JIMMA UNIVERSITY

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JIMMA INSTITUTE OF TECHNOLOGY

FACULTY OF CIVIL AND ENVIRONMENTAL ENGINEERING

HIGHWAY ENGINEERING STREAM

EXPERIMENTAL INVESTIGATION OF WASTE PLASTIC BOTTLES AS PARTIAL REPLACEMENT OF AGGREGATES IN FLEXIBLE PAVEMENTS.

A research paper Submitted to School of Post Graduate Studies of Jimma University, Jimma Institute of Technology in Partial Fulfillment of the Requirements for Masters of Science in Civil Engineering (Highway Engineering)

By:

Yetimgeta Mekonnen

May, 2019

Jimma, Ethiopia

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By:

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Main Advisor: Engr. Elmer C. Agon

Co-advisor: Mr. Bushirelkerim Oumer

May, 2019

Jimma, Ethiopia

DEDICATION

Dedicated to my beautiful, fantastic, lovely and awesome mother Zerfinesh Wachamo, for whom she set off her Triple Crown academic progress in order to care for her lovely son; that is me.

DECLARATION

I declare that this thesis entitled "experimental investigation of waste plastic bottles as partial replacement of aggregates in flexible pavements" is my original work and has not been presented by any other person on an award of degree in this or other university and all sources of materials used for this thesis have been boldly acknowledged and credited.

Yetimgeta Mekonnen	___________________	___/_____/_______
Researcher	Signature	Date

As masters research advisors, this thesis paper is done under our guidance, by Yetimgeta Mekonnen entitled "experimental investigation of waste plastic bottles as partial replacement of aggregates in flexible pavements."

We recommend that it can be submitted as fulfilling the MSc thesis requirement.

Engineer Elmer C.Agon	___________________	____/____/_______
Main Advisor	Signature	Date
Mr Bushirelkerim Oumer	___________________	____/____/_______
Co-Advisor	Signature	Date

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2. Internal examiner Signature Date

   Mr. Biruk Yigezu ________________ ____/____/_______

3. Chairman Signature Date

   Mr. Oluma Gudina ________________ ____/____/_______

4. Main advisor Signature Date

   Eng. Elmer C. Agon ________________ ____/____/_______

5. Co-advisor Signature Date

   Mr. Bushirelkerim Oumer ________________ ____/____/_______

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ABSTRACT

Global plastic pollution reported that; 1 million plastic bottles bought every minute, 100,000 marine animals killed by plastic each year, 500 years to degrade in the environment, 90% of bottled water contain plastic particles. Ethiopia is facing rapid urbanization and industrialization leading to packing of different industrial products with plastic bottles which finally becomes waste and on the other side pavements is behaving different structural failure and surface defects before the end of construction period and service year.

In order to minimize the above serious problems, this research was initiated to do experimental investigation of waste plastic bottle as partial replacement of aggregate in bituminous concrete mix through dry process to enhance the desired performance of bitumen concrete mix and to reduce plastic bottles disposal problem. Before applying PET bottles as additives, optimum bitumen content was determined for conventional bitumen concrete mix which is selected as 5.33%; up on which the effect of PET bottles was experimented. Waste plastic bottles are collected and cut in to pieces using scissors. Then it was melted in oven at 180 ^{0}c for 30 minute. Then after cooling down it was pulverized. Finally weighing the required amount of pulverized plastic and replacing the aggregate by 0%, 4%, 6%, 8% and 10% by weight of aggregate, the marshal test were held and volumetric properties on each specimen were computed.

Based on the laboratory result, the optimum plastic content was selected at the specimens that have high stability; high bulk density and minimum air void values are 20.66 KN, 2.59gm/cm^{3} and 3.25% respectively. The optimum plastic content is selected at 4% of plastic bottle by weight of aggregate. Lastly this study concluded that, partial replacement of aggregate by waste plastic bottle can increase the overall performance of bitumen concrete mix.

Finally this study recommends it is better to apply this new construction technology on the ground and to adopt it. It is better to know the cost benefit analysis on partial replacement of aggregate by waste plastic bottles in flexible pavements.

Keyword:- Bitumen Concrete, Modified Bitumen, Optimum Binder Content, Optimum Plastic Content, Plain Bitumen

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ACRONYMS

ACRA	Addis Ababa City Road Authority
AASHTO	Association of American State Highway and Transportation Officials
ASTM	American Society for Testing and Materials
BC	Bituminous Concrete
CD	Compacted Disc
CFC	Chloro Floro Carbon
DBM	Dense Bitumen Macadam
DVD	Digital Video Disc
ERA	Ethiopian Road Authority
HDPE	High Density Polyethylene
HMA	Hot Mix Asphalt
LDPE	Low Density Polyethylene
MS	Marshal Stability
OBC	Optimum Bitumen Content
OPC	Optimum Plastic Content
PC	Polycarbonate
PET	Polyethylene Terephthalate
PP	Polypropylene
PS	Polystyrene
PVC	Polyvinyl Chloride
RCCP	Roller Compacted Concrete Pavement
RPWA	Recycled Plastic Waste Aggregate
SMA	Stone Mastic Asphalt
SW	Solid Waste
VA	Air Voids
VFB	Void Filled With Bitumen
VMA	Void in Mineral Aggregate
WRAP	Waste And Resources Action Program
XLPE	Cross-Linked Polyethylene

CHAPTER ONE

INTRODUCTION

1.1Background of the Study

Bituminous binders are widely used in paving industry. In general pavements are categorized into 2 groups, such as flexible and rigid pavement. Flexible pavements are those, on which the whole pavement have low flexural strength and are rather flexible in their structural action under loads. These types of pavement layers reflect the deformation of lower layers on to the surface of the layer. If the surface course of a pavement is of Plain Cement Concrete then it is called as rigid pavement since the total pavement structure does not bend or deflect due to traffic loads.

Bituminous concrete is one of the widely used and costliest types of flexible pavement layer used in the surface course. Properties of a good bituminous mix are skid resistance, stability, durability etc. The mix design should aim at economical blends with the proper gradation of aggregate and an adequate proportion of bitumen so as to fulfill the desired properties of the mix. Marshall Stability test carried out to find the stability, flow value, bulk density, air voids, voids filled with mineral aggregate, voids filled with bitumen and finally finding the optimum binder content of the mix. Marshall Stability test is conducted on compacted cylindrical moulds of bituminous mix to determine the optimum binder content [1].

Semi-dense bituminous concrete is the most commonly used pavement material due to its construction procedures. The ever increasing economic cost and scarcity of availability of natural material have opened the opportunity to explore locally available waste material. If industrial waste materials can be suitably used in road construction, the pollution and disposal problems may be partially reduced [2]. Utilization of waste material as secondary material is being developed world wide. One of these waste materials is plastic bottles which are being accessible in large amount. In food industries, plastic bottle is mostly made by PolyethyleneTerephthalate (PET). PET becomes very popular during the last decade because it is known as safe, durable and good material for packaging [3].

