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SCHOOL OF CIVIL ENGINEERING AND ARCHITECTURE

Department of construction Management Technology Teacher Education A thesis in Partial fulfillment of the requirement for the Degree of Master of Science in construction Management technology Teacher Education

ALTERNATIVE APPROACH TO IMPROVE ROAD BASE QUALITY

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CANDIDATE'S DECLARATION

We hereby declare that the work which is being presented in the thesis entitled "**Alternative Approach to Improve Road Base Quality**" in partial fulfillment of the requirements for the award of the degree of masters in construction management technology teacher's education is an authentic record of our own work carried out from March 2015 to June 2015.

The matter embodied in this thesis has not been submitted by us for the award of any other degree or diploma. All relevant resources of information used in this thesis have been duly acknowledged.

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This is to certify that the above statement made by the candidate is correct to the best of my knowledge and belief. This thesis has been submitted for examination with my approval.

Advisor	Signature	Date

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Abstract

A flexible pavement system basically consists of an asphalt surface layer, a base course, sub base and the sub grade. The base course which is in between the surface layer and the sub grade plays a very prominent role in transferring the loads coming on to the surface layer to the natural soil sub grade. Thus, base courses in flexible pavements help to distribute the traffic load.

The main objective of this study is to identify alternative approach to improve road base quality by hot asphalt treated base (HATB) through conducting marshal tests.

The research reviewed previous studies related to Asphalt Treated Base (ATB) course materials, resilient modulus and tensile strength and Laboratory Investigation.

Weak aggregate(less durable and weak in strength) and 60/70 bitumen grade asphalt binder was used at three different percent. The method of study consists of problem identification, literature review; and laboratory investigation, analysis and conclusion. The Finding of the investigation have shown that treated aggregate has three times durable and two times stronger than the normal aggregate so that we can achieve strong and durable road base with the minimum depth.

Finally, recommendation forwarded to further quality improvement by comparing this research results with Ethiopian quality standard manuals concerning to this discipline.

Key Words: *Road base, resilient modules, tensile strength, stabilization, durability, hot mix asphalt*

Abbreviations

MR	Resilient modulus
CBR	California bearing ratio
ITS	Indirect tensile strength test
HATB	Hot asphalt treated base
ERA	Ethiopian road authority
ATB	Asphalt treated base
EATB	Emulsified Asphalt Treated Base
FATB	Foamed-Asphalt Treated Base
CAEC	Cement-Asphalt Emulsion composite
BSMs	Bitumen-stabilized materials

CHAPTER ONE

INTRODUCTION

1.1. General

A flexible pavement system basically consists of an asphalt surface layer, a base course, sub base and the sub grade. The base course which is in between the surface layer and the sub grade plays a very prominent role in transferring the loads coming on to the surface layer to the natural soil sub grade. Thus, base courses in flexible pavements help to distribute the traffic load. This ability to distribute load is primarily a function of depth of base course. The quality of the base course material also affects the rate of load distribution. While distributing the load, the base course itself must not be a cause of failure. Therefore, the base course must have enough strength to carry loads without shear failure (Potturi, 2006).

Traditionally natural aggregates derived from a variety of source rocks have been used as a road base material. But the extraction of these natural aggregates resources is increasingly being constrained by urbanization, increased costs and environmental concerns. Thus, stabilizing the base materials are being used to supplement natural aggregates in road construction (Potturi, 2006).

Engineers use stabilization to enhance materials properties for pavement design procedures or to overcome deficiencies in available materials. In many areas, clean, durable aggregates normally utilized for base course either require long hauls from outside, or they are difficult to obtain within the project limits (Peng Li, 2010). The stabilization of near-surface granular pavement materials is accepted practice in transportation maintenance and capital development projects. Stabilization in this context involves the mechanical introduction of reactive agents, including cement, lime and bitumen, into existing or manufactured granular materials, with or without existing seal inclusion. (W Gray, 2011)

Pavement designers, contractors and asset managers use stabilization methods to improve the long-term performance and load-carrying capacity of pavement materials and structures. The process of stabilization enables the following changes within granular materials (W Gray, 2011)

- Reduces in-situ water content and therefore susceptibility to strength reduction due to wetting in sensitive materials
- Reduces the plasticity in cohesive materials
- Binds together the particles in the granular material, producing a ‘stronger’, more resilient near surface pavement layer

A base course constructed of stabilized material has many characteristics that contribute to the performance of the pavement. It has excellent load dispersion properties and is minimally affected by moisture. In addition, a stabilized base, by cushioning sub grade movement, preserves the integrity of the overlying pavement structure. The dosage of stabilizer to realize these benefits is often an issue. But one approach is that the end product should meet certain durability criteria. Occasionally, the dosage required to meet this criteria results in a rigid layer, which, if undergoes shrinkage, will develop cracks. In time, these cracks are likely to become wide. The result may be a reduction in the service life of the pavement owing primarily to water infiltration and/or reduction of load transfer across cracks.

Therefore it is imperative to replace this road base material by other suitable material without affecting the required strength and durability. To do so, in this research works, we are going to replace aggregate by HATB.

1.2. Statement of the problem

Road construction costs becoming higher and higher from year to year. One of the parameters that determine this road construction is aggregates. The road base composition of aggregates is becoming in a higher cost and less quality. Even though aggregate is available naturally, without adding scientific knowledge, it is depleting from time to time.

Therefore it is imperative to replace this road base material by other suitable material without affecting the required strength and durability.

To do so, in this research works, we are going to replace aggregate by HATB. The main reason to conduct this study is pointed below,

1. By replacing the road base material with HATB, testing and evaluating the strength of HATB.

2. The resilient modulus and tensile strength are the main factors for designs.
3. Up to this days pure aggregates with fine sand is the only materials to form the road base, in our study result, we give another alternatives material to aggregates.
4. The resilient modulus and strength found in our test is used to compare and contrast with respect to the ERA manual.
5. Regarding this HATB, enough study was not made, so it is our duty to do this research

1.3. Objectives of the study

1.3.1. General objectives

To investigate alternative approach to improve road base quality by hot asphalt treated base [HATB].

1.3.2. Specific objectives

1. To evaluate the indirect tensile strength of hot asphalt treated base by using weak aggregate at three different binder contents
2. To evaluate resilient modulus of HATB by using weak aggregate
3. To compare the indirect tensile strength and resilient modulus of hot asphalt treated base with Ethiopia Road Authority Manual.
4. To estimate the depth of the road using stabilized material

1.4. Scope of the study

For this study weak aggregate and 60/70 bitumen grade are collected from ERA training and laboratory center, Alemgena site. Aggregate and bitumen property was pre-determined at ERA laboratory. The study concentrated on measuring and evaluating durability, tensile strength and resilient modulus of road base material by using Marshall test at three different bitumen content (2%, 3%, and 4%). We use granular base course (GB1), traffic class T7and sub grade strength class S5 from ERA manual.

CHAPTER TWO

LITERATURE REVIEW

2.1. General

This chapter presents a comprehensive review of previous studies related to Asphalt Treated Base (ATB) course materials, resilient modulus, indirect tensile strength and durability of aggregates.

2.2. Asphalt Treated Base

The performance of a pavement depends on many factors such as the properties of the materials, structural capacity of the pavement, construction method, traffic loading, and climatic conditions. For flexible pavements, the quality of the base layer is one of the most important factors. Previous research has found that much of the distresses that flexible pavements experience can be traced to problems encountered in the base (Saeed et al., 2001).The use of a cost efficient base layer, that would extend the pavement life, that would require less thickness, or that would use local materials, is highly desirable. Asphalt-Treated Bases (ATB) fit this category.

