 % tannery sludge with 15 samples of specimens for each. 60 specimens [(15 sample *4 trials) with sludge + (15 sample * 1 trial) without sludge] with a total of 75 Sample of specimens. In conducting this research a different materials had been sampled from different sources which could help as an input for the laboratory tests.

3.4 Study Design

In this study, the effects of using tannery sludge as partial replacement of fine aggregate on HMA were evaluated in the laboratory. The research evaluated various materials (i.e., aggregates, binders, and tannery sludge) using multiple test methods and conditioning procedures. Type of bitumen (with penetration grade of 80 – 100) is used for this experiment. Aggregate sources were used with three samples (stock pile) are blended to meet the specification given by Asphalt Institute 1997. One of the mix designs is referred as "no-tannery sludge “or controlled condition. The other mixes have been done by using partial replacing of fine aggregate with tannery sludge at 2%, 4%, 6% and 10%.

3.5 Data Collection

The data collection for accomplishing this research paper works. The sources of the data are collected from different area by using primary data collecting techniques. The primary data include aggregate, bitumen, and tannery sludge and filler collection from their sources. To attain the objective of this research, different types of quantitative data namely aggregate, tannery sludge and bitumen are collected and its detail discussed below.

3.5.1 Bitumen

In construction of Asphalt pavement bitumen is the crucial and expensive material in our country since it’s imported. Considering these 20 liters of bitumen had sampled from the quarry site it has been referred and permitted to collect the bitumen by Mafcon engineering and construction pvt .Ltd.com. Using penetration of 80/100 bitumen grade for the production of HMA. Therefore for this research 80/100 PG bitumen collected from the company.

Figures 3.2: 80/100 Penetration Grade Bitumen.

3.5.2 Aggregate

The best aggregate gradation is the one that have the maximum gradation density. Based on that, three different sizes of aggregates had sampled from the stockpiled production at the quarry site. Each aggregate weigh 20 kilograms to prepare the necessary specimens. Aggregates for HMA are usually classified by size as coarse aggregates, fine aggregates, or mineral fillers. ASTM defines coarse aggregates as particles retains on No.4 (4.75 mm) sieve, fine aggregate as that passing a No.4 sieve (4.75 mm), and mineral filler as material with at least 70 percent passing the No. 200 (75 micrometer) sieve. For this research, aggregates collected from the site found at CMC area. Fifteen kilograms of fine aggregates, intermediate aggregates and coarse aggregates with three bags for each size which is a total of 60 kilograms has been collected based on their size.

Figures 3.3: Coarse Aggregate

Figures3.4: Fine Aggregate

3.5.3 Tannery Sludge

Tannery industries generate sludge containing various types of organic particles and toxic elements (Like chromium and other hazardous chemicals). For this research work 30 kilogram of tannery sludge sample has been collected directly from the industries site. The sludge has been taken from AWASH TANNERY located in Nifas silk area.

Figures3.5: Tannery Sludge

3.6 Material Selection

3.6.1 Bitumen

- Penetration at 25 ^{o}C ,100g,5 sec (AASHTOT49)
- Specific gravity at 25 ^{o}C (ASTM D 70)
- Ductility(cm) (AASHTOT51)
- Ductility on Residue (cm) (AASHTOT51)
- Flash point ^{o}C (AASHTOT48)
- Softening point (^{o}C) (ASTM D36)
- Solubility in Trichloroethylene (%) (AASHTOT44)
- Loss on heating (%) (ASTM D6)
- Penetration of residue percent of original, at 25 ^{o}C, 100g, 5sec (AASHTOT49)

3.6.2 Aggregate

- Shape
  - Flakiness Index (British Standard 812, Part 105 (1990)
  - Aggregate Crushing Value (ACV) (British Standard 812, Part 3 (1985))
  - 10% Fines Aggregate Crushing Test (10%FACT) (British Standard 812,Part 111)
    - DRY (TVF)
    - WET (TFV)
  - Aggregate Impact Value (AIV) (British Standard 812, Part 3 (1985))
  - Los Angeles Abrasion (LAA) (AASHTO T96)
- Durability
  - Water Absorption (British Standard 812, Part 2 1975)
  - Soundness - Sodium or Magnesium Test (AASHTO T104)
- Cleanliness
  - Clay Content.

3.7 Marshal Method of Mix Design

In this method, the resistance to plastic deformation of a compacted cylindrical specimen of bituminous mixture has been measured when the specimen loaded diametrically at a deformation rate.. There are two major features of the Marshall method of mix design.

- density-voids analysis and
- Stability-flow tests.

The Marshall stability of the mix is defined as the maximum load carried by the specimen at a standard test temperature. The flow value is the deformation that the test specimen undergoes during loading up to the maximum load. Flow is measured in mm units. In this test, an attempt is made to obtain optimum Binder content for the type of aggregate mix used and the expected traffic intensity.

Purpose:

This test method covers the measurement of the resistance to plastic flow of cylindrical specimens of bituminous paving mixture loaded on the lateral surface by means of the Marshall apparatus.

Steps of Design

1. Select aggregate grading to be used
2. Determine the proportion of each aggregate size
3. Determine the specific gravity of the aggregate combination and asphalt cement.
4. Prepare the trial specimens with varying asphalt contents.
5. Determine the specific gravity of each compacted specimen.
6. Perform stability tests on the specimens.
7. Calculate the percentage of voids, and percent voids filled with Bitumen in each specimen.
8. Select the optimum binder content from the data obtained.
9. Evaluate the design with the design requirements.

Apparatus Required:

- Specimen Mold Assembly –
- Specimen Extractor,
- Compaction Hammer.
- Compaction Pedestal -
- Specimen Mold Holder,
- Breaking Head -
- Loading Jack -
- Ovens or Hot Plates
- Mixing Apparatus - Mechanical mixing is recommended.
- Water Bath - Miscellaneous Equipment:
- Containers
- Mixing Tool
- Thermometers
- Balance
- Gloves
- Rubber Gloves
- Marking Crayons
- Scoop
- Spoon

3.7.1 Preparation of Test Specimens:

- Number of Specimens - Prepare at least three specimens for each combination of aggregates and Bitumen content
- Preparation of Aggregates - Dry aggregates to constant weight at 221 to 230 °F (105 to 110 °C) and Separate the aggregates to dry sieving into the desired size fractions.
- Determination of Mixing and Compacting Temperatures:
- The temperatures to which the asphalt cement must be heated to produce a viscosity of 170 $\pm$20 cSt It shall be the mixing temperature.

- The temperature to which asphalt cement must be heated to produce a viscosity of 280 ±30 cSt It shall be the compacting temperature.
- Preparation of Mixtures: Weigh into separate pans for each test specimen the amount of each size fraction required to produce a batch that result in a compacted specimen 2.5 ° 0.05 in. in height (about 1200 g). Place the pans on the hot plate or in the oven and heat to a temperature not exceeding the mixing temperature by more than approximately 28 °C. Charge the mixing bowl with the heated aggregate and dry mix thoroughly. Form a crater in the dry blended aggregate and weigh the preheated required amount of bituminous material into the mixture. Mix the aggregate and bituminous material rapidly until thoroughly coated.
- Compaction of Specimens:
- Thoroughly clean the specimen mold assembly and the face of the compaction hammer and heat them either in boiling water or on the hot plate to a temperature between 200 and 300 °F (93.3 and 148.9 °C). Place a piece of filter paper or paper toweling cut to size in the bottom of the mold before the mixture is introduced. Place the entire batch in the mold, spade the mixture vigorously with a heated spatula or trowel 15 times around the perimeter and 10 times over the interior. Remove the collar and smooth the surface of the mix with a trowel to a slightly rounded shape.
- 75 times Compaction number of blows at each end of specimen.

3.7.2 Marshall Mix Design

For this study the Marshall Mix Design method for HMA mixtures was used to identify the optimum asphalt binder contents for all mixtures. Therefore preparing Marshall Specimens using the Marshall procedures for individual specimens are necessary. Dry and sieve aggregates into sizes (preferably individual sizes) and store in clean sealable containers. Separate enough material to make 1 (types of aggregate) × 15 (samples for five bitumen and three samples for each bitumen) for conventional method as a control condition and at least 4 trial (four partially replaced sludge with fine aggregate) sample. This is approximately 1200gm each. Next weigh the aggregate for each sieve retained and partially replaced fine aggregate with the same weight tannery sludge placing each in a separate container and heat to mixing temperature determined from the asphalt property. Then heat sufficient asphalt cement to prepare the total specimens on each step. Asphalt contents have been selected at 0.5 percent increments with at least two asphalt contents above "optimum" and at least two below "optimum."

It is necessary to mix asphalt cement and aggregate until all the aggregate is coated. It is helpful to work on a heated table. Mixing can be by hand, but a mechanical mixer is preferred. Also it is essential to check temperature of freshly mixed material. Bituminous mixes (sometimes called asphalt mixes) are used in the surface layer of road and airfield pavements. The mix is composed usually of aggregate and asphalt cements. Some types of bituminous mixes are also used in base coarse. The design of asphalt paving mix, as with the design of other engineering materials is largely a matter of selecting and proportioning constituent materials to obtain the desired properties in the finished pavement structure.

The desirable properties of Asphalt mixes are:

1. Resistance to permanent deformation is more important at high temperatures.
2. The mix should not crack when subjected to repeated loads over a period of time.
3. Resistance to low temperature cracking.
4. The mix should contain sufficient asphalt cement to ensure an adequate film thickness around the Aggregate particles. The compacted mix should not have very high air voids, which accelerates the aging Process.
5. Resistance to moisture-induced damage.
6. Skid resistance.
7. Workability: the mix must be capable of being placed and compacted with reasonable effort.
8. Low noise and good drainage properties.

Weight Volume relationships on compacted hot mix asphalt and volumetric analysis

Bulk Specific Gravity (Gsb)

Determination of the BSG's of the aggregates is based on the oven dried weight. Accuracy of measurement is important and it is recommended that they are determined to four Significant figures, i.e. three decimal places. If the BSG's of the different aggregate sizes do not differ by more than 0.2 then the inaccuracies produced by proportioning by weight rather than by volume will be small. The BSG's of the individual coarse aggregate fractions, the fine aggregate and mineral filler fractions are used to calculate the Bulk Specific Gravity (Gsb) of the total aggregate.

The ratio of the weight in air of a unit volume of a permeable material (including both permeable and impermeable voids normal to the material) at a stated temperature to the weight in air of equal volume of gas free distilled water at a stated temperature. Using the following formula;

$$Gsb = \frac{P_1 + P_2 + \ldots\ldots P_n}{\frac{P_1}{G_1} + \frac{P_2}{G_2} + \ldots\ldots \frac{P_n}{G_n}}$$

Where:

Gsb = bulk specific gravity for the total aggregate

P1, P2... Pn = individual percentages by weight of aggregates

G1, G2.. Gn = individual bulk specific gravities of aggregates

Effective Specific Gravity of Aggregate (Gse)

The ratio of the weight in air of a unit volume of a permeable material (excluding voids permeable to asphalt) at a stated temperature to the weight in air of equal density of an equal volume of gas free distilled water at a stated temperature.

$$Gse = \frac{100 - Pb}{\frac{100}{G_{mm}} - \frac{P_b}{G_b}}$$

Where

Gse = effective specific gravity of aggregate;

Gmm = maximum specific gravity of mixed material (no air voids);

Pb = bitumen content at which ASTM D2041 test (Gmm) was performed, percent by total weight of mixture;

Gb = specific gravity of bitumen

Maximum Specific Gravity of Mixtures with Different Bitumen Contents (Gmm)

The Gmm for a given mix must be known at each bitumen content to allow the Va to be calculated Gmm can be measured at each bitumen content and a plot of VMA against bitumen content should produce a smooth relationship. This will indicate if any test result is suspect and that it should be repeated.