The threat of disposal of plastic will not be solved until the practical steps are not initiated at the ground level. It is possible to improve the performance of bituminous mix used in the surfacing course of roads. Studies reported that the use of re-cycled plastic, mainly polyethylene, in the manufacture of blended indicated reduced permanent deformation in the form of rutting and reduced low temperature cracking of the pavement surfacing. The field tests proved that plastic wastes used after proper processing as an additive on flexible pavement would enhance the life of the pavement and also solve environmental problems [4].

Plastic and tyre is a non-biodegradable material. Despite, the quantum of plastic waste is also increasing day by day which is hazardous to our health. Thus using plastic waste for construction purpose of flexible pavements will be one of the alternatives for disposing them in an eco-friendly manner [5].

1.2 Statement of the Problem

The production of plastics increased by more than twenty-fold between 1964 and 2015, with an annual output of 322 million metric tonnes (Mt), and is expected to double by 2035, and almost quadruple by 2050. A second analysis indicates that annual global plastics production rose from 2 Mt to 380 Mt between 1950 and 2015, of this it is estimated that only 9% plastic waste generated was recycled and 4900 Mt of the estimated 6300 Mt total of plastics ever produced have been discarded either in landfills or elsewhere in the environment. Plastics stay in the environment for up to 500 years to break down [6]. Global plastic pollution by the numbers show that 13 million tonnes of plastic leak into the ocean each year, 1 million plastic bottles bought every minute, 100,000 marine animals killed by plastics each year, 100 years for plastic to degrade in the environment [7]. The problem with plastic material is that it is accumulating because it does not decay and therefore is increasing in volume. On the other hand the rapid increase in traffic intensity, effect of temperature changes on pavement and effect of heavy rain on pavement leads numerous structural and surface defects [1].

Ethiopia is facing rapid urbanization leading to overcrowding and the development of slums and informal settlements with poor waste management practices. Urban dwellers generally consume more resources than rural dwellers, and so generate huge quantities of solid wastes [8].

Flexible pavements constructed in southern part of Ethiopia for instance around Omo river valley exhibits different types defective failures such as fatigue failures, formation of waves and corrugations, frost heaving, potholes and slippage, alligator or map cracking, formation of pavement layers or rutting, bleeding, pumping, longitudinal cracking and other.

1.3 Research Questions

This research was conducted based up on the following research question.

1. What are the marshal test results of conventional and modified bituminous concrete and the corresponding optimum bitumen content (OBC) and optimum plastic content (OPC) respectively?
2. What relationship is there between marshal test results and volumetric properties with percentage replacement of aggregate by plastic bottles?
3. Does the laboratory test result of plastic bottle modified bitumen concrete mix fulfill the requirements of standard specification?

1.4 Research Objectives

1.4.1 General Objective

The general objective of this research is to investigate the effect of using waste plastic bottles as partial replacement of aggregates in flexible pavement.

1.4.2 Specific Objectives

The specific objectives of this research are as listed below:

1. To determine the marshal test result of conventional and plastic bottle modified bitumen concrete mixes in order to determine optimum bitumen content (OBC) and optimum plastic content (OPC).
2. To analyze the relationship of the marshal test result and volumetric properties with the percentage replacement of the aggregate by plastic bottle.

3. To compare the laboratory test results of plastic modified bitumen concrete with the standard specification.

1.5 Significance of the Study

The use of plastic bottles in bitumen concrete mixtures as partial replacement of aggregate reduces the negative environmental impact due to exploitation of aggregates for construction purpose and the problem of municipal solid waste disposal problem by win-win approach. And it also reduces the construction cost, since the plastic bottle is cheap and highly available. Moreover this can highly solve the plastic waste management problems since plastic bottle waste is one of enormously increasing, the reason due to that we use plastic bottles in our day to day life. It also solves the problems of municipal drainage system since the plastic bottles clog them. The use of plastic bottles as partial replacement of aggregate enhance the overall performance of flexible pavements when the marshal test results of conventional bitumen concrete mix and the modified bitumen concrete mix were compared.

This study genuinely proves that the use of plastic bottles as partial replacement of aggregate in flexible pavement is good for heavy traffic because of its surprising overall performance. It also enables to solve solid waste disposal problems in a useful and ecofriendly manner which imply that it solves the problems in a better way than that of incineration and land filling. Utilization of plastic waste with the bitumen is not new in the construction of flexible pavement. But in this study it was used as partial aggregate replacement. As indicated in many research; it did not only increase its smoothness life but also minimizes permanent deformations due to overload; increases resistance to flow at higher temperature, water repellent property, makes it environment-friendly and economical.

In this study waste plastic bottles were used as partial replacement of aggregate by various percentages by weight of aggregate and it increases flow value and marshal stability, decreases the unit weights (bulk density) which helps in enhancing hauling cost.

Flexible pavement Roads which were constructed by using plastic bottles as an aggregate had better overall performance in the bituminous mixes as compared to those constructed without plastic (conventional BC mix).

1.6 Scope of the Study

This research aims on the use of waste plastic bottle as partial replacement of an aggregate in flexible pavement construction. Marshal test results were conducted on conventional and modified BC mix and the effect in the test results and volumetric properties were compared. Mix design for the blend was also done for marshal test to determine the optimum plastic content and optimum bitumen content. The results obtained from plain bitumen enabled to determine the optimum bitumen content which was 5.33% and then various percentages of plastic was added to replace aggregate by 0%, 4%, 6%, 8%, and 10% by weight of aggregate. The marshal test and volumetric properties for each percentage of the plastic bottle content by weight of aggregate were done and the percentages of plastic with best performance was selected as optimum plastic content, which was marked at higher stability (20.66 KN at 4% plastic), high bulk density (2.51 at 0% plastic) and 3-5% air voids (3.25% at 8% of plastic) and the average of this percentage of replacement is selected as optimum plastic content.

CHAPTER TWO

LITERATURE REVIEW

This chapter provides a review of literature on the Effects of Using waste plastic bottle as partial replacement of aggregate in BC mixes. The main purpose of a literature review is to establish the academic and research areas that are relevant to the subject under study.

2.1 Theoretical Review

The benefits of using waste materials like fly ash and plastic waste are considerable reduction in the use of natural raw materials, responsible for industrial sustainability, solves the disposal problems of wastes as these are utilized in construction activities, plastic improves some properties of bituminous mixes used for paving roads [9].

2.2 Materials in Bitumen Concrete Mix

2.2.1 Bitumen

Bitumen is a black or dark colored solid or viscous cementitious substance having an adhesive property. And it consist chiefly high molecular weight hydrocarbons derived from distillation of petroleum or natural asphalt. And also it is a semi-solid hydrocarbon product produced by removing the lighter fractions (such as liquid petroleum gas, petrol and diesel) from heavy crude oil during the refining process [10].