One of the main problems with asphaltic pavements that include a stabilized base course is the incidence of transverse cracking in the stabilized base and the related propagation of cracks to the surface, which diminishes the life of pavements. In this case, ATB may be more flexible and resistant to fatigue cracking as compared to cement stabilized bases (Dykman et al. 2003).

Besides new construction, ATB can be beneficial in rehabilitation projects. According to Dykman et al. (2003), the crucial factors in choosing ATB as a way of rehabilitation are:

1. Quick construction time, therefore decreased delays and diminished traffic disturbance
2. Low permeability to moderate pore water pressure effect (Cedergren,1977)
3. Minimal moisture sensitivity as a consequence of moisture ingress
4. Quite flexible, consequently decrease the possibility of reflective cracking (Marks and Heisman, 1985.)

Compare to untreated granular base, ATBs increase the stiffness of base course layer, leading to more efficient load distribution. It also improves durability and reduces the frost heave susceptibility. Depending on the type of treatment applied to a granular material, there are three types of ATBs: 1) Hot Asphalt Treated Base (HATB), 2) Emulsified Asphalt Treated Base (EATB), and 3) Foamed-Asphalt Treated Base (FATB)

2.2.1. Hot Asphalt Treated Base

According to the National Asphalt Pavement Association (NAPA), ATB is a dense-graded Hot Mix Asphalt (HMA) with a wide gradation band with a lower asphalt content that can be used as a base course. Among the features that make it different from HMA are (Wong et al., 2004):

1. HMA layer may receive direct impact from traffic and experience more serious weather conditions than those experienced by the ATB
2. Thickness of ATB is greater than the one of the HMA
3. Asphalt layer can be superimposed to improve surface performance, or removed to construct a new surface layer when the damage has attained certain level

These differences make the ATB's design vital, since it must preserve necessary performance in the entire pavement life.

2.2.2. Emulsified Asphalt Treated Base (EATB)

Emulsified Asphalt Treated Base (EATB) is a cold mixture of emulsified asphalt and granular material. Emulsified asphalt is a mixture of asphalt and water assisted by an emulsifying agent. This technique greatly reduces the viscosity of asphalt at low temperature, which makes it possible to produce asphalt mixture at room temperature. Li et al. (1998) conducted experimental study Cement-Asphalt Emulsion composite (CAEC).

They performed Laboratory test on fatigue, strength, rigidity, temperature susceptibility and stress-strain relationship to evaluate mechanical properties of CAEC. The preliminary test result showed that CAEC possessed most of characteristics of both cement and asphalt, namely the longer fatigue life and lower temperature susceptibility of cement concrete, and higher toughness and flexibility of asphalt concrete.

Visser et al. (2002) investigated structural performance of emulsion treated material using HVS. HVS test results were used to determine structural design and performance model for fatigue and permanent deformation for the material tested. The mechanical properties such as bearing strength, permeability and erodability and behavior of material and pavement under repeated loading are being investigated. Californian Bearing Ratio (CBR), Indirect Tensile Strength (ITS), Unconfined Compressive Strength (UCS), flexural beam test and static and dynamic triaxial test were conducted. The laboratory test indicated that addition of cement strength the material while emulsion contributes to the flexibility.

Liebenberg et al. (2002) presented the data and analyses from accelerated pavement testing by the HVS on an emulsion-treated material recycled with a deep in-situ recycler. The HVS test sections performed well in the dry condition and most distress only started to develop after water was added during trafficking. The elastic deflection data were used to back calculate the effective elastic stiffnesses and these data showed that the stiffness of the treated material rapidly decreases initially, with a more gradual decrease towards an ‘equivalent granular state’. The laboratory tests indicated that the addition of cement strengthens the material while the emulsion contributes to the flexibility. A fine balance is therefore necessary to ensure the optimum combination of these stabilizers.

Nazarian et al. (2012) presented a report on a laboratory test protocol to help in mix design and guidelines for the construction of bases with emulsion treatment .As part of their study, different materials were sampled and subjected to various forms of testing in order to document the effects of several parameters on their engineering properties. Construction activities at four sites were also documented.

Twagira et al. (2012) tested the validity of moisture damage on BSM (bitumen stabilized material) using Model Mobile Load Simulator (MMLS3). And investigated the addition of active filler (cement or lime) on BSMs. The influence of traffic on laboratory prepared specimen (compacted and cured) was simulated using an accelerated pavement tester, i.e. MMLS3. Specimens were prepared and cured, all specimen were cut to design size to able to fit the MMLS3 test bed and subjected to MMLS3 trafficking in wet and dry condition. Subsequent to MMLS3 trafficking, an ITS test are carried out on specimens to monitor the performance of BSMs. The finding on MMLS3 testing and ITS testing on wet and dry trafficked BSMs led to ranking of different BSMs in terms of moisture susceptibility. MMLS3 trafficking of BSMs specimen submersed in water results in significant distress in terms of raveling and reduction in tensile strength. This does not exist under dry condition. The inclusion of active filler and especially cement in BMSs is vital for an improvement in moisture resistance. Materials stabilized with bitumen emulsion are less susceptible to moisture damage compared with similar material stabilized with foam bitumen.

Grilli et al. (2012) studied about compactability and thermal sensitivity of cement–bitumen treated materials (CBTMs). They used proctor and shear gyratory compactor to study the volumetric characteristics and the optimum liquid content of CBTMs. The influence of temperature on the stiffness modulus of CBTMs was investigated using two testing methods: indirect tensile stiffness modulus and ultrasonic pulse velocity (UPV). The study showed that, the increase of residual bitumen generally caused a decrease of dry density and an increase of voids in the aggregate.

Jenkins et al.(2012) developed new testing procedures for bitumen-stabilized materials BSMs).and evaluated performance of BSMs mixes with varying aggregate type and addition of different types and contents of active filler. The laboratory testing procedures applied are: Material selection, specimen compaction, curing of BSMs, Moisture damage simulation, Simple Triaxial Test (STT). The findings showed that the newly developed testing procedures can consistently produce BSM specimens and reliably classified BSMs for mix design as well as pavement design purposes.

The influence of the addition of an active filler (cement or lime) results in a significant improvement of BSMs in terms of moisture resistance. This shows that the addition of 1% cement is vital for the durability of most BSMs.

Namutebi et al (2012) presented a new method for determining the optimal compaction characteristics of laterite gravels–foamed bitumen mixes. A gyratory compactor was used for compaction. The modified locking point concept was used to determine the number of gyrations to compact mixes of laterite gravels and foamed bitumen. The optimal compaction moisture content was subsequently established at this point. The average number of gyrations that gave the locking point was 44; Optimum Moisture Content (OMC) for compaction varied from 86% to 92% for gravels only. The modified locking point seems to be suitable for determining the optimal compaction characteristics of these mixes. Thus, future gyratory compaction of these mixes will be conducted at these compaction optimum moisture content conditions. In addition, gyratory compaction of foamed bitumen-treated materials can be carried out at moisture conditions that are less than the optimum moisture conditions of the aggregates only, as compaction of the materials at 100% OMC gave lower densities.