The Asphalt Institute suggests an alternative procedure because the precision of the test is best when the mixture is close to the design bitumen content. By calculating the effective SG (Gse) for the measured Gmm, using Equation C4 the Gmm for any other bitumen content can be obtained as follows:

$$Gmm = \frac{100}{\frac{P_s}{G_{se}} + \frac{P_b}{G_b}}$$

Where

Gmm = maximum specific gravity of mixture (no air voids)

Ps = aggregate content, percent by total weight of mixture

Pb = bitumen content, percent by total weight of mixture

Gse = effective specific gravity of aggregate

Gb = specific gravity of bitumen

Bitumen Absorption (Pba)

It is defined as the percent by weight of the bitumen that is absorbed by the aggregates based on the total weight of the aggregates. This is given as

$$Pba = \frac{100\,(Gse - Gsb)\,Gb}{Gse\;\;Gsb}$$

Where:

Pba = absorbed bitumen, percent by weight of aggregate

Gse = effective specific gravity of aggregate

Gsb = bulk specific gravity of total aggregate

Gb = specific gravity of bitumen

Effective Bitumen Content of the Mix (Pbe)

The total bitumen content of a paving mixture minus the portion of asphalt that is lost by absorption into the aggregate particles.

$$Pbe = Pb - \frac{Pba\;Ps}{100}$$

Where

Pbe = effective bitumen content, percent by total weight of mix

Pb = bitumen content, percent by total weight of mix

Pba = absorbed bitumen, percent by weight of aggregate

Ps = aggregate content, percent by total weight of mix

Percent Voids in Mineral Aggregate (VMA)

The percent voids in compacted mineral aggregates are the percentage of void spaces between the granular particles in the compacted paving mixture, including the air voids and the volume occupied by the effective asphalt content. It usually is calculated as a percentage of the bulk volume of the compacted

Mixture based on the bulk specific gravity of the aggregates.

$$VMA = 100 - \frac{G_{mb} P_s}{G_{sb}}$$

Where:

VMA = voids in mineral aggregate

Gmb = bulk specific gravity of compacted mix

Gsb = bulk specific gravity of total aggregate

Ps = aggregate content, percent by total weight of mix

Percent Air Voids in a Compacted Mix (va)

The total volume of the small pockets of air between the coated aggregate particles throughout a compacted paving mixture, expressed as percent of the bulk volume of the compacted paving mixture.

$$Va = 100 * \left[\frac{G_{mm} - G_{mb}}{G_{mm}} \right]$$

Where

Va = air voids in compacted mix, percent of total volume

Gmm = maximum specific gravity of mix

Gmb = bulk specific gravity of compacted mix

Percent Voids Filled with Bitumen (VFB) in a Compacted Mix (VFB)

The voids filled with bitumen, VFB, is the percentage of VMA that is filled with bitumen.

It is calculated using:

$$VFA = 100 * \left[\frac{VMA - Va}{VMA} \right]$$

Where

VFB = voids filled with bitumen (per cent of VMA)

VMA = voids in mineral aggregate, per cent of bulk volume

VIM = air voids in compacted mix, percent of total volume

CHAPTER FOUR

RESULT AND DISCUSSION

4.1 Bitumen Quality Test

A series of tests including penetration, specific gravity, softening point, flash point, ductility, and solubility in carbon tetrachloride were conducted for the basic characterization properties of penetration grade asphalt. The test results are shown in Table 4.1, which complies with the requirement of ERA specifications.

Table 4.1: Laboratory test result of 80 /100 PG Bitumen.

TYPES OF TEST	TEST METHOD	TEST RESULT	SPECIFICATION (AASHTO)
Penetration at 25 ^oC,100gm, 5 sec	AASHTOT49	92	85-100
Ductility at 25 ^oC (cm)	AASHTOT51	100+	100+
Softening point (^oC)	ASTM D36	50	42-51
Flash point (^oC)	AASHTOT48	282	232+
Loss on heating (%)	ASTM D6	0.03	<1
Penetration of residue percent of original, at 25 ^oC, 100g, 5sec	AASHTOT49	75	50+
Ductility on Residue(cm)	AASHTOT51	100+	10+
Solubility in Trichloroethylene (%)	AASHTOT44	99.68	99+
Specific gravity at 25 ^oC (kg/m3)	ASTM D70	1.031	1.01-1.05

4.2 Aggregate Quality Test

Important properties and performance tests has been conducted when selecting aggregates for the asphalt mix design. First the bulk and apparent specific gravities has been calculated for the range of aggregates. Then performance tests for durability, angularity, and clay content has been conducted.

Table 4.2: Quality tests of the aggregates used for laboratory test

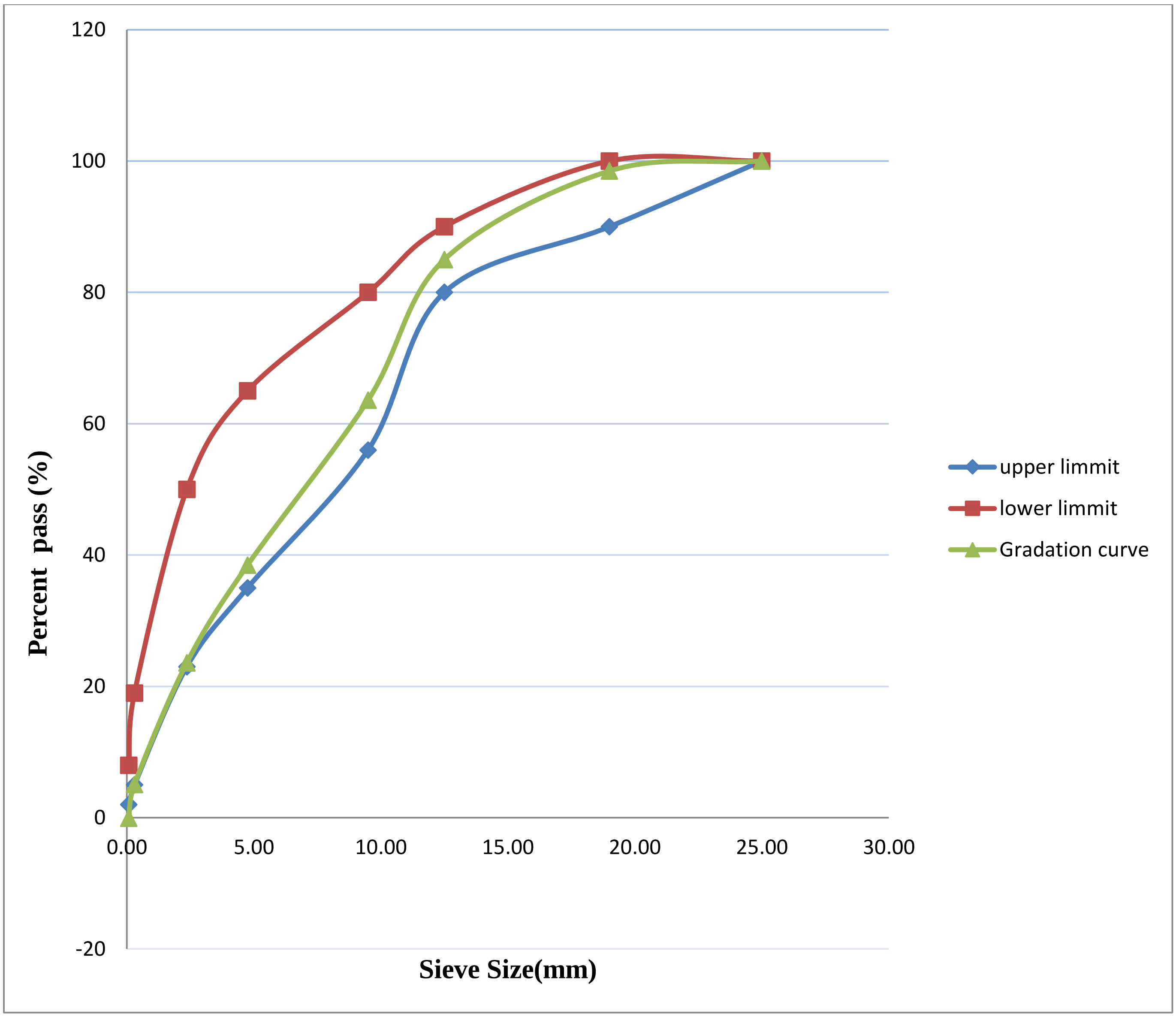
TYPES OF TEST	TEST METHOD	TEST RESULT	SPECIFICATION (ERA)
Flakiness Index (%),	British Standard 812, Part 105 (1990)	18	< 35 %
Aggregate Crush Value (ACV) (%)	British Standard 812, Part 3 (1985)	16	< 25 %
Ten Percent Fine value Dry(TFV)	BS 812 Part 111	182.3	>160
Ten Percent Fine value Wet(TFV)	BS 812 Part 111	174.6	
Aggregate Impact Value(ACV)	British Standard 812, Part 3 (1985)	14	< 25 %
Los Angeles Abrasion(%), Grading A	AASHTO T96	17	<30 (wearing coarse) <35 for others
Water absorption (%)	British Standard 812, Part 2 1975	1.89	< 2
Bulk Specific Gravity	AASHTO T85	2.7	
Soundness loss by NaSO4 (%),	AASHTO T104	4.31	< 10 %

19mm Pass-4.75 mm retain (01)			
Soundness loss by NaSO4 (%),	AASHTO T104	4.55	< 10 %
Bulk specific gravity	AASHTO T85	2.7	N/A
Water absorption (%)	British Standard 812, Part 2 1975	2.03	< 2

4.75mm Pass-0.075 mm retain(Crushed fine)			
Clay content		4.6	N/A
Water absorption (%)	British Standard 812, Part 2 1975	3.6	< 2

4.3 Aggregate Gradation

Figure 4.1 Aggregate gradations for Controlled Conditions (0% Tannery Sludge)



4.4 Test Result of Marshall Mixture

Table 4.3 Bulk specific gravity for controlled condition (0% Tannery Sludge)