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. 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. 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. Cutback bitumen is bitumen in which a suitable solvent is mixed to reduce viscosity. Bitumen emulsion is suspended in finely divided condition in aqueous medium 60% bitumen and 40% water. Bituminous primers are obtained by mixing of penetration bitumen with petroleum distillate. Modified bitumen is blend of bitumen with modifiers such as waste plastics or crumb rubber or fly ash [11].

In order to withstand tyre and weather, pavement surface layers contain the strongest and most expensive materials in road structures. Characteristics they exhibit like friction, strength, noise and ability to drain off surface water are essential to vehicles' safety and riding quality [12].

Bitumen content in the mix should be 4% (by weight) of the total mix. Bitumen grades can be industrial (which includes waterproofing) or pave grade (grading used for pavement structures). In India, 60/70 and 180/200 of bitumen are usually used. Often, choice of the grade depends on environment conditions of the area [13]. Bitumen is a material which is a byproduct of petroleum refining process. It is a highly viscous at temperature above 100 degrees Celsius and is solid at room temperature [14]. A grade of 40/50 bitumen means the penetration value is in the range 40 to 50 at standard test conditions. In hot climates, a lower penetration grade is preferred. There are so many properties of bitumen required to be fulfilled as depicted in Table 2.1 [15].

Table 2. 1 The Properties of bitumen [15].

Sl No.	Properties	Grade		Test methods
		60/70	80/100	
1	Penetration at 25° C	67	90	IS:1203-1978
2	Softening point (R&B) °C	51	41	IS:1205-1978
3	Ductility @27°C, cm	73.5	75.5	IS:1208-1979
4	Flash point, °C	330	261	IS:1209-1981
5	Fire point, °C	345	283	IS:1209-1981
6	Specific gravity of bitumen	1.017	1.02	IS:1202-1980

2.2.2 Aggregate

Aggregate is a major component of asphalt mixes, so their properties play a significant role on the asphalt paving mixtures. An aggregate gradation that yields maximum solid density and maximum particle interlock is highly desirable for the asphalt concrete mixes. Maximum particle interlock leads to high mix density and stability. While minimum voids in a certain material composition leads to high strength [16].

Aggregate is the major structural framework of asphalt mixture to absorb and control different stresses on the pavement. Mineral aggregates make up 90 to 96% of a HMA mix by weight or approximately 75 to 85% by volume. The properties of the mineral aggregates have significant effects in performance of our roadways which offers the possibility of investment in these properties towards resisting different ranges of external applied loads and environmental conditions. Therefore, aggregate characteristics deeply affect the performance of asphalt pavements. Gradation is one of the important characteristics of aggregates affecting permanent deformation of hot mix asphalt. Fine, medium and coarse gradation mixtures for different aggregate types were tested to investigate the effects of variation in the aggregate types and gradation on mix properties. The asphalt contents of the mixes were maintained at the job mix design contents. Properties investigated were, Marshall Stability, Marshall Flow, unit weight, air voids, and voids in mineral aggregate [17].

Coarse aggregate used for road construction should be hydrophobic to the bituminous surface. Other than this it should be hard, tough and durable. Gravels should not have fineness modulus of less than 5.75 and should be well graded (6.4mm to 38mm and free from organic matter, silt and clay [14]. Some of the required properties of aggregate were as depicted in Table 2.2. Aggregates without plastic and aggregates coated with of waste plastic equal to 0.5%, 0.55%, and 0.6% of weight of dry aggregates. The use of plastic waste in the construction of flexible pavement is one of the best methods for the safe disposal and better performance of the bituminous mix, if plastic coated aggregates are used [18].

OBC for conventional SMA, BC and DBM mixes are found as 6%, 4.5% and 4.5% similarly OBC are found as 4% for modified SMA, BC and DBM mixes with polyethylene at different concentration. With addition of polyethylene, stability value also increases up to certain limits and further addition decreases the stability. This may be due to excess amount of polyethylene which is not able to mix in asphalt properly. That polyethylene concentration in mix is called optimum polyethylene content (OPC) which is found as 2% for SMA and 1.5% for DBM bitumen mixes [19].

Density is the mass per unit volume of a material, expressed as kilograms per cubic meter (pounds per cubic foot). Relative density (specific gravity) (SSD) is used if the aggregate is wet, that is, if its absorption has been satisfied. It is the ratio of the density (SSD) of the aggregate to the density of distilled water at a stated temperature; the values are dimensionless. It is related to aggregate particles, the condition in which the permeable pores of aggregate particle are filled with water to the extent achieved by submerging in water for the prescribed period of time, but without free water on the surface of the particles. It is the mass of saturated-surface-dry aggregate per unit volume of the aggregate particles, including the volume of impermeable pores and water-filled voids within the particles, but not including the pores between the particles. Conversely, the relative density (specific gravity) (OD) is used for computations when the aggregate is dry or assumed to be dry. It is the ratio of the density (OD) of the aggregate to the density of distilled water. It is the condition in which the aggregates have been dried by heating in an oven at 110 ± 5°C for sufficient time to reach a constant mass. It is including the volume of permeable and impermeable pores within the particles, but not including the voids between the particles. Apparent density and apparent relative density (apparent specific gravity) pertain to the solid material making up the constituent particles not including the pore space within the particles which is accessible to water. It is density of the impermeable portion of the aggregate particles. Absorption values are used to calculate the change in the mass of an aggregate due to water absorbed in the pore spaces within the constituent particles, compared to the dry condition. Aggregates mined from below the water table commonly have moisture content greater than the absorption determined by this test method, if used without opportunity to dry prior to use. Conversely, some aggregates which have not been continuously maintained in a moist condition until used are likely to contain an amount of absorbed moisture less than the 24-h soaked condition. For an aggregate that has been in contact with water and that has free moisture on the particle surfaces, the percentage of free moisture is determined by deducting the absorption from the total moisture content determined by Test Method C 566. The pores in lightweight aggregates are not necessarily filled with water after immersion for 24 h. In fact, the absorption potential for many such aggregates is not satisfied after several days' immersion in water. Therefore, this test method is not intended for use with lightweight aggregate. A sample of aggregate is immersed in water for 24 ± 4 h to essentially fill the pores. It is then removed from the water, the water dried from the surface of the particles, and the mass determined. Subsequently, the volume of the sample is determined by the displacement of water method. Finally, the sample is oven-dried and the mass determined. Using the mass values thus obtained and formulas in this test method, it is possible to calculate density, relative density (specific gravity) and absorption [20].

Table 2. 2 The required properties of aggregate [14].

Sl no	Aggregate tests	Test results obtained	Requirements as per Table 500-14 of MoRTH (IV revision) Specifications
1	Crushing value (%)	24.8	-
2	Impact value (%)	20.8	Max 24%
3	Los Angeles abrasion value (%)	32	Max 30%
4	Combined index (%)	29%	Max 30%
5	Water absorption (%)	0.25	Max 2%
6	Specific gravity of coarse aggregates	2.72	2.5-3.0
7	Specific gravity of fine aggregates	2.76	
8	Specific gravity of filler	2.5	

2.2.3 Waste Plastic Bottle

Polymers can be broadly classified as either thermoplastics or thermosets. The fundamental physical difference between the two has to do with the bonding between molecular chains. Thermoplastics have only secondary bonds between chains, while thermosets also have primary bonds between chains. Thermoplastic polymers can be melted or molded while thermosetting polymers cannot be melted or molded in the general sense of the term. Thermoplastic or thermosetting polymers are sometimes identified by other names such as “linear” and “cross-linked” respectively. The Figure 2.1, below demonstrate the triangle, in the recycle code of plastic, indicates that the plastic material is recyclable, and each number inside the triangle indicates a specific type of plastic [21].