2.3. Resilient Modulus

Resilient modulus is used as an elastic modulus in theory of elasticity, for materials shows indication of non-elasticity as there is very small permanent deformation after the load application. However, as the applied load is much less than the strength of materials, deformation caused by each load application almost everything back to its original condition and can be considered the material as an elastic. As the load applied repeatedly, later the permanent deformation can be detected. Plastic strain is the difference between total strain and elastic strain. After 100 – 200 load repetitions, plastic strain is hardly visible anymore. For this kind of material, its modulus of elasticity due to load repetition is referred to as resilient modulus, Mr, and is calculated by Equation

Mr= Repeated deviatoric stress/ Resilient recoverable strain**.**

Where: Mr: resilient modulus

The loading wave form used in the resilient modulus testing should simulate the actual loads in pavements during the service conditions. When a vehicle is approaching to a certain point on the pavement, the amount of load increases from zero to a maximum value. The maximum load level will be reached when the edge of the tire is just above the reference point according to the pseudo-energy simulations [Sousa et al., 1994; Monismith et al., 2000].

2.3.1. Predicting MR from Empirical Correlation

Various empirical tests have been used to characterize the pavement material. Most of tests are simple to perform and wildly adopted as routine tests, such as Marshall Stability test and California bearing ratio (CBR) test. The correlations between MRs and the testing results from these tests have been developed. The coefficients in these correlations vary according to local practices. For asphalt concrete, the most well-known predicting method was proposed by Nijboer (1957) using Marshall stability-flow ratio as follows:

Mr = 1.6(stability/flow)

Where: Mr is the modulus given in kilograms per square centimeter, stability in kilograms, and flow in millimeters.

2.4. Indirect Tensile Strength

The tensile properties of bituminous mixtures are of interest to pavement engineers because of the problems associated with cracking. The indirect tensile strength test (ITS) is used to determine the tensile properties of the bituminous mixture which can further be related to the cracking properties of the pavement. Low temperature cracking, fatigue and rutting are the three major distress mechanisms. A higher tensile strength corresponds to a stronger cracking resistance. At the same time, mixtures that are able to tolerate higher strain prior to failure are more likely to resist cracking than those unable to tolerate high strains (Tayfur et al., 2007).

A lot of research work has been reported on the performance of bituminous pavements relating the tensile strength of bituminous mixtures (Zhang et al., 2001; Behbani et al, 2009; Anderson et al., 2001). A higher tensile strength corresponds to a stronger low temperature cracking resistance (Huang et al., 2004). The test provides information on tensile strength, fatigue characteristics and permanent deformation characteristics of the pavement materials.

The resistance of bituminous mixtures to fatigue cracking is dependent upon its tensile properties, notably its tensile strength and extensibility characteristics. Fatigue has been defined in the literature as the phenomenon of fracture under repeated or fluctuating stresses.

The layers in a flexible pavement structure are subjected to continuous flexing as a result of the traffic loads that they carry, resulting in tensile stresses and strains at the bottom of the bituminous layers of the pavement. The magnitude of the strain is dependent on the overall stiffness of the pavement. Indirect tensile strength test is an indicator of strength and adherence against fatigue, temperature cracking and rutting.

$$St = 2000p/\pi Dt$$

Where:

St = ITS strength, kPa

P = maximum load, N

t = specimen height immediately before test, mm

D = specimen diameter, mm

2.5. Marshall Test

In this method, the resistance to plastic deformation of cylindrical specimen of bituminous mixture is measured when the same load is loaded at the periphery at the rate of 5cm per minute. The test procedure is used in the design and evaluation of bituminous paving mixes.

Marshall Stability measures the maximum load sustained by the bituminous material at a loading rate of 50.8 mm/minute. The test load is increased until it reaches a maximum. Beyond that, when the load just starts to decrease, the loading is ended and the maximum load (i.e. Marshall Stability) is recorded. During the loading test, dial gauge is attached which measures the specimen's plastic flow owing to the applied load. The flow value refers to the vertical deformation when the maximum load is reached.

Marshall Stability is related to the resistance of bituminous materials to distortion, displacement, rutting and shearing stresses. The stability is derived mainly from internal friction and cohesion. Cohesion is the binding force of binder material while internal friction is the interlocking and frictional resistance of aggregates. As bituminous pavement is subjected to severe traffic loads from time to time, it is necessary to adopt bituminous material with good stability and flow.

Figure 1.0 Marshall Test Machine

CHAPTER THREE

STUDY METHODOLOGY

3.1. General

In previous chapter a comprehensive review of previous studies related to Asphalt Treated Base (ATB) course materials, durability of aggregate material, resilient modulus and indirect tensile strength were presented. In this chapter methodology adopted for the study will be discussed. To meet the objectives of this study, different stage of ware be accomplished. This can be classified in to three different tasks.

Task 1: problem identification and literature review

- Identification of objectives
- Literature review

Task 2: Laboratory Investigation

- Selection of test equipments
- Aggregate material selection and performing aggregate property tests.
- Aggregate durability test
- Specimen fabrication.
- For prepared specimens of HATB's performing Indirect Tensile strength (ITS) and resilient modulus will be performed using marshal apparatus.

Task 3: Analysis and conclusion

- Analyzing test data obtained.
- Comparing the test results.

Based up on above tasks, a summary of research results and finding from this study ware provided in this task.

3.2. Task1 Problem Identification and Literature Review

In this the main objective of this project is to identified and comprehensive literature search of published materials and on-going research projects to obtain the latest information related to

HATB characterization. The characterization of HATBs included evaluation of material properties such as MR, tensile strength, testing methods, influencing factors.

3.3. Task 2 Laboratory Investigation

Prior to any laboratory investigation test equipment's used in this study are identified. Weak aggregate are used in this investigation. The aggregate properties were evaluated prior to the mix design, and those properties included aggregate gradation, moisture content, abrasion resistance, percentage of fractured face, and flat or elongated particles. The asphalt binder used in this study was 60/70 bitumen grade type of asphalt. Three binder contents were used (2%, 3%, and 4%).

To test the durability of aggregates Sodium Sulphate was used. To investigate the effect of treatment two type of aggregate was used, weak aggregate and treated aggregate

Resilient modulus and tensile strength of HATB were evaluated using Marshall test. The indirect tensile strength (ITS) was used to evaluate the MR. to investigate the effect of binder content three different content of asphalt was used.

3.4. Task 3 Analysis and Conclusion

Data obtained from different tests were analyzed in this task. The effects of binder content and aggregate type on tensile strength and MR were shown. The result from the analysis were compared and concluded.