Tannery Sludge (%)	Trial	%BC by weight of total mix	MTD of mix	Weight of specimen in air	Weight of specimen in water	Weight of specimen in air (SSD)	Bulk volume of specimen	Bulk specific gravity of specimen
Control Condition(0% Tannery Sludge)	1	4.0	2.536	1219.74	689.64	1221.99	532.35	2.29
	2	4.0	2.536	1216.00	691.66	1220.14	528.49	2.30
	3	4.0	2.536	1220.75	691.48	1225.33	533.85	2.29
	Average		2.536					2.293
	1	4.5	2.516	1224.90	699.38	1229.21	529.83	2.31
	2	4.5	2.516	1226.02	700.12	1230.12	530.00	2.31
	3	4.5	2.516	1224.46	696.98	1226.17	529.19	2.31
	Average		2.516					2.313
	1	5.0	2.498	1227.98	702.36	1231.98	529.62	2.32
	2	5.0	2.498	1226.27	701.25	1230.38	529.13	2.32
	3	5.0	2.498	1229.48	703.37	1232.18	528.81	2.32
	Average		2.498					2.320
	1	5.5	2.480	1228.77	701.72	1230.45	528.73	2.32
	2	5.5	2.480	1230.45	702.78	1232.53	529.76	2.32
	3	5.5	2.480	1227.76	700.74	1229.42	528.68	2.32
	Average		2.480					2.323
	1	6.0	2.461	1246.64	714.88	1250.71	535.82	2.33
	2	6.0	2.461	1244.91	712.32	1249.08	536.76	2.32
	3	6.0	2.461	1248.17	717.76	1250.91	533.15	2.34
	Average		2.461					2.329

Table 4.4 Bulk specific gravity for 2% Tannery Sludge

Tannery Sludge (%)	Trial	%BC by weight of total mix	MTD of mix	Weight of specimen in air	Weight of specimen in water	Weight of specimen in air (SSD)	Bulk volume of specimen	Bulk specific gravity of specimen
2% Tannery Sludge	1	4.0	2.536	1218.53	672.52	1223.24	550.72	2.21
	2	4.0	2.536	1214.80	670.46	1219.49	549.03	2.21
	3	4.0	2.536	1219.54	673.08	1224.25	551.17	2.21
	Average		2.536					2.213
	1	4.5	2.516	1220.63	677.20	1227.07	549.87	2.22
	2	4.5	2.516	1218.93	681.70	1225.37	543.66	2.24
	3	4.5	2.516	1222.12	678.03	1228.57	550.54	2.22
	Average		2.516					2.227
	1	5.0	2.498	1223.69	684.83	1230.46	545.63	2.24
	2	5.0	2.498	1224.81	685.46	1231.59	546.13	2.24
	3	5.0	2.498	1223.25	680.48	1230.01	549.53	2.23
	Average		2.498					2.237
	1	5.5	2.480	1227.56	702.58	1234.35	531.77	2.31
	2	5.5	2.480	1229.23	710.87	1236.03	525.16	2.34
	3	5.5	2.480	1226.54	702.00	1233.33	531.33	2.31
	Average		2.480					2.319
	1	6.0	2.461	1245.41	712.23	1252.30	540.07	2.31
	2	6.0	2.461	1243.68	712.69	1250.56	537.87	2.31
	3	6.0	2.461	1246.93	711.10	1253.83	542.73	2.30
	Average		2.461					2.305

Table 4.5 Bulk specific gravity for 4% Tannery Sludge

Tannery Sludge (%)	Trial	%BC by weight of total mix	MTD of mix	Weight of specimen in air	Weight of specimen in water	Weight of specimen in air (SSD)	Bulk volume of specimen	Bulk specific gravity of specimen
4% Tannery Sludge	1	4.0	2.536	1215.74	658.96	1217.98	559.02	2.17
	2	4.0	2.536	1212.01	660.98	1216.14	555.16	2.18
	3	4.0	2.536	1216.74	658.59	1221.31	562.72	2.16
	Average		2.536					2.173
	1	4.5	2.516	1217.82	657.15	1221.80	564.65	2.16
	2	4.5	2.516	1216.13	659.22	1220.21	560.99	2.17
	3	4.5	2.516	1219.31	661.30	1222.00	560.70	2.17
	Average		2.516					2.166
	1	5.0	2.498	1220.88	662.30	1225.17	562.87	2.17
	2	5.0	2.498	1222.00	662.50	1226.08	563.58	2.17
	3	5.0	2.498	1220.44	669.30	1222.15	552.85	2.21
	Average		2.498					2.182
	1	5.5	2.480	1224.74	668.90	1226.41	557.51	2.20
	2	5.5	2.480	1226.41	669.20	1228.49	559.29	2.19
	3	5.5	2.480	1223.73	669.20	1225.39	556.19	2.20
	Average		2.480					2.197
	1	6.0	2.461	1242.55	679.00	1246.60	567.60	2.19
	2	6.0	2.461	1240.83	674.30	1244.98	570.68	2.17
	3	6.0	2.461	1244.07	665.30	1246.81	581.51	2.18
	Average		2.461					2.181

Table 4.6 Bulk specific gravity for 6% Tannery Sludge

Tannery Sludge (%)	Trial	%BC by weight of total mix	MTD of mix	Weight of specimen in air	Weight of specimen in water	Weight of specimen in air (SSD)	Bulk volume of specimen	Bulk specific gravity of specimen
6% Tannery Sludge	1	4.0	2.536	1211.37	648.48	1216.03	567.55	2.13
	2	4.0	2.536	1207.66	646.50	1212.31	565.81	2.13
	3	4.0	2.536	1212.37	649.02	1217.04	568.02	2.13
	Average		2.536					2.134
	1	4.5	2.516	1213.45	652.81	1218.12	565.31	2.15
	2	4.5	2.516	1211.77	651.91	1216.43	564.52	2.15
	3	4.5	2.516	1214.94	653.61	1219.61	566.00	2.15
	Average		2.516					2.147
	1	5.0	2.498	1216.50	655.58	1221.18	565.60	2.15
	2	5.0	2.498	1217.61	656.18	1222.30	566.12	2.15
	3	5.0	2.498	1216.05	655.34	1220.74	565.40	2.15
	Average		2.498					2.151
	1	5.5	2.480	1220.34	668.55	1225.04	556.49	2.19
	2	5.5	2.480	1222.01	669.46	1226.71	557.25	2.19
	3	5.5	2.480	1219.33	668.00	1224.03	556.03	2.19
	Average		2.480					2.193
	1	6.0	2.461	1238.09	671.00	1242.85	571.85	2.17
	2	6.0	2.461	1236.37	674.45	1241.13	566.68	2.18
	3	6.0	2.461	1239.60	679.23	1244.37	565.14	2.19
	Average		2.461					2.180

Table 4.7 Bulk specific gravity for 10% Tannery Sludge

Tannery Sludge (%)	Trial	%BC by weight of total mix	MTD of mix	Weight of specimen in air	Weight of specimen in water	Weight of specimen in air (SSD)	Bulk volume of specimen	Bulk specific gravity of specimen
10% Tannery Sludge	1	4.0	2.536	1204.90	621.49	1209.55	588.06	2.05
	2	4.0	2.536	1201.21	619.59	1205.85	586.26	2.05
	3	4.0	2.536	1205.90	622.01	1210.55	588.55	2.05
	Average		2.536					2.049
	1	4.5	2.516	1206.97	622.56	1213.34	590.78	2.04
	2	4.5	2.516	1205.30	621.70	1211.66	589.96	2.04
	3	4.5	2.516	1208.45	623.32	1214.83	591.51	2.04
	Average		2.516					2.043
	1	5.0	2.498	1210.00	624.12	1216.70	592.57	2.04
	2	5.0	2.498	1211.11	624.69	1217.81	593.12	2.04
	3	5.0	2.498	1209.56	623.89	1216.25	592.36	2.04
	Average		2.498					2.042
	1	5.5	2.480	1213.82	626.09	1220.54	594.45	2.04
	2	5.5	2.480	1215.48	626.95	1222.21	595.26	2.04
	3	5.5	2.480	1212.82	625.58	1219.53	593.96	2.04
	Average		2.480					2.042
	1	6.0	2.461	1231.48	635.20	1238.29	603.09	2.04
	2	6.0	2.461	1229.77	634.32	1236.57	602.26	2.04
	3	6.0	2.461	1232.98	635.98	1239.80	603.83	2.04
	Average		2.461					2.042

4.5. Optimum Bitumen Content Determination

Method I-NAPA Procedure

1. Determine the Bitumen content which corresponds to the specification's median air void content (4 percent typically). This is the optimum Bitumen content.
2. Determine the following properties at this optimum bitumen content by referring to the plots:
   - Marshall stability
   - Flow
   - VMA and
   - VFB.
3. Compare each of these values against the specification values and if all are within the specification, then the preceding optimum bitumen content is satisfactory. If any of these properties is outside the specification range, the mixture should be redesigned.

Method 2-Asphalt Institute Method

1. Determine:
   (a) Bitumen content at maximum stability
   (b) Bitumen content at maximum density
   (c) Bitumen content at midpoint of specified air void range (4 percent typically)
2. Average the three bitumen contents selected above.
3. For the average bitumen content, determine the following properties:
   - Stability;
   - Flow;
   - Air voids; and
   - VMA.
4. For this research the Asphalt Institute Method is selected to determine the optimum bitumen binder.

Table 4.8 AC Wearing Course Specifications for up to 5 million esa Asphalt Institute (MS-2, 1994)

Description	Category and design traffic (million ESA)					
	Light Traffic (<0.4)		**Medium Traffic (0.4-1)**		**Heavy Traffic (1-5)**	
	Min	**Max**	**Min**	**Max**	**Min**	**Max**
Compaction number of blows at each end of specimen	35		50		75	
Stability No.minimum (N)	3300		5300		8000	
Flow, in mm	2	4.5	2	4	2	3.5
Percent Air Voids at OBC (%)	4		4		4	
Percent Voids in mineral aggregate (VMA) for 19mm nominal aggregate size and 4% air void	12	14	11	13	13	
Percent filled with Bitumen (VFB)	70	80	65	78	65	75

4.6 Analysis on Physical Properties of Compacted HMA.

Table 4.9 Volumetric properties for controlled condition (0% Tannery Sludge)

Tannery Sludge (%)	Trial	% Bitumen content by weight of total mix	Air void (%)	VMA (%)	VFB (%)	Stability(KN)	Flow(mm)
Control Condition(0% Tannery Sludge)	1	4.0	9.65	17.68	45.45	11.53	2.52
	2	4.0	9.26	17.33	46.56	11.23	2.63
	3	4.0	9.82	17.84	44.95	10.88	2.40
	Average		9.577	17.619	45.651	11.214	2.515
		4.5	8.11	17.37	53.30	13.95	2.64
		4.5	8.06	17.32	53.48	13.59	2.57
		4.5	8.04	17.30	53.56	13.22	2.51
	Average		8.069	17.332	53.444	13.589	2.575
		5.0	7.18	17.57	59.11	12.87	2.62
		5.0	7.23	17.60	58.96	12.50	2.67
		5.0	6.93	17.34	60.05	12.14	2.51
	Average		7.111	17.502	59.373	12.501	2.602
		5.5	6.29	17.81	64.68	11.77	2.73
		5.5	6.34	17.85	64.47	11.41	2.77
		5.5	6.36	17.87	64.41	11.48	2.82
	Average		6.331	17.843	64.520	11.553	2.776
		6.0	5.46	18.15	69.91	10.69	2.76
		6.0	5.76	18.41	68.72	10.32	2.72
		6.0	4.87	17.64	72.39	9.96	2.83
	Average		5.364	18.066	70.339	10.321	2.770