Figure 2. 1 Triangle representing specific types of plastic types [21].

The ocean is estimated to already contain over 150 Mt of plastics; or more than 5 trillion micro (less than 5mm) and macroplastic particles. The amount of oceans plastic could triple by 2025 without further intervention. By 2050, there will be more plastics, by weight, in the oceans than fish, if the current ‘take, make, use, and dispose’ model continues [6]. 90% of bottled water found to contain plastic particles, 83% of tap water found to contain microplastic particles, 50% of consumer plastics are single use, 10% of all human-generated waste is plastic. In the next 10-15 years global plastic production is projected to nearly double [7].

About 2.8 Mt of waste plastics is generated per annum in the UK. Most of those recycled are from industrial and commercial sources; recycling from domestic sources (e.g. bottles) is more difficult, for economic reasons. A future increase in recycling relies on the successful recycling of plastics mixed with other waste, and the support from robust environmental assessment method. Data from UK WRAP indicate that about 0.4 Mt of waste plastics generated each year is suitable for aggregates use. Presently only 0.008 Mt is being recycled for that purpose. Although plastic packaging accounts for most waste plastics recycled in the UK, PVC (polyvinyl chloride) is among the main types that have the lowest recycling rate. Financial incentives are believed to be more effective than specifications in affecting the recycling activity. Thus plastics used in asphalt pavements may provide an important outlet for such materials [12].

Solid waste management is the thrust area. Of the various waste materials, plastic waste and municipal solid waste are of great concern. Finding proper use of the disposed plastics waste is the need of the hour. The traffic intensity is increasing. The load bearing capacities of the road are to be increased. The use of PCA for asphalt pavement helps for the reuse of plastics waste and for the improvement of road strength. Plastics, a versatile packing material and a friend to common man, become a problem to the environment after its use. Most used materials are bags, cups, films and foams, made up of PE, PP or PS. The use of plastics in India is hoped to reach 12 million tonne by the end of 2010. Around 55% is being used for packing. They are mostly littered after their use. The littered plastics, a non-biodegradable material, get mixed with domestic waste and make the disposal of municipal solid waste difficult. The municipal solid waste is either incinerated or used for land filling. Both are not right techniques to dispose the waste and it will create both land and air pollution. This process helps to dispose the waste by eco- friendly method. This process can promote value addition to the waste plastic too. Waste polymers namely PE, PP and PS are hydrocarbons with long chains. The bitumen is a complex mixture of asphaltenes and maltenes which are also long chain hydro carbon [22]. Polyethylene Terephthalate commonly abbreviated PET, is the most common thermoplastic polymer resin of the polyester family and is used in fibers for clothing, containers for liquids and foods, thermoforming for manufacturing, and in combination with glass fiber for engineering resins. Its chemical formula is denoted as $(C10H8O4)$ n [23].

Reuse of bulk wastes is considered the best environmental alternative for solving the problem of disposal. The large volume of composite materials required for the construction and maintenance of road pavements in the UK is potentially a major area for the reuse of waste materials. Because the amount of ‘new’ materials like mineral aggregates required in the road construction industry is large, approximately 20,000 t per mile of motorway constructed, the environmental benefits are not only related to the safe disposal of bulk waste but also to the reduction of environmental impacts arising from the extraction of aggregates which include the loss of mature countryside, visual intrusion, heavy lorry traffic on unsuitable roads, noise, dust and blasting vibration. In 1995, the plastic consumption in the UK was about (24,350, 000 t across Western Europe}. The major users of plastic are the packaging industries, consuming about 41%, 20% in building and construction, 15% in distribution and large industries, 9% in electrical and electronic, 7% in automotive, 2% in agriculture and 6% in other uses. In the UK, the total plastic waste was estimated at around 2,158,000 t in 1995; 1,279, 000 t (59.2%) arising from municipal solid waste, 446,000 t (20.7%) arising from distribution and large industry, 15 1,000 t (7%) from automotive industries, 128,000 t (5.9%)

from electrical and electronics, 122,000 t (5.7%) from construction/ demolition and civil works, and 32,000 t (1.5%) from agriculture. From the total household waste in Western Europe in 1995, about 129,061, 000t; the amount of plastic waste is about 8% by weight, approximately 10,139, 000 t. The largest component of the plastic waste is low density polyethylene/linear low density polyethylene (LDPE) at about 23%, followed by 17.3% of high density polyethylene, 18.5% of polypropylene, 12.3% of polystyrene (PS/extended PS), 10.7% polyvinyl chloride, 8.5% polyethylene terephthalate and 9.7% of other types [24].

Cross-linked polyethylene (XLPE) is widely used as an insulating material for electric wires and cables. XLPE wastes are non-biodegradable components. The accumulation of polymer wastes including waste plastic, waste rubber and polyethylene materials such as XLPE has become a worldwide concern. The total amount of cable waste produced in Japan in 2003 was approximately 10,000 tons. Also, in Sweden, the amount of electrical cables waste was estimated to be 40,000 tons in 2007. These statistics indicate large quantities of XLPE waste. In recent years, cross-linked polyethylene (XLPE) is one such waste material that has been growing rapidly. In fact, XLPE used for the insulation of electric wires and cables is a non-biodegradable component [25].

Some plastics items such as plastic bottles become waste only in a short time after being purchased. After collecting plastics from customer or plant cycle, recycling plastic is more preferable method because plastics can lend themselves to be recycled many times over. PET is selected in the soft-drink container market or plastic bottle because this material is tough (so that it can withstand when it drops), cheap, clarity, durability, excellent, odour resistance and low permeability to carbon dioxide. PET also is used as high performance films such as photographic, magnetic tape, electrical insulation and decorative film laminates. The performance of PET as aggregate replacement had been done in concrete technology. For example, Algeria has investigated the usage of PET as an aggregate for concrete. The usage of waste PET granules pellet was experimented as a partial fine aggregate replacement in asphalt mixture. According to the Waste and Resources Action Program (WRAP) survey, most plastics collected for recycling from the household waste stream are plastic bottles. The majority of bottles are made from Polyethylene Terephthalate (PET), estimated that the ratio is 55-60%. This plastic material was identifiably Low Density Polyethylene (LDPE) principally used as a recycled material in manufacturing of plastic bags and allied products. However, the RPWA may contain traces of other plastic waste materials such as HDPE, PET and PP and so on [26].