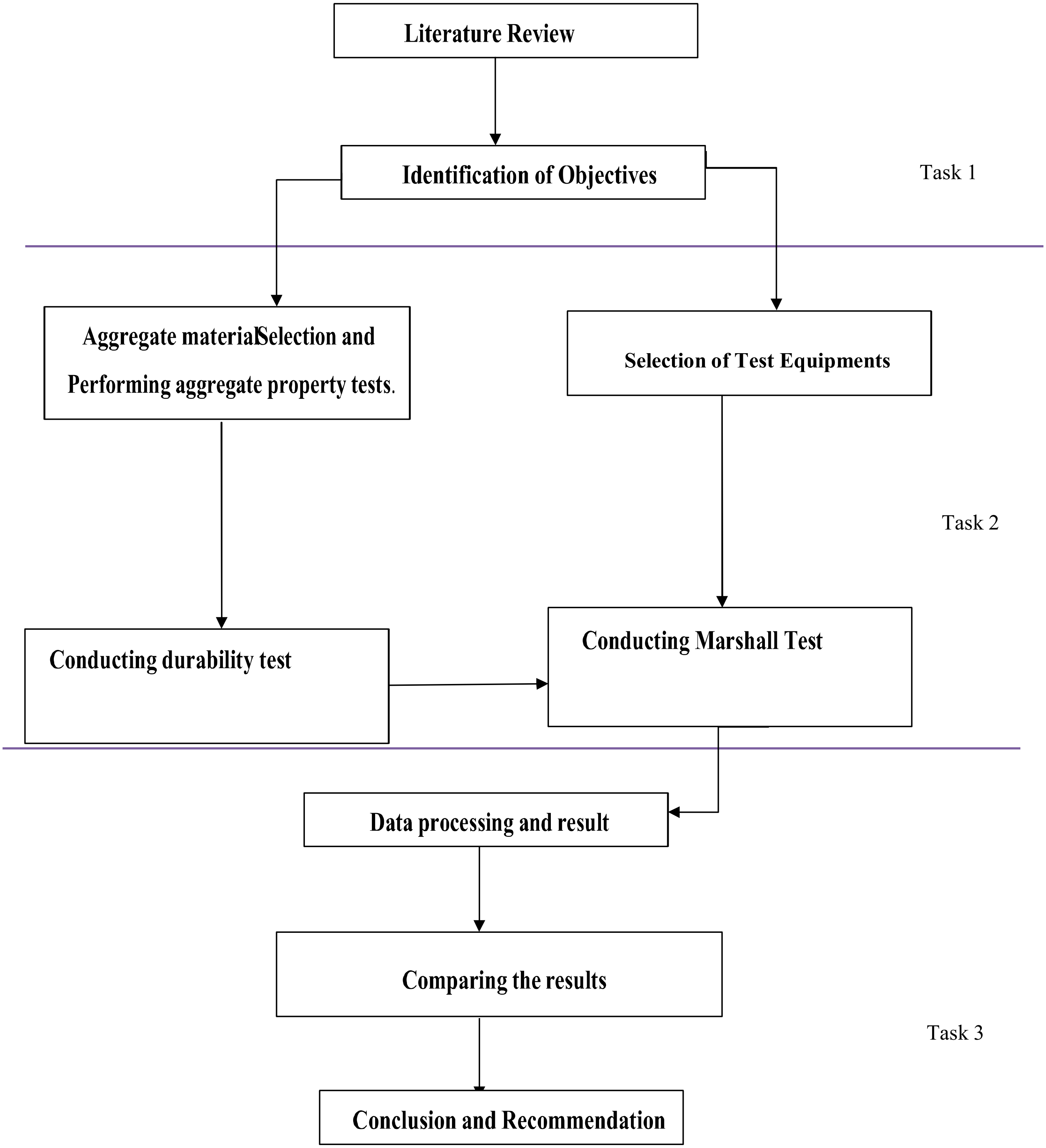

Figure 3.1.Adopted Methodology for Study

CHAPTER FOUR

LABORATORY TESTING

4.1. General

In the previous chapter the detailed methodology was discussed. Types of materials used, specimen fabrication, equipment's used and test method adopted are discussed in this chapter. Properties of material are discussed as well.

4.2. Materials

Weak aggregate(less durable and weak in strength) and 60/70 bitumen grade asphalt binder is used at three different percent.

4.2.1. Aggregate (weak)

Weak aggregate materials are used in this project. The aggregate used in this work are locally available source. Aggregate properties were tested before treatment. Those properties included are aggregate gradation, percent of fractured surface, abrasion resistance and percent of flat and elongated aggregate.

The shape of aggregate particles is determined by the percent of flaky and elongated particles contained in it. The flakiness index of aggregate is the percentage by weight of particles whose least thickness is less than three fifth or 0.6 of their mean dimension.

1. Elongation index

The elongation index of an aggregate is the percentage by weight of particles whose greatest dimension (length) is greater than 1.8 times of their mean dimension.

Table 4.1 Gradation of weak Aggregate

Sieve Designation(mm)	Percentage passing (%)	Specification (%)
50.00	100	100
37.5	98	95- 100
28.00	-	-
20	80	60-80
10	35	40- 60
5	32	25-40
2.36	25	15-30
0.425	12	7-19
0.075	4	5-12

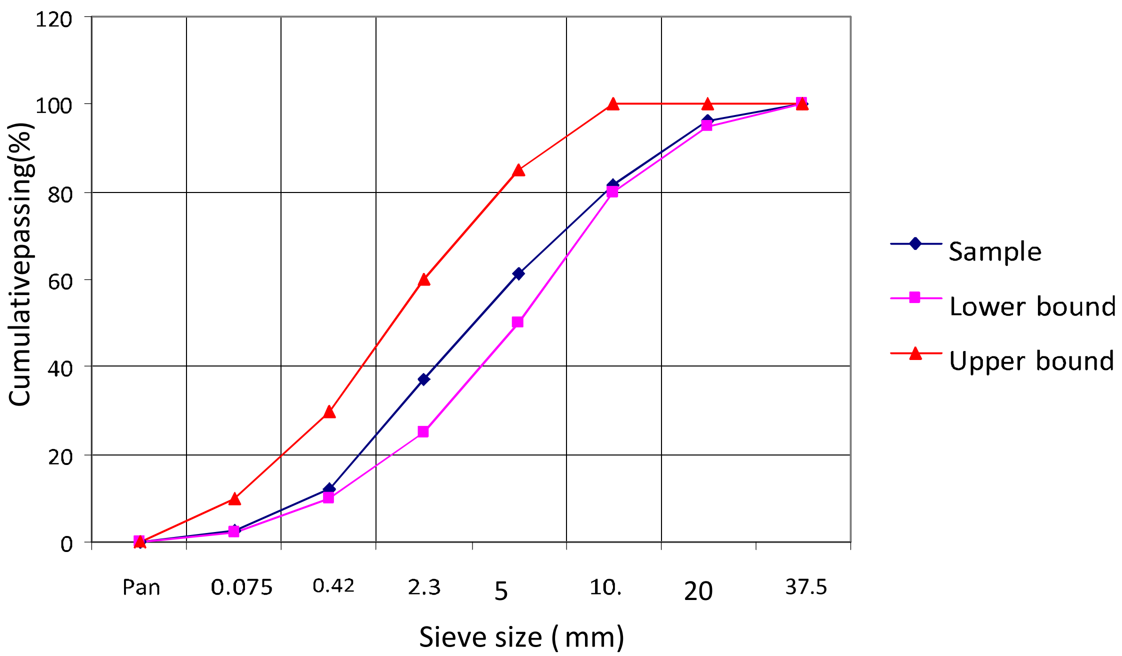

Figure 4.0 Gradation chart of aggregate

Figure 4.1 Gradation of weak Aggregate

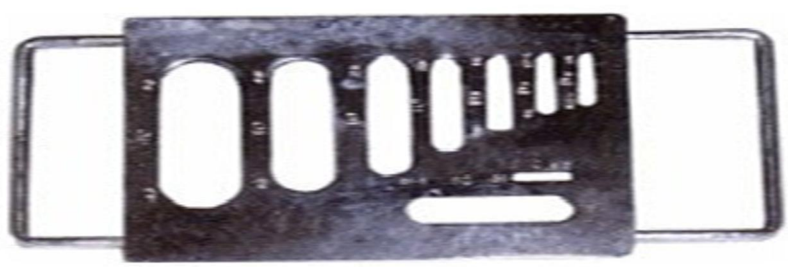

Figure 4.2 Flakiness Index Testing Apparatus

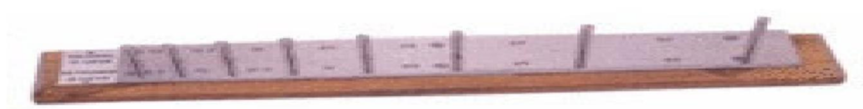

Figure 4.3: Elongation Index Testing Device

2. Abrasion test

The principle of abrasion test is to find the percentage of wear due to the relative rubbing action between aggregate and steel balls used as abrasive charge. Los Angeles abrasion testing machine is used for this test. Fig 4.4 shows the device. The result is presented as loss of aggregate passing 1.7mm sieve after abrasion. The lower the percent, the better resistance of aggregate.