Table 4.10 Volumetric properties for 2% Tannery Sludge

Tannery Sludge (%)	Trial	% Bitumen content by weight of total mix	Air void (%)	VMA (%)	VFB (%)	Stability(KN)	Flow(mm)
2% Tannery Sludge	1	4.0	12.74	21.04	39.42	10.15	2.45
	2	4.0	12.74	21.04	39.42	10.45	2.56
	3	4.0	12.74	21.04	39.42	10.57	2.34
	Average		12.744	21.036	39.418	10.391	2.449
		4.5	11.77	21.19	44.46	13.56	2.54
		4.5	10.89	20.40	46.64	13.21	2.48
		4.5	11.77	21.19	44.46	12.85	2.41
	Average		11.476	20.928	45.183	13.209	2.477
		5.0	10.22	20.80	50.86	12.51	2.52
		5.0	10.22	20.80	50.86	12.15	2.57
		5.0	10.89	21.39	49.08	11.80	2.41
	Average		10.443	20.993	50.267	12.151	2.503
		5.5	6.92	18.90	63.41	11.44	2.63
		5.5	5.62	17.77	68.39	11.09	2.67
		5.5	6.92	18.90	63.41	11.16	2.71
	Average		6.484	18.527	65.068	11.230	2.671
		6.0	6.30	18.81	66.53	10.39	2.65
		6.0	6.05	18.60	67.49	10.03	2.62
		6.0	6.64	19.11	65.24	9.68	2.72
	Average		6.329	18.841	66.421	10.032	2.665

Table 4.11 Volumetric properties for 4% Tannery Sludge

Tannery Sludge (%)	Trial	% Bitumen content by weight of total mix	Air void (%)	VMA (%)	VFB (%)	Stability(KN)	Flow(mm)
4% Tannery Sludge	1	4.0	14.24	21.81	34.71	10.24	2.18
	2	4.0	13.91	21.50	35.33	9.98	2.26
	3	4.0	14.73	22.26	33.81	9.66	2.08
	Average		14.291	21.855	34.618	9.960	2.174
		4.5	14.28	22.86	37.54	12.39	2.21
		4.5	13.84	22.46	38.39	12.07	2.16
		4.5	13.57	22.22	38.93	11.74	2.10
	Average		13.894	22.512	38.288	12.069	2.155
		5.0	13.17	22.83	42.30	11.43	1.90
		5.0	13.20	22.85	42.24	11.10	1.85
		5.0	11.63	21.45	45.80	10.78	1.80
	Average		12.666	22.377	43.447	11.103	1.850
		5.5	11.42	22.25	48.67	10.45	1.75
		5.5	11.58	22.39	48.28	10.14	1.70
		5.5	11.28	22.13	49.01	10.19	1.65
	Average		11.427	22.255	48.654	10.261	1.697
		6.0	11.05	22.93	51.82	9.49	1.60
		6.0	11.65	23.45	50.32	9.16	1.54
		6.0	11.42	23.25	50.89	8.85	1.49
	Average		11.372	23.211	51.012	9.166	1.544

Table 4.12 Volumetric properties for 6% Tannery Sludge

Tannery Sludge (%)	Trial	% Bitumen content by weight of total mix	Air void (%)	VMA (%)	VFB (%)	Stability(KN)	Flow(mm)
6% Tannery Sludge	1	4.0	15.83	23.26	31.94	9.51	2.12
	2	4.0	15.83	23.26	31.94	9.82	2.21
	3	4.0	15.83	23.26	31.94	10.08	2.02
	Average		15.830	23.258	31.938	9.805	2.115
		4.5	14.68	23.22	36.77	12.20	2.22
		4.5	14.68	23.22	36.77	11.89	2.16
		4.5	14.68	23.22	36.77	11.56	2.11
	Average		14.685	23.223	36.767	11.884	2.165
		5.0	13.90	23.47	40.79	11.25	2.21
		5.0	13.90	23.47	40.79	10.93	2.25
		5.0	13.90	23.47	40.79	10.62	2.11
	Average		13.899	23.473	40.788	10.932	2.188
		5.5	11.58	22.39	48.29	10.29	2.30
		5.5	11.58	22.39	48.29	9.98	2.33
		5.5	11.58	22.39	48.29	10.04	2.37
	Average		11.576	22.385	48.289	10.104	2.334
		6.0	12.03	23.78	49.42	9.35	2.32
		6.0	11.35	23.19	51.07	9.02	2.29
		6.0	10.87	22.78	52.27	8.71	2.38
	Average		11.415	23.248	50.921	9.026	2.329

Table 4.13 Volumetric properties for 10% Tannery Sludge

Tannery Sludge (%)	Trial	% Bitumen content by weight of total mix	Air void (%)	VMA (%)	VFB (%)	Stability(KN)	Flow(mm)
10% Tannery Sludge	1	4.0	19.20	26.88	28.57	10.15	2.06
	2	4.0	19.20	26.88	28.57	10.45	2.15
	3	4.0	19.20	26.88	28.57	9.83	1.96
	Average		19.199	26.878	28.568	10.142	2.058
		4.5	18.80	27.47	31.56	12.60	2.16
		4.5	18.80	27.47	31.56	12.28	2.11
		4.5	18.80	27.47	31.56	11.94	2.05
	Average		18.800	27.470	31.562	12.274	2.106
		5.0	18.26	27.89	34.53	11.62	2.15
		5.0	18.26	27.89	34.53	11.29	2.19
		5.0	18.26	27.89	34.53	10.96	2.05
	Average		18.257	27.887	34.532	11.291	2.129
		5.5	17.66	28.27	37.51	10.63	2.24
		5.5	17.66	28.27	37.51	10.31	2.27
		5.5	17.66	28.27	37.51	10.37	2.31
	Average		17.664	28.266	37.510	10.435	2.271
		6.0	17.03	28.11	39.43	9.65	2.26
		6.0	17.03	28.11	39.43	9.32	2.23
		6.0	17.03	28.11	39.43	9.00	2.31
	Average		17.028	28.112	39.427	9.322	2.267

Effect of Partially Replaced Tannery Sludge on Stability of Mix

Stability is defined as the maximum compressive load carried by a compacted specimen tested at 60^0C at a loading rate of 50.8 mm/min. The Marshall Stability values can be increased by using "stiffer" or more viscous asphalt binder grade, aggregates that are more angular or a blend of all crushed aggregates and any material that can stiffen an asphalt binder also increase the Marshall stability. Generally a measure of the mass viscosity of the aggregate-asphalt cement mixture and is affected significantly by the angle of internal friction of the aggregate and the viscosity of the asphalt cement. Anything that increases the viscosity of the asphalt cement increases the Marshall stability

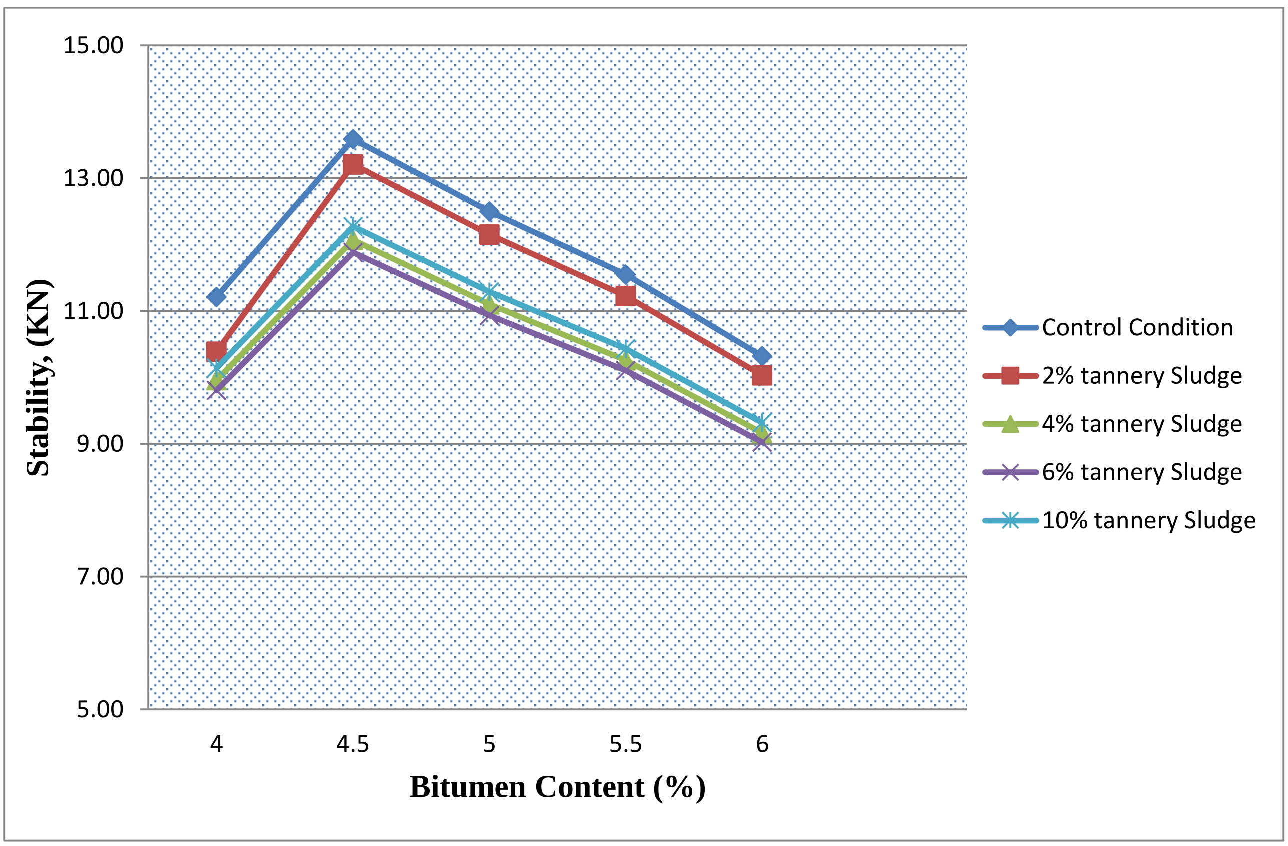


Figure 4.2: Effect of Partially replaced tannery sludge on Stability of Mix

Effect of Partially Replaced Tannery Sludge on Flow of Mix

The flow is the vertical deformation of the compacted specimen from the start of the Marshall stability loading until the stability values begin to decrease in 0.25mm. High flow values indicate an asphalt mixture that has plastic behavior and has the potential for permanent deformation, such as rutting or shoving, under traffic loading. Low flow values indicate a mixture that may have insufficient asphalt binder, which may lead to durability problems with the pavement. Low flow values may also indicate a mixture with a binder so stiff, that the pavement experiences low temperature or fatigue cracking. Marshall Flow is a function of the asphalt binder stiffness and the asphalt binder content of the mixture.