Plastic disposal is one of the major problems encountered in all countries. In India, more than 15,000 tons of plastic wastes are generated every day, of which 6,000 tons remain uncollected and littered as per the Government statics. Reuse of bulky wastes is considered the best environmental alternative for solving the problem of disposal. One such waste is plastic, which could be used in various applications [27].

Disposal of huge amount of discarded waste materials like plastic, polythene bags, bottles, rubber tyre and so on, which are generated in huge quantity and causes environmental hazards after their disposal. A recent survey of 60 cities in India by Central Pollution Control Board estimated that about 33.7 million pounds of plastic waste is being generated out every day, of which about 13.2 million pounds remain uncollected and are choking environment. Being non-biodegradable products, plastic and rubber stay for a long time on site and cause environmental pollution. Conventional techniques such as land filling and incineration which are used to dispose plastic waste and rubber tyres create leachate on degradation, which have negative effect on land, water and air [28]. Disposal of waste plastic materials, e.g. bottles, baskets, is becoming urgent issue and is the main reason which causes environmental pollution [29].

2.2.3.1 Classification of plastic

A). Polyethylene Terephthalate

Safe and recyclable, plastic bottles and containers made of it used for water, juice, soft drinks and peanut butter packaging [21]. Polyethylene terephthalate (PET or PETE) is the workhorse of America's plastic drinking bottle industry, polyethylene terephthalate (PET) is one of the most versatile and widely used types of scrap plastic. Figure 2.2 below depict the PET or PETE types of plastic [30].

Figure 2.2 PET (PETE) Polyethylene terephthalate [30].

B). High-Density Polyethylene

It is one of safe and recyclable, used for the manufacturing of packages for shampoo, detergents and milk, as well as plastic toys. It is safer than any other plastic material especially the transparent type [21]. HDPE (High Density Polyethylene) is scrap types of plastic which is used to make milk jugs, detergent bottles, juice bottles, butter tubs, and toiletry bottles. HDPE is a higher density, heavy duty scrap plastic and recycled. HDPE is often used to make more durable product which is as shown in Figure 2.3 below [30].

Figure 2. 3 HDPE (High-density polyethylene) [30].

C). Polyvinyl Chloride

Polyvinyl chloride is harmful and toxic if used for long time. It is commonly abbreviated PVC and used in the manufacturing of plumping pipes, bathroom curtains, toys, and transparent plastic wraps for meat and cheese. It is widely used because of its cheap price, so it is considered the most dangerous type of plastic [21]. PVC (Polyvinyl Chloride) is used for all kinds of pipes and tiles, but it is most commonly found in plumbing pipes. This kind of plastic should not come in contact with food items. Recycled PVC is used to make flooring, mobile home skirting, and other industrial-grade items. The Figure 2.4 below depicted PVC types of plastic [30].

Figure 2.4 PVC (Polyvinyl Chloride) [30].

D). Low-Density Polyethylene

LDPE is proportionally safe, recyclable, used for the manufacture of CDs, bottles and grocery bags [21]. LDPE (Low Density Polyethylene) tends to be both durable and flexible. Plastic cling wrap, sandwich bags, squeezable bottles, and plastic grocery bags all are made from LDPE. Recycled LDPE is used to make garbage cans, lumber, furniture, and many other products seen in and around the house [30]. The Figure 2.5 below depicted LDPE (Low Density Polyethylene) class of plastic.

Figure 2.5 LDPE (Low Density Polyethylene) [30].

E). Polypropylene

Polypropylene is one of the best and safest types of plastic, suitable for cold and hot liquids and other products. It is not harmful, used in manufacturing of food containers, plates, medicine bottles and all food related products. It is recommended that all food containers should be made of this substance, especially children's food containers used for school meal packaging, and water bottles reused for multiple times [21]. PP (Polypropylene) is strong and can usually withstand higher temperatures. Among many other products, it is used to make plastic diapers, Tupperware, prescription bottles, and some stadium cups. Plastic bottle caps often are made from PP as well. Recycled PP is used to make ice scrapers, rakes, battery cables, and similar items that need to be durable [30]. The Figures 2.6 below represent PP (Polypropylene) types of plastic.

Figure2.6 PP (Polypropylene) [30].

F). Polystyren

Polystyren is dangerous and unsafe, used for burger, hotdog and teacups packaging. It looks like the cork and was being used in the international fast food chains in our region until recently, although the USA has prohibited the use of it for 20 years. MacDonald's also has stopped using it since 1980, so let us be cautious of this material that is still being used here in fast food and popular restaurants. This material has impact on the ozone layer because it is made of harmful Chloro Floro Carbon gas (CFC) [21]. Recycled Polystyrene (PS) is used to make many different kinds of products, including insulation, license plate frames, and rulers [30]. The figure 2.7 below depicted PS (Polystyrene) class of plastic.

Figure 2.7 PS (Polystyrene) [28].

G). PC and Others

Such material does not come under any category of the above mentioned types of plastic. It can be mixture or compound of the six international companies started to produce toys and baby-feeding bottles made of it [21]. PC and Other (Polycarbonate and Other Recycled Plastic) are products produced from polycarbonate include sports equipment, medical and dental devices, CDs, DVDs, and even [30]. The Figure 2.8 below shows Polycarbonate and other recycled plastic.

Figure 2.8 PC and Other (Polycarbonate and Other Recycled Plastic) [30]

The word plastic is derived from the greek (plastikos) meaning capable of being shaped or molded. Plastic those are made up of polymers having only aliphatic (linear) C atoms in their backbone chains. e.g.: poly propylene. Plastics that are made up of heterochain polymers contain O, N, and S in their backbone chains, in addition to C. e.g.: poly carbonate. Plastic behaviour of polymers is influenced by their morphology (arrangement of molecules).they are either amorphous or crystalline. Most thermosets are amorphous, while thermoplastics may be amorphous or semi crystalline. Plastics are a range of synthetic or semi-synthetic polymerization products that can be molded into a permanent object having the property of plasticity. Plastic are found extensive industrial applications. Plastics having a variety of properties are available at present. They have low specific gravities, ease of fabrication, resistance to low thermal and electrical conductivities. Many plastics can take range of colour to enable them useful for decorative purposes. Plastics are widely used in making electical instruments, telephones, panelling for walls, instrument boards, automoblile parts, lamps, googles, optical instruments, household appliances and so on [21].

Waste plastic bottles that used in this study were obtained from waste PET bottles. In order to, provide appropriate plastic particles the bottles were cut to small parts then crushed and sieved. The particles which were smaller than 2.36 mm were considered for this investigation. It should be noticed that different percentages of crushed plastic bottled were designated for this study namely: 0%, 0.2%, 0.4%, 0.6%, 0.8% and 1 % by weight of aggregate particles [3].