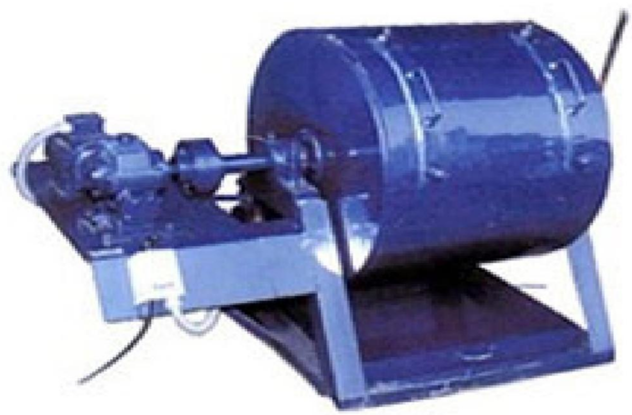

Figure 4.4 Los Angeles Abrasion Testing Machine

3. Aggregate impact (toughness)

Toughness is the property of material to resist impact. During the construction of pavement layers , particularly compaction by heavy rollers and also due to movement of heavy wheel loads of traffic , the road aggregate are subjected to impact or pounding action and there is possibility of some stones breaking in to smaller pieces. Aggregate impact test has been designed to evaluate the toughness or resistance of the stones aggregates breaking down under repeated application of impact. Aggregate impact test is conducted aggregate using impact testing machine according to ERA standards.

Figure 4.5 shows apparatus used for this test. Table 4.2 summarizes properties of Aggregate material used for this project.

Figure 4.5 Aggregate Impact Testing Machine**.**

Table 4.2: Summary of Properties of Aggregate

S.No.	Properties	Obtained value	Specification
1	Flat or elongated pieces (%)	28	30 max
2	Abrasion resistance (%)	33	30 max
3	Percent Fractured Face (two fractured face %)	90	90
4	Impact Resistance (%)	35	30 max

4.2.2. Asphalt Binder Selection

60/70 bitumen grade asphalt binder was used for this study. The main reason of using this grade is its wide use in all road projects in Ethiopia. Three binder contents, 2%, 3%, and 4% by weight of total mixture were used to prepare specimens of HATB. Bitumen properties test were conducted. Those properties are viscosity test, penetration test, ductility test, softening point test and flash and fire point tests.

1. Viscosity and temperature

The degree of fluid of a bituminous binder at the application temperature influences the ability of a binder to spread, penetrate into the voids and also to coat the aggregate and hence affects the characteristics of the resulting paving mixes. For each type and grade bituminous binder, there is a suitable range of temperature at which the fluidity or viscosity is appropriate to effect good mixing. Viscosity of a liquid is the property that retards its flow due to internal friction and it is a measure of resistance to flow of the liquid. Higher the viscosity, slower will be its movement or rate of flow. Figure 4.6 shows apparatus used for viscosity test.

Figure 4.6 Tar Viscometer

2. Consistency

Figure 4.7 below was used to determine grade of bitumen. The penetration tests determine consistency of bitumen for the purpose of grading Depth in units 1/10 of millimeter to which a standard needle having a standard weight will penetrate vertically in a duration of five seconds at a temperature of 25 ºC determines penetration for gradation. Consists of a vertical pillar mounted on a base provided with leveling screw The head together with dial gauge rod and cone (or needle) slides on a pillar and can be clamped at required height. A rack and pinion and pointer assembly provides adjustment of needle or cone tip to sample. It incorporates a slipping clutch mechanism which makes reading of penetration and subsequent resting a simple and accurate operation the dial is graduated in 400 1/10th mm sub-divisions, and the red needle pointer against black figures makes for easy reading. Supplied complete with one 50 gram weight and one 100 gram weight and one needle. The difference between the initial and final penetration reading is taken as penetration value. The mean value of three consistent penetration measurements was taken.

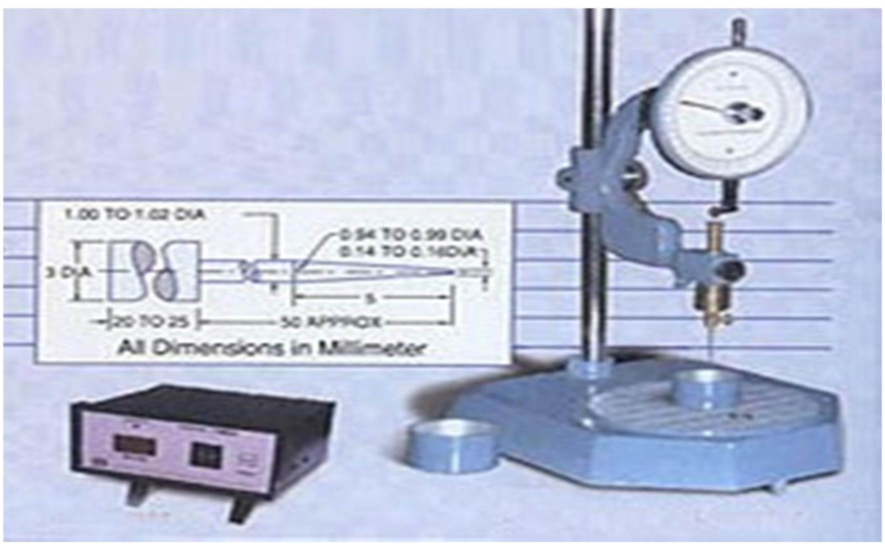

Figure 4.7 Penetrometer

3. Ductility

Ductility is defined as distance in cms to which a standard briquette of bitumen can be stretched before the thread breaks. The briquette is stretched at a rate of 50 mm /min. /2.5 mm per minute at a temperature of 27ºC /0.5ºC.

4. Softening point

The softening point is the temperature at which the substance attains particular degree of softening under specified condition of test. Ring and ball test was used to determine softening point according to ERA standards. A brass ring containing the test sample of bitumen is suspended in liquid like water or glycerin at a given temperature. A steel ball is placed up on bitumen and liquid medium is then heated at specified rate. The temperature at which the softened bitumen touches the metal plate placed at a specified distance below the ring is recorded as the softening point of particular bitumen.

5. Flash point

The flash point of a bituminous binder is defined as the lowest temperature at which application of a test flames causes the vapors of the binder to catch an instant fire in the form of flash under specified test conditions. The fire point is defined as the lowest temperature at which application of a test flame causes the binder material to ignite and burn at least for five seconds under specified test conditions. Table 4.3 summarizes properties of bitumen material used for this project.