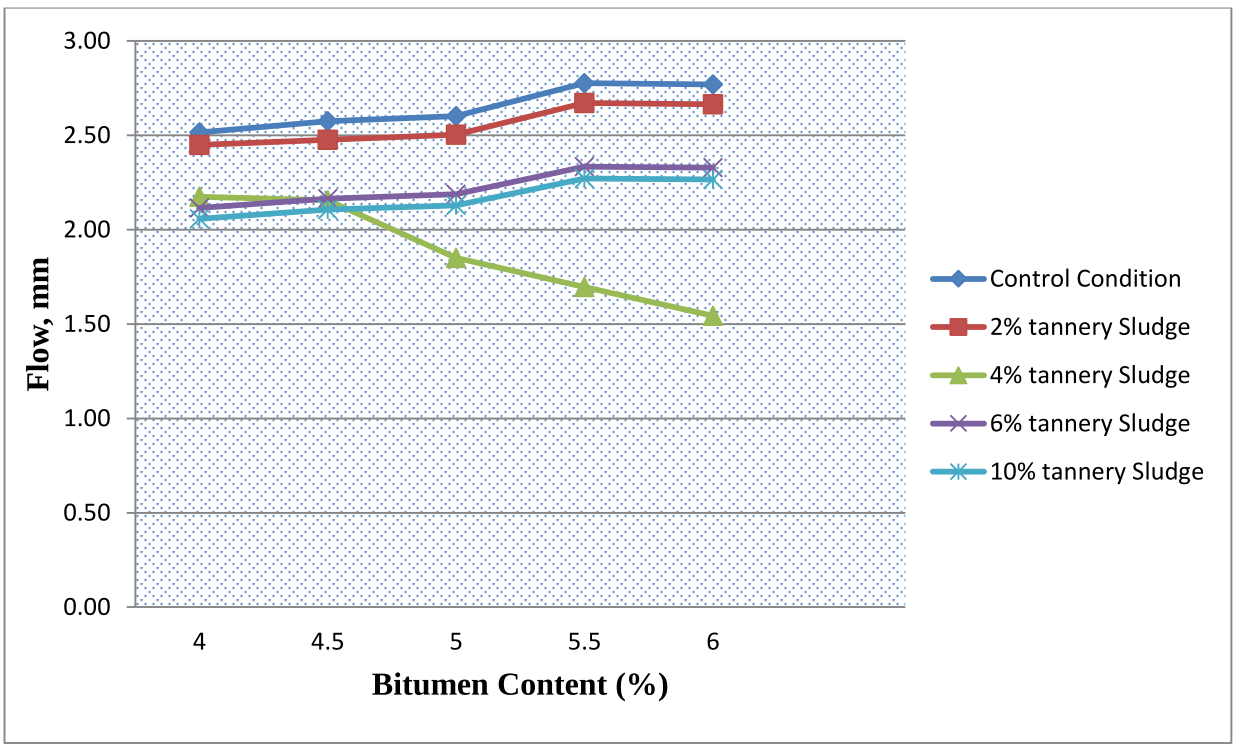


Figure 4.3: Effect of Partially replaced tannery sludge on Flow of Mix

Effect of Partially Replaced Tannery Sludge on Bulk Specific Gravity (Gsb)

In the Marshall Mix design procedure, the density varies with asphalt content. Density increases initially as the asphalt content increases because the hot asphalt cement lubricates the particles allowing the compacting effort to force them closer together. The density reaches a peak and then begins to decrease because the additional asphalt cement produces thicker films around the individual aggregates, thereby pushing the aggregate particles further apart and resulting in lower density. Anything that decreases the in-place air voids will increase the percent density.

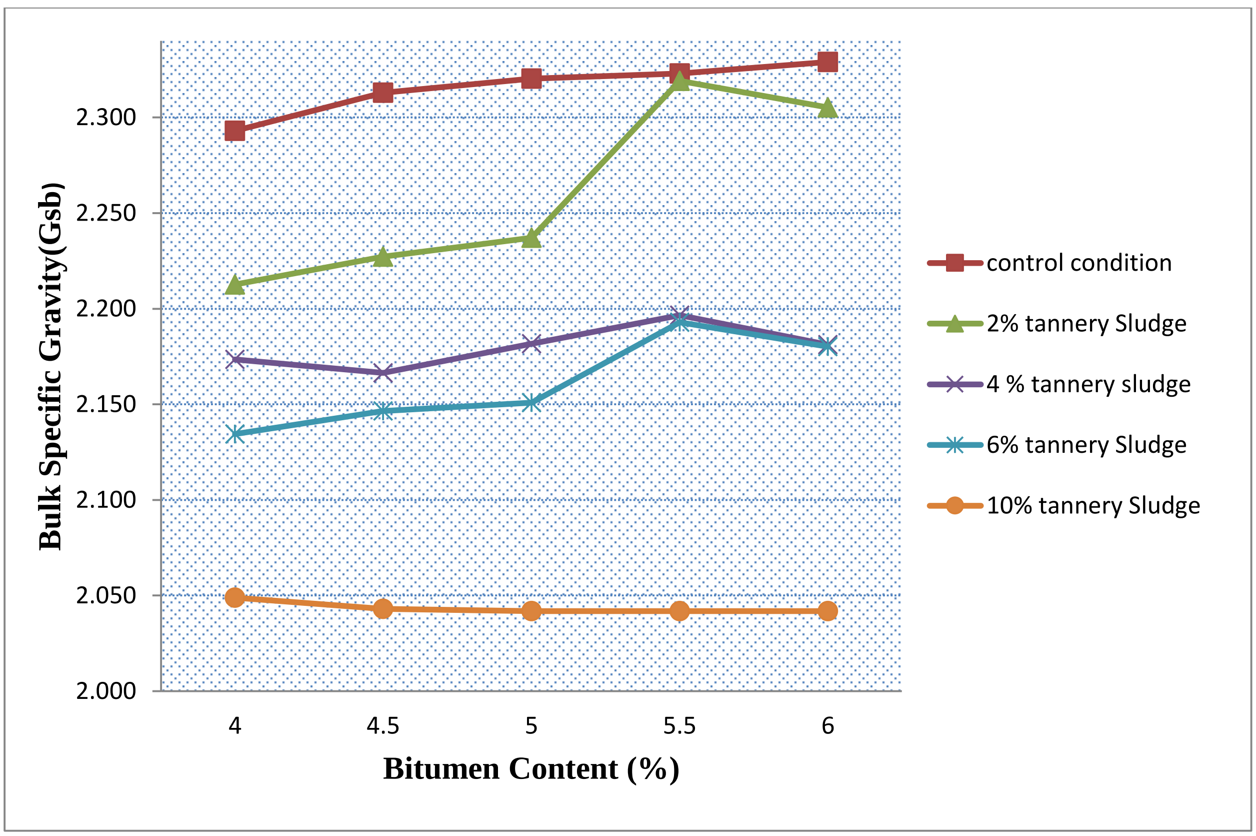


Figure 4.4: Effect of Partially replaced tannery sludge on Bulk specific gravity (Gsb)

Effect of Partially Replaced Tannery Sludge on Air Void of Mix (Va)

Total void in the mix refers that the total volume of the small pockets of air between the coated aggregate particles throughout a compacted paving mixture, expressed as percent of the bulk volume of the compacted paving mixture.

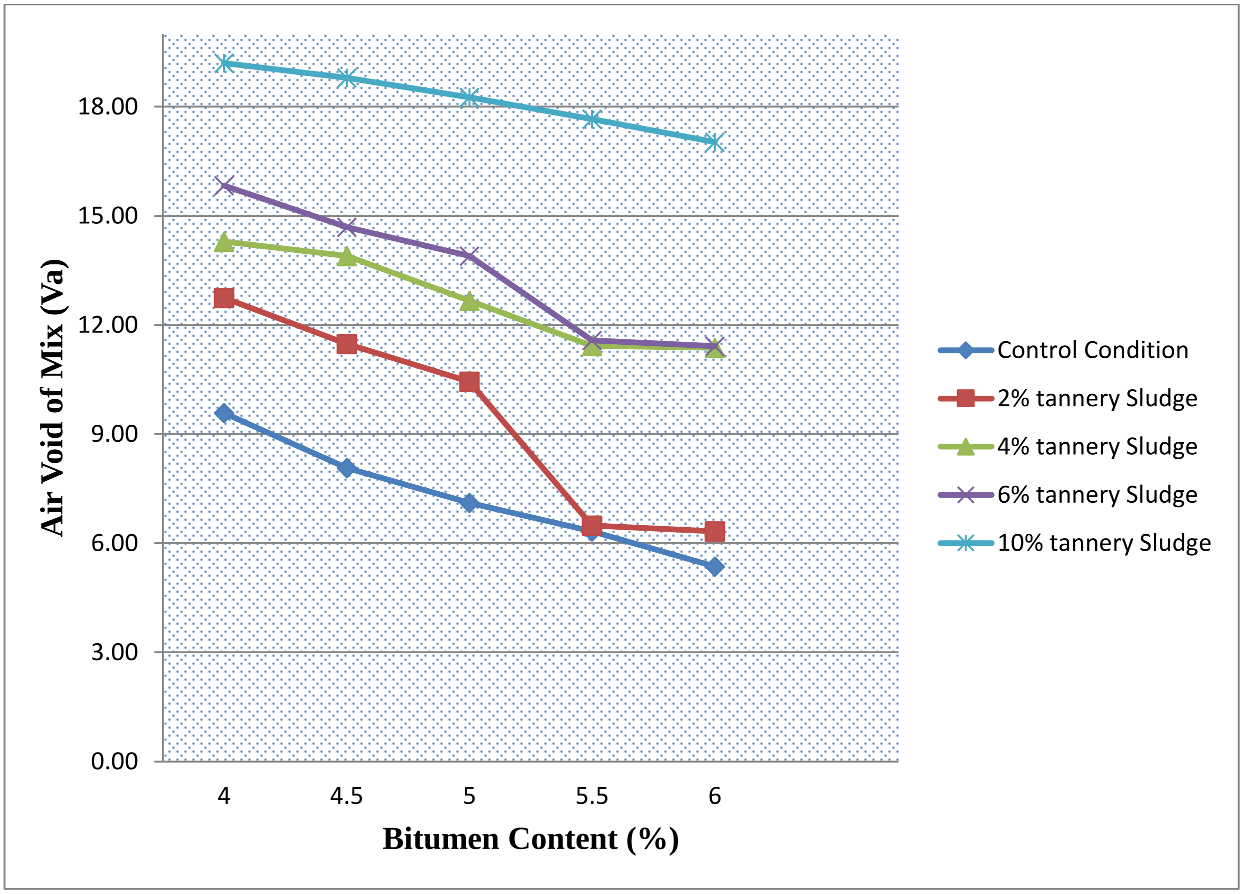


Figure 4.5: Effect of Partially replaced tannery sludge on Air void of Mix (Va)

Effect of Partially Replaced Tannery Sludge on Void in Mineral Aggregate (VMA)

VMA is the total volume of voids within the mass of the compacted aggregate. This total amount of voids significantly affects the performance of a mixture because if the VMA is too small, the mix may suffer durability problems, and if the VMA is too large, the mix may show stability problems and be uneconomical to produce.