The production rate of plastic is getting increased day by day in all parts of the world since past few decades. Due to the tremendous growth in population, consumerism, industrialization and technological development, there has been a rapid increase in the rate of the production of plastic which is a toxic persistent material [31]. Addis Ababa, the capital city of Ethiopia suffers from poor solid waste management. The inadequate solid waste management system has rendered development, lessened the aesthetic beauty of the city and most importantly endangered the lives of the people. Regard-less of the harmfulness of the waste, solid waste management has not been given the amount of attention it requires. The insufficient management and lack of attention to the matter can be observed from the unbearable litter in the rivers, drains and streets in Addis Ababa. It is obvious that immediate action is needed in the solid waste management sector [32].

The daily SW generation rate of Sodo town for low-income, middle and high-income was 28 kg/capita/day, 0.38 kg/capita/day 0.76 kg/capita/day, respectively. This indicates that the waste generation rate of higher income was about 2.7 times higher than lower income. The average SW generated in Sodo town is estimated to be 0.47 kg/capita/day; 14.2 Kg/capita/month 170.4Kg/capita/year. This generation rate is higher when compared with study findings of comparable major Ethiopian towns [33].

Hot stone aggregate (150^{o}c) is mixed with hot bitumen (170^{o}c). The aggregate is chosen on the basis of its strength, porosity and moisture absorption capacity as per IS coding. The bitumen is chosen on the basis of its binding Property, Penetration value and visco-elastic property. The aggregate, when coated with plastics and rubber improved its quality with respect to voids, moisture absorption and soundness. The coating of plastic and rubber decreases the porosity and helps to improve the quality of the aggregate and its performance in the flexible pavement [34].

Marshall Properties such as stability, flow value, unit weight, air voids were used to determine optimum polythene content for the given grade of bitumen. Thermo gravimetric analysis has shown that there is no gas evolution in the temperature range of 130-180°C. Moreover the softened plastics have a binding property [9]. Here waste plastic/polymer was used as modifiers added on the aggregate before mixing Optimum Binder Content (OBC) in dry process at 150-160^{0}C temperature which increases the bonding between aggregates coated with plastic/polymer which increases the strength of the bituminous concrete mixes. Stability values and indirect tensile strength values were observed to be more in polymer modified bitumen than in conventional bitumen [14].

The mechanical properties obtained from the Marshall test are Marshall Stability and Flow value. Marshall Stability indicates the maximum load that a sample can carry when being tested at 60°C, and Marshall Flow is the deformation that a sample undergoes during loading until the maximum load is reached. An increase in the Marshall Stability value indicates an improvement in the stability of an asphalt mixture to resist shoving and rutting under heavy traffic load [35].

Optimum dose of HDPE in VG30 bitumen is between 0.2 to 0.4%. Using Marshall Method of mix design the optimum binder content and optimum plastic has been determined which is 5.66% and 0.6% respectively. It has been observed that addition of HDPE waste plastic into the conventional mix can enhance the stability of mixture with lesser flow value in comparison with conventional mix, up to a certain dose of HDPE. The existence of waste plastic and waste glass cullet in bituminous binder course mixture is considered as an eco-friendly material and sustainable management of these waste products in Pavement construction [36].

Table 2. 3 Properties of shredded plastic waste [9].

Properties Test Value	Properties Test Value	Properties Test Value
Initial Decomposition	TGA Curve	392°C
Melting Point	DSC	125°C
Plastic type	Grinded waste thin plastic packaging bags	
Plastic material	Low density Polyethylene (LDPE)	
Density (gm/cm3)	0.92	

2.3 Plastic as an aggregate

Recycled LDPE can substitute a portion between 15 and 30% of aggregates depending on its particle size [12].

Polymer material is coated over stone aggregate and this PCA is used as a raw material for pavement construction. Plastics waste like PE, PP and PS is coated over stone aggregate and the PCA is mixed with bitumen and the mix is used for flexible pavement construction. Higher percentage of plastic waste (10–15%) can be used without separation. Different waste plastics used for coating over the aggregate then PCA along with stone aggregate, next to this PCA mix with bitumen and Polymer coated bituminous road scrap. Most of the packing materials used are made up of PE, PP, PS. All these materials can be shredded and used for road construction. For the asphalt pavement, stone aggregate with specific characteristics is used for road laying. The waste plastics namely films, cups and foams shredded to the required size of 2.5–4.36 mm. The aggregate is heated to 170 ^{0}C. The shredded waste plastic was sprayed over the hot aggregate. Plastics got softened and coated over the aggregate. The extent of coating was varied by using different percentage of plastics. The shredded plastics on spraying over the hot aggregate get melted and spread over the aggregate giving a thin coating at the surface. When the aggregate temperature is around 140–160 ^{0}C the coated plastics remains in the softened state. Over this, hot bitumen (160 ^{0}C) is added. The added bitumen spreads over the aggregate. At this temperature both the coated plastics and bitumen are in the liquid state, capable of easy diffusion at the inter phase. This process is further helped by the increase in the contact area (increased surface area). In the construction of asphalt pavement, hot bitumen is coated over hot stone aggregate and rolled. Bitumen acts as a binder. Yet when water is stagnated, over road it penetrates and results in pot holes, a defective spot on the pavement. Use of plastic as virgin as well as waste to modify the bitumen and also the use of PCA are being studied to find better results for the better performance of the pavement [22].

Intending to minimize the dependence on the supply of stone aggregate, it has become essential to inspect the possible applications of alternative materials for the construction of roads as a substitute of stone aggregate [37].

Recycled waste plastics, predominantly composed of low density polyethylene (LDPE) in pellet form, were used in dense graded bituminous mixes to replace (by volume) a portion of the mineral aggregates of an equal size, i.e., 5.00.-2.36 mm. The origin of the plastic materials employed in the investigation was municipal waste (plastic bottles, plastic containers, washing-up liquid bottles, etc.) Based on the selected AC grading and the size of the waste plastic pellets, a maximum of 29.7% by weight of the total control mix was replaced with waste plastics. The main variable between the Plastiphalt and the control AC mix would therefore be the bulk density of the combined aggregate fractions. Laboratory design methodology and test results of a continuously graded bituminous composite Asphaltic concrete (AC) containing recycled plastics aggregate replacement is called (Plastiphalt). The test results were compared to those obtained from a control mix having a very similar gradation manufactured with conventional mineral aggregates. The potential for recyclability of the aged Plastiphalt mixes, containing recycled waste plastic was also investigated. Softer bitumen was selected for the Plastiphalt because early trials indicated that the mix was very strong and did not require the use of hard bitumen. This has added advantage that the mixing and compaction temperatures of the bituminous mix, which are controlled by the viscosity of the binder, can thus be lowered [24].

The use of XLPE waste as an aggregate in roller compacted concrete pavement (RCCP) mixes. XLPE waste as an aggregate with several volume percentages was utilized to replace the natural coarse aggregate of concrete mix. This replacement was conducted with 5%, 15%, 30% and 50% contents [25].