Table 4.3 Summary of Bitumen Property

S.No.	Characteristics	Obtained Values	Specification
1	Kinematic viscosity	400	350 min
2	Absolute Viscosity at 60°C	2500	2400 min
3	Penetration @ 25^{0}C, 0.1mm 100gm, 5sec	65	50-70
4	Ductility at 25°C, cm, after thin-film oven test	99	40min
5	Softening point , ^{0}C	54	47min
6	Flash point , ^{0}C	220	220min

4.3 Laboratory Tests

The laboratory tests conducted in this study are Marshall Test and durability test. Using Marshall Test, the value of Indirect Tensile Strength (ITS) and resilient modulus (M_R) are calculated. In this study the values of indirect tensile strength was used as a precondition for resilient modulus test.

4.3.1 Soundness (durability) with Sodium Sulphate

The test determines the resistance to disintegration of aggregate by saturated solution of Sodium Sulphate. It indicates soundness against weathering action.

For each Soundness test, the following procedures were followed:

1. Prepare saturated solutions of Sodium Sulphate by adding sufficient quantities of salt into water at a temperature of 25 to 30^{o}C. The solution may be cooled to 27+1^{o}C and kept at that temperature at least for 48 hr before use.
2. Prepare the samples

   Coarse Aggregate

   Coarse Aggregates for the test shall consist of materials from which sizes finer than 4.75 mm have been removed. The sample shall be of such a size that it will yield not less than the following amounts of the different sizes, which shall be available in amounts of 5% or more.

Sieve size(mm)	Weight retained(gm)
60	-
40	300
20	1500
10	1000
4.75	300

3. Wash the sample and dry to the constant weight at 105^{o}C to 110^{o}C. Separate into different sizes as shown above by sieving to refusal. Weigh out the samples and keep them in separate containers.

4. Immerse the samples in prepared solutions of sodium sulphate for not less than 16 hr and not more than 18 hr in such a manner that the solution covers them to a depth of at least 15 mm.
5. Cover the container to reduce evaporation and maintain the solution at a temperature of $27+1^{o}C$.
6. Remove the sample after the immersion period and allow it to drain for 15+5 min. Place it in the drying oven at a temperature of $105^{o}C$to $110^{o}C$; and dry it to a constant weight.
7. Repeat a number of cycles and determine the loss of weight of specimen after each cycle in accordance with the procedure given below.
8. After the sodium sulphate solution has been removed, each fraction of the sample shall be dried to constant weight at $105^{o}C$ to $110^{o}C$ and weighed. Fine aggregates shall be sieved over the same sieve on which it was retained before the test and coarse aggregate over the sieve shown below for the appropriate size of particle.
9. Calculate percentage loss of weight

Calculation

Loss (%) = (weight before test – weight after test/weight before test) *100

4.3.1.1 Soundness with Sodium Sulphate lab test

Figure 4.10 Prepare saturated solutions of sodium sulphate Figure 4.11 Prepare the samples

Figure 4.12 Wash the sample and dry Figure 4.13 Immerse the samples in prepared

Solutions of sodium sulphate

Figure 4.15 dried to constant weight Figure 4.16 Measure

4.3.2. Marshall Test

4.3.2.1. Mix design

The selection of mix proportions is a process of choosing suitable ingredients of HATB and determining their relative quantities with the object of producing as economically as possible HATB of certain minimum properties, notably strength, durability and a required consistency.

The key to achieving a strong, durable HATB rests in the careful proportioning and mixing of the ingredients. A HATB mixture that has no enough asphalt has a dry clean appearance, lacking the shining black luster of a well-coated mix. It may be difficult to spread, and transverse cracks may appear under the roller which readily heals up. A mixture with an excess of asphalt binder will be easy to place and will produce a smooth surface; however, the resulting HATB is likely to shrink more and be uneconomical. A properly designed HATB mix will possess the desired durability and strength for the base.

4.3.2.2. Marshal Mix design

Size of standard test specimen (64 mm height) & (102 mm diameter)

Total full (loose sample) volume of the specimen = 0.000522863424m3

After compaction the height of the sample will be reduced to (63.5 +/- 0.127 mm)

Compacted volume of the sample = 0.0005187785535m

The aggregate required for the above specimen is approximately 1200gm with different gradation

Table 4.4 Marshall Mix design

sieve size(mm)	1.200kg(0.0005187785535m3) compacted	
	percent	weight(gm)
20	28	336
12.5	17	204
9.5	20	240
4.75	10	120
2.36	10	120
0.075	10	120
pass 0.075	5	60
Asphalt by total mix	3%	37.11

4.3.2.3. Specimens Preparation

Marshal specimens were fabricated for HATB for marshal test to calculate indirect tensile strength (ITS) and resilient modulus (M_R). The specimen is fabricated from weak aggregate. Three binder contents, i.e. 2%, 3% and 4%, were used for weak aggregate materials. The target air voids content was 6%. Approximately 1200gm of aggregates is heated to a temperature of 175^{o}C to 190^{o}C. Bitumen is heated to a temperature of 121^{o}C to 125^{o}C, to the heated aggregates and thoroughly mixed at temperature of 154^{o}C to 160^{o}C. The mix is placed in a preheated mould and compacted by a rammer with 50 blows on either side at temperature of 138^{o}C to 149^{o}C. The specimen prepared is kept in room temperature for 24 hrs.

Figure 4.17 Heating of Aggregate

Figure 4.18 Mixing of Aggregate with Bitumen

Figure 4.19 Weighting of Bitumen

Figure 4.20 Compacting of the Specimen

4.3.2.4. Marshall Laboratory test

Marshall Stability measures the maximum load sustained by the bituminous material at a loading rate of 50.8 mm/minute. The test load is increased until it reaches a maximum. Beyond that, when the load just starts to decrease, the loading is ended and the maximum load (i.e. Marshall stability) is recorded. During the loading test, dial gauge is attached which measures the specimen's plastic flow owing to the applied load. The flow value refers to the vertical deformation when the maximum load is reached. Marshall Stability is related to the resistance of bituminous materials to distortion, displacement, rutting and shearing stresses. The stability is derived mainly from internal friction and cohesion.

Cohesion is the binding force of binder material while internal friction is the interlocking and frictional resistance of aggregates. As bituminous pavement is subjected to severe traffic loads from time to time, it is necessary to adopt bituminous material with good stability and flow.

1. Place the sample in a water both at $60^o \pm 1^o$c x for 30-40 min.
2. Place one sample in the loading yoke, add the top part of the yoke, place the flow meter over one of the pasts, an adjust it to read zero.
3. Apply a load at a rate of 50mm per minute until the max. Load reading is obtained.
4. Record the max load reading, at the same instant; obtain the flow as recorded on the flow meter.
5. Calculate Mr and ITS

Calculation of Mr and ITS from

Mr = 1.6(stability/flow)

Where:

Mr is the resilient modulus given in kilograms per square centimeter, stability in kilograms, and flow in millimeters.

St = 2000p/πDt

Where:

St = ITS strength, kPa

P = maximum load, N

t = specimen height immediately before test, mm

D = specimen diameter, mm

Figure 4.21 place one sample in the loading yoke

Figure 4.22 Adjust the machine to read zero

Figure 4.23 Record the max load and flow reading

CHAPTER FIVE

RESULTS AND ANALYSIS

5.1. General

In previous chapter, various laboratory investigations conducted in this study were discussed. In this chapter testing result and conclusion from the laboratory tests are elaborated. In this study, durability and marshal test were performed on hot asphalt treated base (HATB) to calculate resilient modulus and indirect tensile strength. ATB Treated aggregate provides more than two times load bearing capacity and durability of unbound aggregates. Effects of binder content and aggregate type were investigated. The durability test result of treated and untreated aggregate are summarized in table 5.1 and 5.2 below. The resilient modulus and indirect tensile strength value at different bitumen content are summarized in table 5.3 and table 5.4 below respectively. The mixes with2% binder content have high resilient modulus than the mix with 3% and 4% binder content.