When aggregate particles are coated with asphalt binder, a portion of the asphalt binder is absorbed into the aggregate, whereas the remainder of the asphalt binder forms a film on the outside of the individual aggregate particles. Since the aggregate particles do not consolidate to form a solid mass, air pockets also appear within the asphalt-aggregate mixture. Therefore the four general components of HMA are: aggregate, absorbed asphalt, asphalt not absorbed into the aggregate (effective asphalt), and air. Air and effective asphalt, when combined, are defined as VMA.

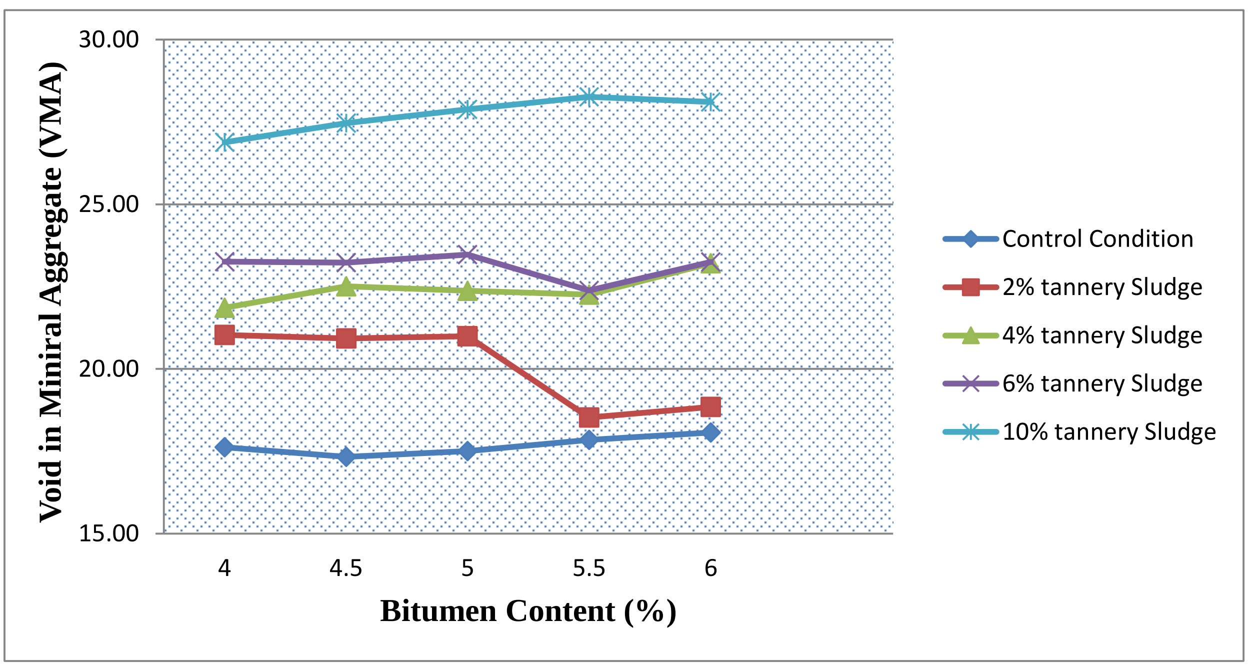


Fig 4.6: Effect of Partially replaced tannery sludge on Void in Mineral Aggregate (VMA)

Effect of Partially Replaced Tannery Sludge on Voids Filled with Asphalt (VFB)

Voids filled with Bitumen (VFB) are the percentage of inter-granular void space between the aggregate particles (VMA) that contains or is filled with asphalt. The Marshal Criteria set under the specification for VFA is 65% - 75%. The durability of mixes is related to the effective bitumen content in the mix. If the percentage of voids filled with bitumen is lower than the limit indicated, there will be less asphalt film around the aggregate particles which will be subjected to moisture and weather effect by easily oxidizes and detached from the aggregate particles and subsequently lower performance of the mixture.

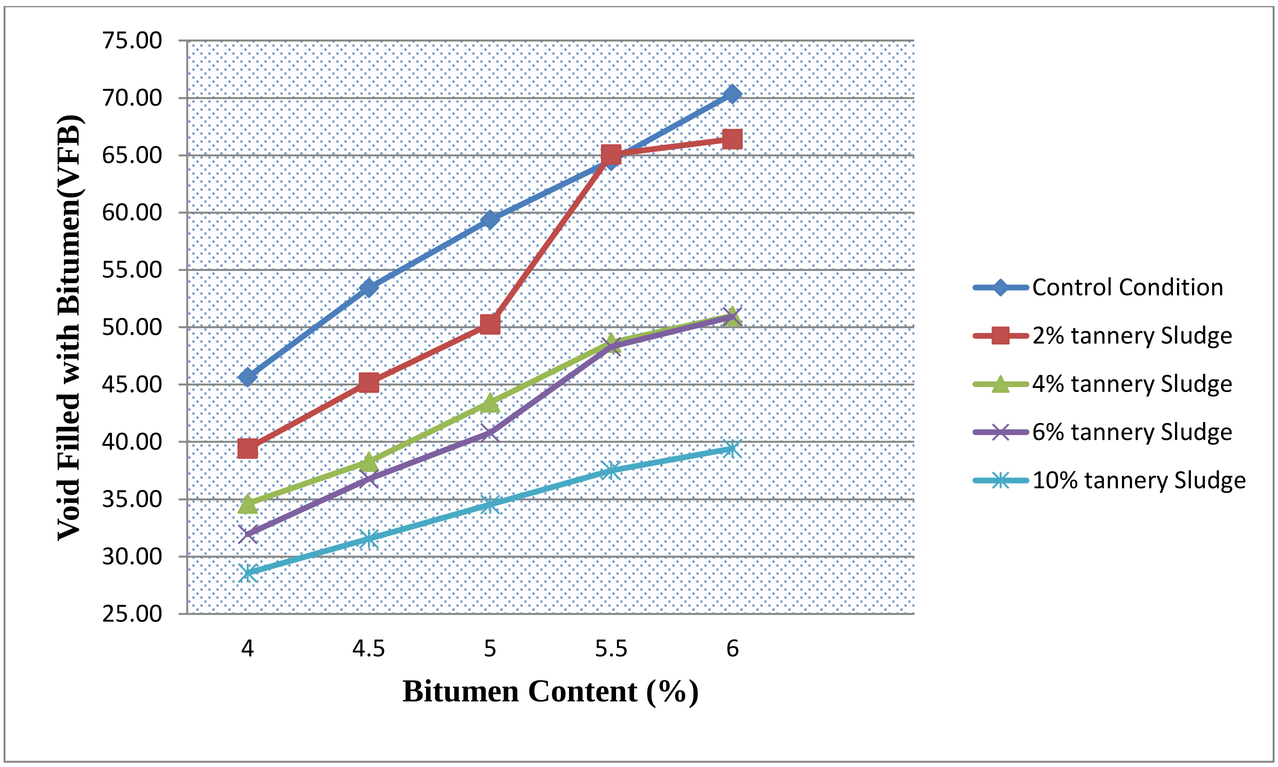


Fig 4.7: Effect of Partially replaced tannery sludge on Voids filled with Asphalt (VFA)

Optimum bitumen determination

Method 2-Asphalt Institute Method is considered for this research

Optimum bitumen content at maximum stability; maximum density and 4% air void is

Table 4.14 determination of optimum bitumen content

Mix	Bitumen Content at maximum density	Bitumen Content at Maximum. Stability	Bitumen Content at 4% void	Optimum Bitumen Content at maximum density
control(0% Sludge)	6.00	4.50	5.50	5.33
2 % Sludge	6.00	4.50	6.00	5.5
4% Sludge	6.00	5.00	6.00	5.67
6% Sludge	6.00	4.50	6.00	5.5
10 % Sludge	6.00	4.50	6.00	5.5

Table 4.15 Summarized test result at optimum bitumen content

No	Mix requirement	Unit	AC Wearing Course Specifications for up to 5 million esa Asphalt Institute (MS-2, 1994) For heavy traffic	TEST RESULT				
				0% sludge	2% sludge	4% sludge	6% sludge	10% sludge
1	Marshal stability minimum	KN	8 KN Min	11.93	11.23	9.88	10.261	10.435
2	Flow, mm	mm	2-3.5	2.7	2.671	1.64	2.334	2.271
3	Percent Air Voids at OBC (%)	%	3-5	6.64	6.464	11.4	11.576	17.664
4	Voids in Mineral Aggregate	%	13% Min	17.7	18.527	22.54	22.384	28.266
5	Voids filled with bitumen	%	65-75	62.46	65.068	49.95	48.289	37.51

4.7 Cost benefit Analysis

The economic analysis of the sludge from tannery industries was analyzed by considering utilization of Fine aggregate mix as a controlled condition and partially replacing the tannery sludge by 2%, 4%, 6% and 10%. The analysis is carried out on material cost producing an asphalt concrete of flexible pavement.

The unit rates used for the computation are shown below.

Table 4.15 Cost Analysis of Different Mixes

AC mix partially replaced with tannery sludge	Production Cost (birr/m2)	Deviation from normal mix
0%	486.90	0%
2%	497.70	-2.21%
4%	508.40	-4.41%
6%	496.70	-2.03%
10%	495.10	-1.71%

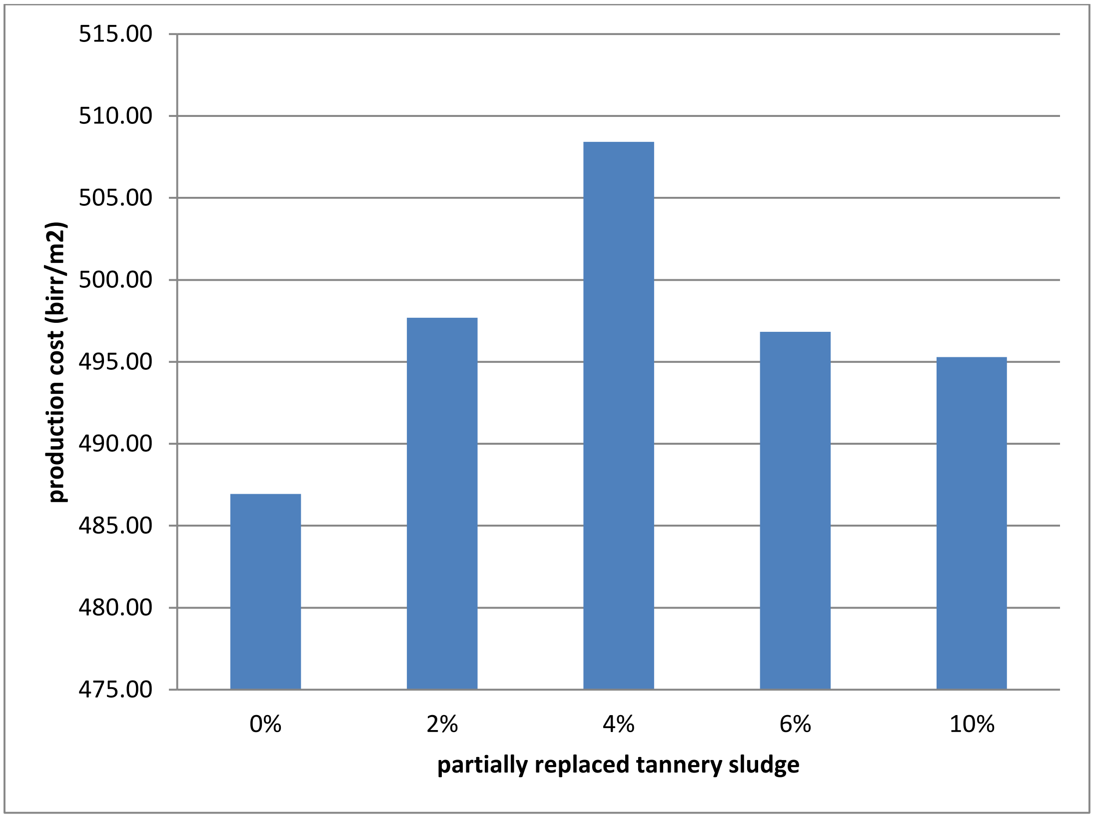


Fig 4.8 Cost Analysis comparisons of Different Mixes

CHAPTER FIVE:
CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The main goal of this research study is to evaluate the performance evaluation of tannery sludge as partially replacement of fine aggregate hot mix asphalt performance based on Marshall Mix design. Based on the results of the research the following conclusions are drawn.