The objective of this research is to determine optimum quality and the effect of using recycled PET as partial fine aggregate replacement in modified asphalt mixture by determining the permanent deformation. The modified asphalt mixtures were produced from content concentrate of recycled PET pallet range between 5 and 25% of the weight of asphalt mixture with sieve size from 2.36mm to 1.18mm and 5% weight of bitumen content as follow hot mix asphalt wearing course 14 (ACW14) in Standard Specification of Road Work in Malaysia. It was tested to use waste plastic bags by conversion into recycled plastic waste aggregate (RPWA) in asphalt mixture. Then this asphalt modified mixture was developed using 20mm aggregation gradation. The 1200g / 3800g of aggregate containing RPWA in proportion from 0 to 15 percent by weight of total aggregate was used to produce Marshall Sample. RPWA can be added in asphalt mixture up to 2.5% by total weight of the aggregate (or up to 6% on volumetric basis). RPWA could be applied both in surface course and base course of pavement. This material substitute aggregate sieve size from 3.35mm to 14mm because their size is 2mm diameter. The experiments were start with develop control asphalt mixture. The optimum bitumen content of control asphalt mixture was determined from bitumen content ranges from 4 to 6% of weight of asphalt mixture. Then the bitumen and aggregate were compacted at temperature 150^0c with 75 blows each surface by Marshall Compactor. The palletized recycled PET was obtained from supplier with diameter of 2cm in transparent color and melting point is 248^0c. The performance of PET as aggregate replacement had been done in concrete technology. For example, Algeria has investigated the usage of PET as aggregate for concrete. The usage of waste PET granules pellet was experimented as a partial fine aggregate replacement in asphalt mixture. The size of this material is 3mm. The asphalt mixture was produced from 60/70 penetration grade bitumen and 12.5mm aggregate grading [26].

The plastic wastes that can be obtained in any household, such as milk pouches, water bottles, chocolate wrappers, plastic bags and so on, are collected and used as replacement for the fine aggregate in concrete. This has dual advantage which is use of waste in a non-destructive way and fulfillment of demands of concrete in large quantity without degrading natural resources like sand. The first step is collection of materials which include Plastic wastes such as, Milk pouches, Polythene bags, water bottles. We must make sure that there are no dirt particles on the plastics which are going to be used. Thus cleaning of the wastes must be done to avoid degradation. The collected items must be shredded to 4-5mm size. This can be achieved by the employment of a shredding machine. We for testing have cut plastic manually. Partial replacement of fine aggregate is done in different proportions such as 15%, 20%, 30%, 40% and 50 % [27].

Marshall Stability analysis was done on both non-modified and modified mixes. Three samples were prepared for each type of mix and the average stability value was considered for analysis [28].

Meanwhile, utilization of waste plastic bags in asphalt mixture around the world, especially in developed countries, has proved that these enhance the properties of mixture in addition to solving disposal problems including Polyethylene Terephthalate (PET), which is a type of plastic bottles in conventional life. Plastic waste is cleaned and cut into two types, i.e. fibrous and fine. The aggregate mix is heated and the plastic is effectively coated over the aggregate. This plastic waste coated aggregate is mixed with hot bitumen and the resulted mix is used for pavement construction. Before Marshall Test, all samples have to be placed in water bath for 40 minute at a temperature of 60^0C. Load is applied vertically at a rate of 50 mm per minute on the sample at 60^0C and specimen stability and flow value are recorded from the linear gauge and load cell. The Marshall stability of the mix is defined as the maximum load carried by the specimen at a standard test temperature of 60°C. The flow value is the deformation that corresponding to Marshall Stability [29].

2.4 Preparation of sample

The required quantities of course aggregates, fine aggregates & fillers were taken in an iron pan and kept in an oven at a temperature of 160°C for about 2 hours. The aggregates in pan were heated at 160°C for a few minute and then required amount of shredded polythene was weighed and added to aggregates and mixed for 2 minutes. Next, bitumen was added to mix and the whole mix was stirred for 15-20 minutes to make a proper uniform and homogenous mix. After that the mix was transferred to a casting mould and 75 numbers of blows were given each side of the sample hence making total 150 numbers of blows per sample. Then each sample was marked and kept separately [38]. The blending of recycled LDPE to asphalt mixtures required no modification to existing plant facilities or technology [12].

This PCA mix was then mixed with a known quantity of 80/100 bitumen. The mixture then transferred to the mold. It was compacted with 75 blows on either side. The specimens (64 mm height and 10.2 mm diameter) were prepared by, varying the percentage of plastics waste and by varying bitumen quantity. These specimens were tested [22]. Samples of 101.6 mm diameter and 63.5 mm height were prepared using moulds of 101.6 mm diameter and 76.2 mm height. For compaction of the samples, a compaction hammer of weight 4.53 kg and a free fall height of 457 mm were used and 75 compaction blows were given in both the sides of the cylindrical sample. Preliminary studies indicated that, for mixtures incorporating polypropylene fibers, the mixing temperature was less than 140^{0}C [37].

The experimental mixtures were manufactured at five different bitumen contents. The Leeds design method was then used to obtain the optimum bitumen content of the design mixture. At optimum bitumen content, further investigations and tests were carried out to fully characterize the properties of the design mixture. The mixing and compaction temperatures need to be carefully controlled to cater for the differing softening points of the two plastic types. At worse, with minimal temperature control, the plastics behave as inert aggregates contributing to the continuation of the mineral aggregate interlock. The Marshall test is an empirical test in which cylindrical compacted specimens, 100 mm diameter by approximately

63.5 mm high are immersed in water at 60°C for 30-40 min and then loaded to failure using curved steel loading plates along a diameter at a constant rate of compression of 51 mm/min. The LDM recommends that the optimum bitumen content for dense graded mixtures should be obtained as the arithmetic mean of the optimum bitumen content at maximum compacted mix density, minimum voids in the mineral aggregate (VMA), and maximum stability. The VMA is defined as the inter-granular void space between the aggregate particles in a compacted specimen and is expressed as a percentage of the bulk volume of the compacted specimen. The MQ (kN/mm) values are defined as the ratio of Marshall stability (kN) to flow (mm). At optimum bitumen content the compacted mix must possess adequate porosity, VFB, VMA, flow, and minimum air permeability [24].

The size of this material is 3mm. The asphalt mixture was produced from 60/70 penetration grade bitumen and 12.5mm aggregate grading. The aggregate and bitumen were mix between 140 and 180°C and then it was compacted using Marshall Hammer with 50 blows on each side [26].

That bottle is crushed and cut in two forms: fibrous type 30x1.5mm and fine type 1.5x1.5mm. For the first time, the HMA and SMA specimens were prepared at 6.0% of the asphalt binder and PET for weight of aggregate. But the specimens are not good in terms of Marshall Stability. Then the percent of asphalt binder and PET was decreased for the second experiment. For the second experiment, only HMA gradation is used. In this time, there are two set of specimen such as: (1) 5% and 5.5% of asphalt and PET (by weight of aggregate); (2) 5% and 5.5% of asphalt without PET. Before mixing, asphalt binder and aggregate were heated at 155ºC during 1.5 hours and 6 hours, respectively. After heating aggregate and asphalt, PET plastic is poured and mixed into aggregates firstly. Then asphalt binder was blended into mixture of aggregates and PET. The specimens were conducted by Marshall Compactor Machine at 150˚C, and 75 blows of compaction were applied on each side of specimens. Many fibrous type of PET exist after compaction, but the fine type of PET are blended with asphalt that cannot be seen [29].