The durability test result shows that the asphalt treatment increase the durability of the aggregate by more than three times and the Marshall Test result also shows that the indirect tensile strength decreases as binder content increase.

Table 5.1 durability test result for untreated sample aggregate

Weight of untreated sample aggregate(gm)			
Before test	After test	Loss (%)	Specification
5800	4749	18.12	12%

Table 5.2 durability test result for treated sample aggregate

Weight of treated sample aggregate(gm)			
Before test	After test	Loss (%)	Specification
5800	5421.26	6.53	12%

Table 5.3 Resilient Modulus Value

Material type	Binder content (%)	Resilient Modulus(KPa)
HATB from weak aggregate	2	120.07
	3	107.066
	4	97.86

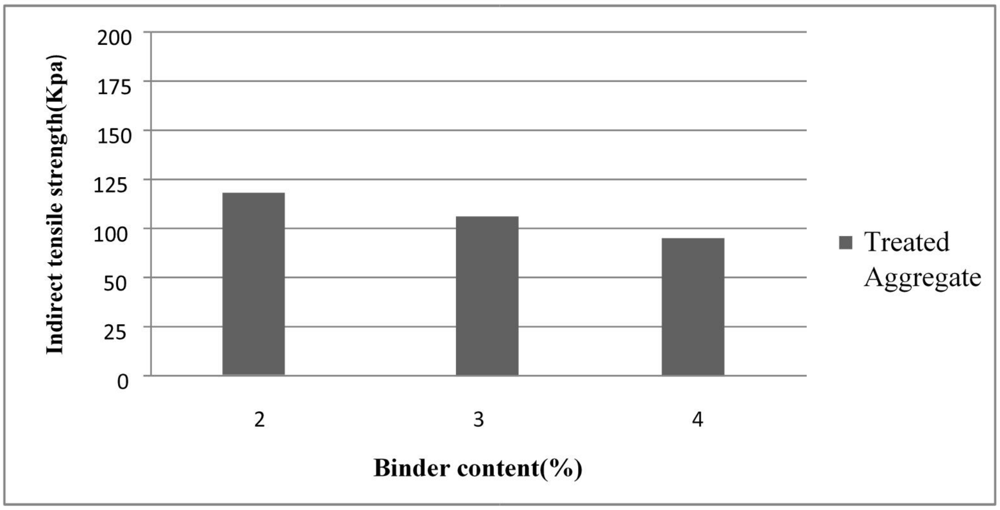

Figure 5.1: Resilient Modulus of treated Aggregate

One can observe from the table 5.1 and figure 5.1 above that, the mix prepared from 2% binder content have high resilient modulus than the mix prepared from 3% and 4% binder content. Low binder content produced higher modulus in the case of hot mix asphalt prepared from weak aggregate. However, this doesn't mean that HATBs with lower binder content have better performance when paved on the roadways. In the layered pavement structure, materials with higher MR helps reducing the stresses in the upper and lower layers, meanwhile it will increase the stress in the layer where they are paved. In addition, lower binder content lead to less flexibility, which means lower fatigue resistance for asphalt mixture. The selection of asphalt binder content should not only depends on the improvement of modulus and durability, but also include the consideration of structure design.

Table 5.4 Indirect Tensile Strength Result of the Study

Material type	Binder content (%)	Tensile strength result(Kpa)
HATB from weak aggregate	2	688.37
	3	639.20
	4	609.70

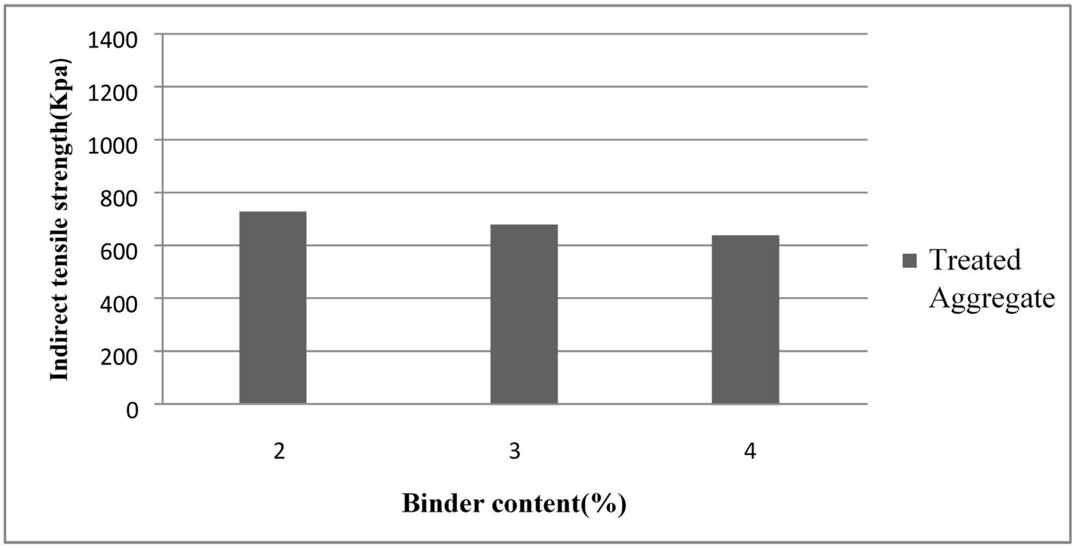

Figure 5.2 Indirect Tensile Strength of treated Aggregate

Table 5.2 above list the indirect tensile strength test result. With increasing of binder content, the indirect tensile strength decreases .The mix with low binder content has high indirect tensile strength.

5.2. Comparison

One can observe from table 5.5 and table 5.6 below that, HATB has high resilient modulus and tensile strength than the untreated base material.

Table 5.5 Comparison of indirect tensile strength

Material type	Binder content (%)	Tensile strength result(Kpa)
HATB from weak aggregate	2	688.37
Normal aggregate	-	230

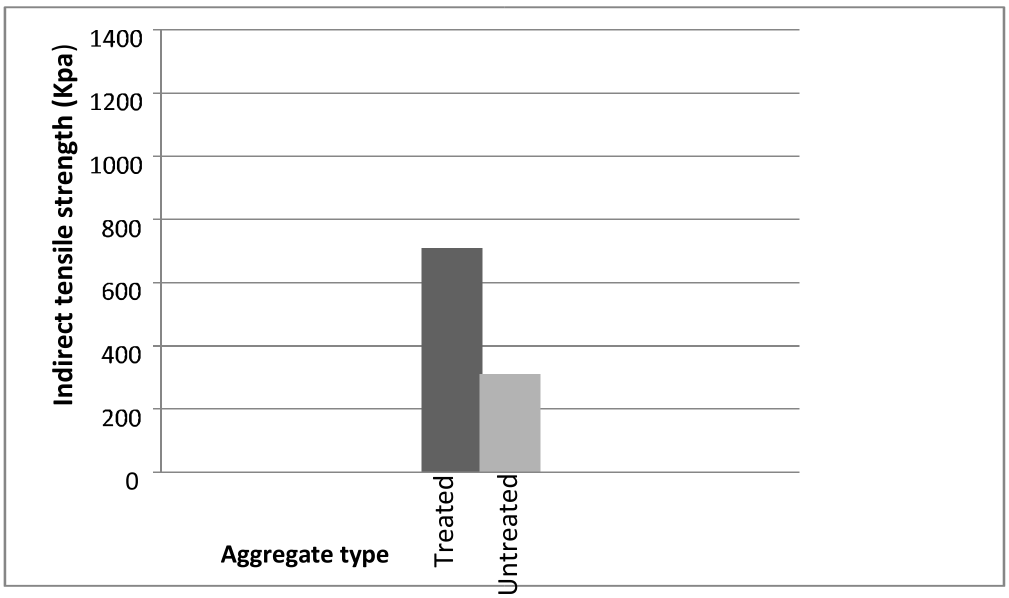

Figure 5.3 Comparison of indirect tensile strength at 2% bitumen content

Table 5.6 comparison of resilient modules

Material type	Binder content (%)	Resilient modules (Kpa)
HATB from weak aggregate	2	120.07
Normal aggregate	-	38