- The test result for 2% partially replaced tannery sludge, 4% partially replaced tannery sludge, 6% partially replaced tannery sludge and 10% partially replaced tannery sludge meet the Marshal Stability specification range set by Asphalt Institute (MS-2, 1994).
- The test result for 2% partially replaced tannery sludge, 6% partially replaced tannery sludge and 10% partially replaced tannery sludge meet flow specification range set by Asphalt Institute (MS-2, 1994) and does not meet the specification at 4% partially replaced tannery sludge.
- Percent Air void is beyond specification range set by Asphalt institute (MS-2, 1994).as the tannery sludge content increase and maximum air void occur at 10% tannery sludge replaced fine aggregate.
- 2 %, 4%, 6% and 10% partially replaced fine aggregate with tannery sludge shows good result for Voids in Mineral Aggregate; meets the specification set by Asphalt institute (MS-2, 1994).
- As partially replaced tannery sludge quantity increase Voids filled with bitumen decreases with 2% partially replaced fine aggregate with tannery sludge and void filled with bitumen in critical condition meets the specification set by Asphalt institute (MS-2, 1994)..

5.2 Recommendation

Based on the findings of this research the following recommendations are made:

- Since the research focused on the performance evaluation of bituminous mix using tannery sludge as partially replaced fine aggregate the result shows more critical conditions and beyond the specification range so the sludge cannot be used for performance evaluations and for asphalt mixes.
- It's highly toxic since it has sulfur and other chemicals in addition to that highly odor when it is exposed to heat other researchers should take care of using this sludge.
- Properties of the hide should be analyzed separately as the properties of different animal hide have different properties it has an impact on the results.

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APPENDICES

Tannery Sludge Hauling Cost

Cost breakdown for tannery sludge

Project title Final Thesis

Asphalt cement Hauling

Performance rate 450 m3/day

56.25 m3/hr.

Material Cost					Labor Cost					Equipment Cost				
													Rental rate	
Material type	Unit	Qty	Unit Price	Price/ unit	Title	Qty	UF	Index Hourly cost	Total Hourly Cost	Equipment type	Qty	UF	hourly	Total
					Equipment operator I	1	0.5	72.11	36.055	Dump truck(Sino)	1	1	575	575
					Equipment operator II	1	0.25	62.1	15.525	Loader	1	0.5	1100	550
					Laborer	3	1	25	75					
Total				0	Total				126.58	Total				1125

A = Material unit Cost 0 B = Labor unit Cost 2.25 birr/m3 C= Equipment unit Cost 20 birr/m3

Direct cost of Work A+B+C 22.25 birr/m3

Assume 10% Overhead cost , 15% profit 25%

Total cost 27.81 birr/m3

N.B

The sludge is obtained near the site

UF = Utilization factor

Rate Computations

0% tannery sludge

Cost breakdown For 0 % tannery sludge

Project title thesis project

Asphalt Concrete production

Performance rate 35 m3/hr.

Material Cost					Labor Cost					Equipment Cost				
Material type	Unit	Qty	Unit Price	Price/ unit	Title	Qty	UF	Index Hourly cost	Total Hourly Cost	Equipment type	Qty	UF	Rental Price hourly	Rental Price Total
Bitumen 80/100	ton	0.1535	37000	5679.6	operator I	1	1	81	81	Asphalt Plant (150 ton/hr.)	1	1	11245	11245
19 mm aggregate for surfacing	M3	0.308	500	154	operator II	1	1.5	67.5	101.25	loader	3	1	1100	3300
4.75 mm aggregate for surfacing	M3	0.8911	600	534.66	Laborer I	3	1	42.19	126.56					
filler	M3	0.0341	650	22.184	Mechanic I	1	1	47.25	47.25					
Tannery Sludge	M3	0	0	0	Electrician I	1	1	47.25	47.25					
Total				6368.3	Total				403.31	Total				14545

A = Material unit Cost 6368 Birr/m3 B = labor unit Cost 11.52 Birr/m3 C= Equipment unit Cost 415.57 birr/m3

Direct cost of Work A+B+C 6795.40 birr/m3

N.B

The sludge is obtained near the site

UF = Utilization factor

Cost breakdown for 0 % tannery sludge

Project title Final Thesis

Asphalt cement Hauling

Performance rate 350 m3/day

43.75 m3/hr.

Material Cost					labor Cost					Equipment Cost				
Material type	Unit	Qty	Unit Price	Price/ unit	Title	Qty	UF	Index Hourly cost	Total Hourly Cost	Equipment type	Qty	UF	Rental rate hourly	Rental rate Total
					Equipment operator I	3	1	72.11	216.33	Dump truck(Sino)	3	1	575	1725
Total				0	Total				216.33	Total				1725

A = Material unit Cost 0

B = labor unit Cost 4.9447 birr/m3

C= Equipment unit Cost 39.429 birr/m3

Direct cost of Work A+B+C 44.37 birr/m3

Assume 10% Overhead cost , 15% profit 25%

Total cost 55.46 birr/m3

N.B

The sludge is obtained near the site

UF = Utilization factor

	Cost breakdown for 0 % tannery sludge Performance rate per day 5000 m2/day
	Unit Price 625 m2/hr.
	Project title Thesis
	Asphalt Concrete placing

Material Cost					labor Cost					Equipment Cost			Rental rate	
Material type	Unit	Qty	Unit Price	Price/ unit	Title	Qty	UF	Index Hourly cost	Total Hourly Cost	Equipment type	Qty	UF	hourly	Total
Hot mix Asphalt	M3	0.05	6795.40	339.77	Forman I	1	1	97.35	97.35	Asphalt Paver	1	1	1299	1299
AC hauling	M3	1	44.37	44.37	operator I	1	1.5	81	121.5	Roller 6t	2	1	450	900
					operator II	3	1	67.5	67.5	Water truck	1	1	593	593
					operator III	1	1	52	52	Roller pneumatic	2	1	1018	2036
					Laborer	6	1	42.19	253.14					
Total				384.14	Total				591.49	Total				2792

A = Material unit Cost 384.143 birr/m2 | B = labor unit Cost 0.946 birr/m2 | C= Equipment unit Cost 4.467 birr/m2

Direct cost of Work A+B+C 389.6 birr/m2

Assume 10% Overhead cost , 15% profit, 25%

Total cost 486.9 birr/m2

N.B

The sludge is obtained near the site

UF = Utilization factor

2% tannery sludge

Cost breakdown For 2 % tannery sludge														
Project title thesis project														
Asphalt Concrete production														
Performance rate 35 m3/hr.														
Material Cost					Labor Cost					Equipment Cost				
													Rental Price	
Material type	Unit	Qty	Unit Price	Price/ unit	Title	Qty	UF	Index Hourly cost	Total Hourly Cost	Equipment type	Qty	UF	hourly	Total
Bitumen 80/100	ton	0.1584	37000	5860.8	operator I	1	1	81	81	Asphalt Plant (150 ton/hr.)	1	1	11245	11245
19 mm aggregate for surfacing	M3	0.308	500	154	operator II	1	1.5	67.5	101.25	loader	3	1	1100	3300
4.75 mm aggregate for surfacing	M3	0.8742	600	524.50	Laborer I	3	1	42.19	126.56					
filler	M3	0.042	650	27.3	Mechanic I	1	1	47.25	47.25					
Tannery Sludge	M3	0.02	27.81	0.5562	Electrician I	1	1	47.25	47.25					
Total				6539.9	Total				403.31	Total				14545

A = Material unit Cost 6540 Birr/m3 B = labor unit Cost 11.52 Birr/m3 C= Equipment unit Cost 415.57 birr/m3

Direct cost of Work A+B+C 6966.95 birr/m3

N.B

The sludge is obtained near the site

UF = Utilization factor

				Cost breakdown for 2 % tannery sludge										
				Project title Final Thesis										
				Asphalt cement Hauling										
				Performance rate				350	m3/day					
								43.75	m3/hr.					
Material Cost					labor Cost					Equipment Cost				
Material type	Unit	Qty	Unit Price	Price/ unit	Title	Qty	UF	Index Hourly cost	Total Hourly Cost	Equipment type	Qty	UF	Rental rate hourly	Rental rate Total
					Equipment operator I	3	1	72.11	216.33	Dump truck(Sino)	3	1	575	1725
Total				0	Total				216.33	Total				1725

A = Material unit Cost 0

B = labor unit Cost 4.9447 birr/m3

C= Equipment unit Cost 39.429 birr/m3

Direct cost of Work A+B+C 44.37 birr/m3

Assume 10% Overhead cost , 15% profit 25%

Total cost 55.46 birr/m3

N.B

The sludge is obtained near the site

UF = Utilization factor

					Cost breakdown		for 2 % tannery sludge			Performance rate per day		5000	m2/day	
					Unit Price							625	m2/hr.	
					Project title	Thesis								
					Asphalt Concrete placing									
Material Cost					labor Cost					Equipment Cost				
													Rental rate	
Material type	Unit	Qty	Unit Price	Price/ unit	Title	Qty	UF	Index Hourly cost	Total Hourly Cost	Equipment type	Qty	UF	hourly	Total
Hot mix Asphalt	M3	0.05	6966.9 5	348.37	Forman I	1	1	97.35	97.35	Asphalt Paver	1	1	1299	1299
AC hauling	M3	1	44.37	44.37	operator I	1	1.5	81	121.5	Roller 6t	2	1	450	900
					operator II	3	1	67.5	67.5	Water truck	1	1	593	593
					operator III	1	1	52	52	Roller pneumatic	2	1	1018	2036
					Laborer	6	1	42.19	253.14					
Total				392.72 1	Total				591.49	Total				2792

A = Material unit Cost 392.72 birr/m2 | B = labor unit Cost 0.946 birr/m2 | C= Equipment unit Cost 4.467 birr/m2