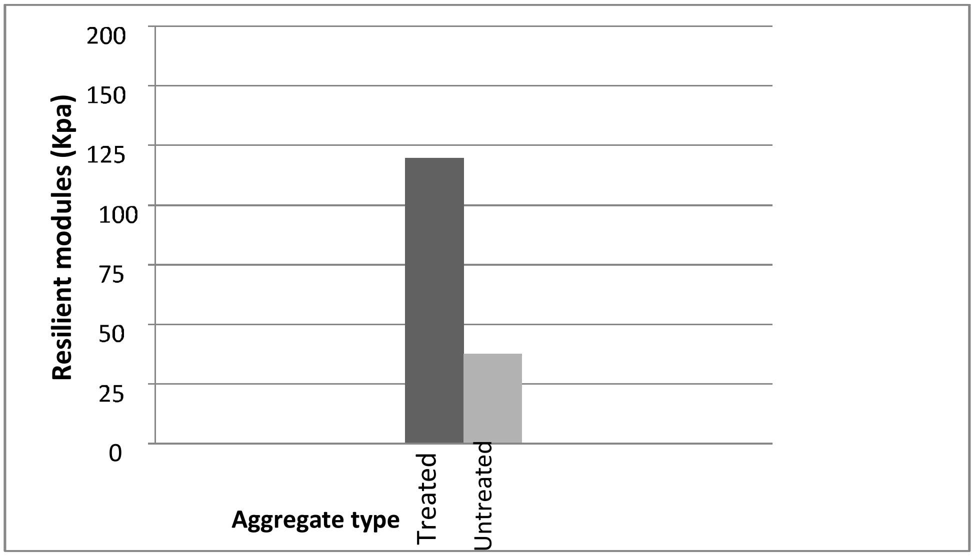

Figure 5.4 comparisons of resilient modules at 2% bitumen content

5.3. Depth estimation

From table 5.7 below one can observe that the HATB can achieve high resilient modules with minimum depth. so that we can have strong and economical base with minimum bitumen content.

Table 5.7 Pavement Structural Section Model for HATB

Pavement Layer	Modulus(kPa)	depth (mm)
HATB	120.07	125
granular base course untreated	38	250

CHAPTER SIX

CONCLUSION AND RECOMMENDATION

6.1. Conclusion

Based on the test result it can be concluded that:-

- The mix prepared from weak aggregate with 2 % binder content has high resilient modulus than the mix with 3% and 4% binder content.
- The result of laboratory investigation shows that, indirect tensile strength decrease as binder content increases.
- ATB aggregates provide more than two times load bearing capacity and three times durability of unbound aggregates.
- HATB has strong base with minimum bitumen content than normal granular base
- The amount of treated aggregate is 50% less than the normal one to construct the base of the road .This indicate that HATB is economical

6.2. Recommendation

1. The present work can be further extended and checked by different test methods
2. The experimentation can be carried out with different grades of aggregate and bitumen.
3. The variation in testing temperature on resilient modulus can be investigated.
4. The effects of air void and mix on resilient modulus can be further investigated.

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APPENDEX 1

Grading Limits for Graded Crushed Stone Base Course Materials

Table 1. Grading Limits for Graded Crushed Stone Base Course Materials (GB1)

Test sieve (mm)	Percentage by mass of total aggregate passing test sieve *Nominal maximum particle* size		
	37.5 mm	28 mm	20 mm
50	100	-	-
37.5	95 – 100	100	-
28	-	-	100
20	60 – 80	70 - 85	90 – 100
10	40 – 60	50 - 65	60 – 75
5	25 - 40	35 - 55	40 – 60
2.36	15 – 30	25 - 40	30 – 45
0.425	7 – 19	12 - 24	13 – 27
0.075 (1)	5 – 12	5 - 12	5 – 12

APPENDEX 2

Key to structural catalogue

KEY TO STRUCTURAL CATALOGUE

Traffic classes
(10^6 esa)

T1 = < 0.3
T2 = 0.3 - 0.7
T3 = 0.7 - 1.5
T4 = 1.5 - 3.0
T5 = 3.0 - 6.0
T6 = 6.0 - 10
T7 = 10 - 17
T8 = 17 - 30

Subgrade strength classes
(CBR%)

S1 = 2
S2 = 3 , 4
S3 = 5 - 7
S4 = 8 - 14
S5 = 15 - 29
S6 = 30+

Material Definitions

Double surface dressing

Flexible bituminous surface

Bituminous surface
(Usually a wearing course, WC, and a basecourse, BC)

Bituminous roadbase, RB

Granular roadbase, GB1 - GB3

Granular sub-base, GS

Granular capping layer or selected subgrade fill, GC

Cement or lime-stabilised roadbase 1, CB1

Cement or lime-stabilised roadbase 2, CB2

Cement or lime-stabilised sub-base, CS

CHART 5 GRANULAR ROADBASE / STRUCTURAL SURFACE

	T1	T2	T3	T4	T5	T6	T7	T8
S1						100 200 225 * 350	125 225 225 350	150 250 250 350
S2						100 200 225 * 200	125 225 225 200	150 250 250 200
S3						100 200 250	125 225 250	150 250 275
S4						100 200 175	125 225 175	150 250 175
S5						100 200 100	125 225 100	150 250 100
S6						100 200	125 225	150 250

Note: 1 * Up to 100mm of sub-base may be substituted with selected fill provided the sub-base is not reduced to less than the roadbase thickness or 200mm whichever is the greater. The substitution ratio of sub-base to selected fill is 25mm : 32mm.

2 A cement or lime-stabilised sub-base may also be used.

APPENDEX 3

Marshal Mix for m3 HMATB

sieve size	1.200kg(0.0005187785535m^3) compacted		2313.1257kg (1m^3) compacted	
	percent	**weight(gm)**	**kg**	**V(m^3)**
20	28	336	**647.68**	**0.100**
12.5	17	204	**393.23**	**0.120**
9.5	20	240	**462.63**	**0.220**
4.75	10	120	**231.31**	**0.170**
2.36	10	120	**231.31**	**0.270**
0.075	10	120	**231.31**	**0.060**
pass 0.075	5	60	**115.66**	**0.060**
Asphalt by total mix	**2**	**24.49**	**47.2**	**-**

ANNEX 1

Laboratory test activities

Compacting of the specimen

Heating aggregate

Place one sample in the loading yoke

Measure