Direct cost of Work A+B+C 398.1 birr/m2

Assume 10% Overhead cost , 15% profit, 25%

Total cost 497.7 birr/m2

N.B

The sludge is obtained near the site
UF = Utilization factor

4% tannery sludge

Cost breakdown For 4 % tannery sludge														
Project title thesis project														
Asphalt Concrete production														
Performance rate 35 m3/hr.														
Material Cost					Labor Cost					Equipment Cost				
													Rental Price	
Material type	Unit	Qty	Unit Price	Price/ unit	Title	Qty	UF	Index Hourly cost	Total Hourly Cost	Equipment type	Qty	UF	hourly	Total
Bitumen 80/100	ton	0.1633	37000	6042	operator I	1	1	81	81	Asphalt Plant (150 ton/hr.)	1	1	11245	11245
19 mm aggregate for surfacing	M3	0.308	500	154	operator II	1	1.5	67.5	101.25	loader	3	1	1100	3300
4.75 mm aggregate for surfacing	M3	0.8567	600	514.04	Laborer I	3	1	42.19	126.56					
filler	M3	0.038	650	24.7	Mechanic I	1	1	47.25	47.25					
Tannery Sludge	M3	0.04	27.81	1.1124	Electrician I	1	1	47.25	47.25					
Total				6711.1	Total				403.31	Total				14545

A = Material unit Cost 6711 Birr/m3   B = labor unit Cost 11.52 Birr/m3   C= Equipment unit Cost 415.57 birr/m3

Direct cost of Work A+B+C 7138.20 birr/m3

N.B

The sludge is obtained near the site

UF = Utilization factor

				Cost breakdown		for 4 % tannery sludge								
				Project title Final Thesis										
				Asphalt cement Hauling										
				Performance rate			350	m3/day						
							43.75	m3/hr.						
Material Cost					labor Cost					Equipment Cost				
Material type	Unit	Qty	Unit Price	Price/ unit	Title	Qty	UF	Index Hourly cost	Total Hourly Cost	Equipment type	Qty	UF	Rental rate hourly	Rental rate Total
					Equipment operator I	3	1	72.11	216.33	Dump truck(Sino)	3	1	575	1725
Total				0	Total				216.33	Total				1725

A = Material unit Cost 0

B = labor unit Cost 4.9447 birr/m3

C= Equipment unit Cost 39.429 birr/m3

Direct cost of Work A+B+C 44.37 birr/m3

Assume 10% Overhead cost , 15% profit 25%

Total cost 55.46 birr/m3

N.B

The sludge is obtained near the site

UF = Utilization factor

					Cost breakdown		for 4 % tannery sludge			Performance rate per day			5000	m2/day
					Unit Price								625	m2/hr.
					Project title	Thesis								
					Asphalt Concrete placing									
Material Cost					labor Cost					Equipment Cost				
													Rental rate	
Material type	Unit	Qty	Unit Price	Price/ unit	Title	Qty	UF	Index Hourly cost	Total Hourly Cost	Equipment type	Qty	UF	hourly	Total
Hot mix Asphalt	M3	0.05	7138.20	356.91	Forman I	1	1	97.35	97.35	Asphalt Paver	1	1	1299	1299
AC hauling	M3	1	44.37	44.37	operator I	1	1.5	81	121.5	Roller 6t	2	1	450	900
					operator II	3	1	67.5	67.5	Water truck	1	1	593	593
					operator III	1	1	52	52	Roller pneumatic	2	1	1018	2036
					Laborer	6	1	42.19	253.14					
Total				401.283	Total				591.49	Total				2792

A = Material unit Cost 401.283 birr/m2 | B = labor unit Cost 0.946 birr/m2 | C= Equipment unit Cost 4.467 birr/m2

Direct cost of Work A+B+C 406.7 birr/m2

Assume 10% Overhead cost , 15% profit, 25%

Total cost 508.4 birr/m2

N.B

The sludge is obtained near the site
UF = Utilization factor

6% tannery sludge

Cost breakdown For 6 % tannery sludge														
Project title thesis project														
Asphalt Concrete production														
Performance rate 35 m3/hr.														
Material Cost					Labor Cost					Equipment Cost				
Material type	Unit	Qty	Unit Price	Price/ unit	Title	Qty	UF	Index Hourly cost	Total Hourly Cost	Equipment type	Qty	UF	Rental Price hourly	Rental Price Total
Bitumen 80/100	ton	0.1584	37000	5860.8	operator I	1	1	81	81	Asphalt Plant (150 ton/hr.)	1	1	11245	11245
19 mm aggregate for surfacing	M3	0.308	500	154	operator II	1	1.5	67.5	101.25	loader	3	1	1100	3300
4.75 mm aggregate for surfacing	M3	0.8477	600	508.62	Laborer I	3	1	42.19	126.56					
filler	M3	0.038	650	24.7	Mechanic I	1	1	47.25	47.25					
Tannery Sludge	M3	0.06	27.81	1.667	Electrician I	1	1	47.25	47.25					
Total				6525.1	Total				403.31	Total				14545

A = Material unit Cost 6525 Birr/m3 B = labor unit Cost 11.52 Birr/m3 C= Equipment unit Cost 415.57 birr/m3

Direct cost of Work A+B+C 6952.18 birr/m3

N.B

The sludge is obtained near the site

UF = Utilization factor

Cost breakdown for 6 % tannery sludge

Project title Final Thesis

Asphalt cement Hauling

Performance rate 350 m3/day

43.75 m3/hr.

Material Cost					labor Cost					Equipment Cost				
Material type	Unit	Qty	Unit Price	Price/ unit	Title	Qty	UF	Index Hourly cost	Total Hourly Cost	Equipment type	Qty	UF	Rental rate hourly	Rental rate Total
					Equipment operator I	3	1	72.11	216.33	Dump truck(Sino)	3	1	575	1725
Total				0	Total				216.33	Total				1725

A = Material unit Cost 0

B = labor unit Cost 4.9447 birr/m3

C= Equipment unit Cost 39.429 birr/m3

Direct cost of Work A+B+C 44.37 birr/m3

Assume 10% Overhead cost , 15% profit 25%

Total cost 55.46 birr/m3

N.B

The sludge is obtained near the site

UF = Utilization factor

					Cost breakdown		for 6 % tannery sludge			Performance rate per day			5000	m2/day
					Unit Price								625	m2/hr.
					Project title	Thesis								
					Asphalt Concrete placing									
Material Cost					labor Cost					Equipment Cost				
													Rental rate	
Material type	Unit	Qty	Unit Price	Price/ unit	Title	Qty	UF	Index Hourly cost	Total Hourly Cost	Equipment type	Qty	UF	hourly	Total
Hot mix Asphalt	M3	0.05	6952.18	347.609	Forman I	1	1	97.35	97.35	Asphalt Paver	1	1	1299	1299
AC hauling	M3	1	44.37	44.37	operator I	1	1.5	81	121.5	Roller 6t	2	1	450	900
					operator II	3	1	67.5	67.5	Water truck	1	1	593	593
					operator III	1	1	52	52	Roller pneumatic	2	1	1018	2036
					Laborer	6	1	42.19	253.14					
Total				391.982	Total				591.49	Total				2792

A = Material unit Cost 392.982 birr/m2 | B = labor unit Cost 0.946 birr/m2 | C= Equipment unit Cost 4.467 birr/m2

Direct cost of Work A+B+C 397.4 birr/m2

Assume 10% Overhead cost , 15% profit, 25%

Total cost 496.7 birr/m2

N.B

The sludge is obtained near the site

UF = Utilization factor

10% tannery sludge

Cost breakdown For 10 % tannery sludge

Project title thesis project

Asphalt Concrete production

Performance rate 35 m3/hr.

Material Cost					Labor Cost					Equipment Cost				
Material type	Unit	Qty	Unit Price	Price/ unit	Title	Qty	UF	Index Hourly cost	Total Hourly Cost	Equipment type	Qty	UF	Rental Price hourly	Rental Price Total
Bitumen 80/100	ton	0.1584	37000	5860.8	operator I	1	1	81	81	Asphalt Plant (150 ton/hr.)	1	1	11245	11245
19 mm aggregate for surfacing	M3	0.308	500	154	operator II	1	1.5	67.5	101.25	loader	3	1	1100	3300
4.75 mm aggregate for surfacing	M3	0.8033	600	481.95	Laborer I	3	1	42.19	126.56					
filler	M3	0.038	650	24.7	Mechanic I	1	1	47.25	47.25					
Tannery Sludge	M3	0.10	27.81	2.781	Electrician I	1	1	47.25	47.25					
Total				6499.5	Total				403.31	Total				14545

A = Material unit Cost 6499.5 Birr/m3 B = labor unit Cost 11.52 Birr/m3 C= Equipment unit Cost 415.57 birr/m3

Direct cost of Work A+B+C 6929.63 birr/m3

N.B

The sludge is obtained near the site

UF = Utilization factor

				Cost breakdown		for 10 % tannery sludge								
				Project title Final Thesis										
				Asphalt cement Hauling										
				Performance rate				350	m3/day					
								43.75	m3/hr.					
Material Cost					labor Cost					Equipment Cost				
													Rental rate	
Material type	Unit	Qty	Unit Price	Price/ unit	Title	Qty	UF	Index Hourly cost	Total Hourly Cost	Equipment type	Qty	UF	hourly	Total
					Equipment operator I	3	1	72.11	216.33	Dump truck(Sino)	3	1	575	1725
Total				0	Total				216.33	Total				1725

A = Material unit Cost 0 B = labor unit Cost 4.9447 birr/m3 C= Equipment unit Cost 39.429 birr/m3

Direct cost of Work A+B+C 44.37 birr/m3

Assume 10% Overhead cost , 15% profit 25%

Total cost 55.46 birr/m3

N.B

The sludge is obtained near the site

UF = Utilization factor

	Cost breakdown	for 10 % tannery sludge	Performance rate per day	5000	m2/day
	Unit Price			625	m2/hr.
	Project title	Thesis			
	Asphalt Concrete placing				

Material Cost					labor Cost					Equipment Cost				
													Rental rate	
Material type	Unit	Qty	Unit Price	Price/ unit	Title	Qty	UF	Index Hourly cost	Total Hourly Cost	Equipment type	Qty	UF	hourly	Total
Hot mix Asphalt	M3	0.05	6926.63	346.332	Forman I	1	1	97.35	97.35	Asphalt Paver	1	1	1299	1299
AC hauling	M3	1	44.37	44.37	operator I	1	1.5	81	121.5	Roller 6t	2	1	450	900
					operator II	3	1	67.5	67.5	Water truck	1	1	593	593
					operator III	1	1	52	52	Roller pneumatic	2	1	1018	2036
					Laborer	6	1	42.19	253.14					
Total				390.705	Total				591.49	Total				2792

A = Material unit Cost 390.705 birr/m2 | B = labor unit Cost 0.946 birr/m2 | C= Equipment unit Cost 4.467 birr/m2

Direct cost of Work A+B+C 396.1 birr/m2

Assume 10% Overhead cost , 15% profit, 25%

Total cost 495.1 birr/m2

N.B

The sludge is obtained near the site

UF = Utilization factor