2.5 Tests to be conducted and Findings of previous studies

It is observed that Marshall Stability value increases with polythene content up to 4% and then decreases. The addition of polythene decreases the Marshall Flow value. This shows the resistance to deformation under heavy wheel loads keeping the value of parameter like VMA, VA, VFB is within required specification. In India where temperature rises up to 50°C, this adversely affects the life of pavement. In the modification process plastic waste is coated over aggregate which increase the surface area of contact and ensure better bonding between aggregate and bitumen [38].

With an increase in binder content, VFB value is increasing. Also as the proportion of plastic increase the VFB value increase as compared to that of the conventional mix. The bulk density of the mix is increasing with increase in binder content up to a certain binder content which is OBC and then its starts decreasing. The values of bulk density are decreasing with increase in waste plastic content. With Increase in binder content, air voids are decreasing but the value decreases with increase in plastic waste content. With an increase in binder content, VMA is also increasing. With Addition of plastic, VMA values are increasing to that of convention mix. Flow value increases as an increase in binder content but with the addition of plastic waste, its values are less than that of conventional values. Its value is increasing with the addition of plastic content [1].

An asphalt paving mixture is a multiphase composite material that consists of an asphalt binder, coarse aggregate, fine aggregate, mineral filler, and other additives. The behavior of an asphalt mixture is highly related to the volumetric fractions and space distribution of these components. Air void is one of the most important volumetric properties of an asphalt mixture that affects the mixture's stability and durability. An asphalt mixture with lower than optimum air voids may cause rutting due to plastic flow, whereas higher air voids can result in premature cracking or raveling due to moistures and oxidation [39].

By using Marshall Stability and Flow test, the result shows that the aggregate replacement of 20% fine aggregate (2.36-4.75mm) by volume with PET granulates (5% total weight of the asphalt mixture) was the effective use to get the highest Marshall Quotient with the lowest flow and the highest of stability. The usage of waste PET granules pellet was conducted as a partial fine aggregate replacement in asphalt mixture. The 80/100 penetration grade bitumen, crushed granite, Portland cement (as mineral filler) and the waste PET were used in their project. The percentage of the added PET in this research was from 0 to 10% by weight of bitumen. The size of this material is 3mm [40].

Marshall Stability value is the basic study on the stability of the mix with application of load. The aggregate mix was coated with plastics waste. This PCA mix was then mixed with a known quantity of 80/100 bitumen. The mixture then transferred to the mold. It was compacted with 75 blows on either side. The voids present in the mix also play an important role in deciding the performance of the mix as pavement. The Marshall Mix block was subjected to different types of tests to find out, Voids filled with Mineral Aggregate, Air Voids, Voids filled with bitumen, Bulk Density, Specific Gravity and Voids in Mix. Marshal Stability Value is indicative of load withstanding property of the flexible pavement [22].

The Marshall test is used widely throughout the world to determine the stability and flow characteristics of bituminous mixes. In this method, the resistance to plastic deformation of a compacted cylindrical specimen of bituminous mixture is measured when the specimen is loaded diametrically till its failure [29].

Similar to tyre rubber, recycled plastics can either replace a portion of aggregates, or serve as a binder modifier. DBM with recycled plastics, mainly low density polyethylene (LDPE) replacing 30% of 2.36–5mm aggregates, reduced the mix density by 16% and showed a 250% increase in Marshall Stability in the ‘Plastiphalt’ mixtures. Recycled LDPE of a size between 0.30 and 0.92mm replacing 15% aggregates in asphalt surfacing nearly doubled the Marshall quotient, and increased the stability retained by 15%. Recycled PE accounting for 8% of the binder as a bitumen modifier, can also increase the mixture’s Marshall Stability [12].

Recycled plastics (PE film) used at 0.4% of mixture weight (about 8% of binder weight) as bitumen modifier, increased the Marshall Stability before and after water logging (60^{0}C, 24 h) by 3.3 and 2.6 times, respectively. It was found that there is significant improvement in the strength properties of the plain aggregate with coating of polymers. This is due to the fact that when the polymer was coated over the aggregate, the aggregate surface is covered with the thin film of polymer. This coating is non-wetting thus preventing the wetting of aggregate when exposed to water and moisture. The film of polymer also fills the pores at the surface and there is no water absorption. The performance of plastic tar road conclusively proves that it is good for heavy traffic due to better binding, increased strength and better surface condition for a prolonged period of exposure to variation in climatic changes. Above all, the process helps to dispose waste plastics usefully and easily. There are so many advantages including increase the strength and performance of the road, avoid the use of anti- stripping agents, reduce the cost to around Rs. 30,000/km of single lane road as on date, carry the process in situ, avoid industrial involvement, avoid disposal of plastics waste by incineration and land filling, generate jobs for rag pickers, add value to plastics waste and develop a technology, which is eco-friendly. Waste plastics, littered both by domestic and industrial sectors was found to be a source of raw material for the flexible pavement. Waste plastics, mainly used for packing are made up of PE, PP and PS, their softening point varies between 110^0C and 140^0C and they do not produce any toxic gases during softening. But the softened plastics have a tendency to form a film like structure over the aggregate, when it is sprayed over the hot aggregate at 160^0C. The formed PCA is a better raw material for the construction of flexible pavement. PCA was then mixed with hot bitumen of different types and the mixes were used for road construction. PCA + bitumen mix showed improved binding property and poor wetting property. The sample showed higher Marshall Stability value in the range of 18–20 kN and the load bearing capacity of the road is increased by 100% and there is no pothole formation. The roads laid since 2002 using PCA + bitumen mixes are performing well. The performance of these roads shows that the PCA bitumen mix roads are performing well. For an effective asphalt pavement, the flow values should be in the range 2–5 and the ratio of MSV and FV (referred to as Marshall Quotient) should be not more than 500. The results obtained for the PCA are within this range. Voids filled with bitumen (VFB) are expected around 65% and the observed value is around 58%. The reduction is attributed to the reduction in the use of percentage of bitumen (90%) and the reduction in voids. The use of plastics waste coated aggregate; the quantity of bitumen needed for a good mix can be reduced by 0.5% of the total weight. This accounts for 10%

reduction in the quantity of bitumen needed to be used. It is a good saving of natural resource. Higher percentage of plastics (more than 15%) results in lesser compatibility with bitumen and lesser bonding resulting in lower MSV. The use of PP gives higher MSV value than PE. The foams of PP and PE also give better MSV results. The flow value and the voids filled with bitumen are within the tolerance value. It is observed that the values of the PCA bitumen mix are 50– 60% higher than that of the PMB mix, showing that the binding strength is higher in the case of PCA bitumen mix. When bitumen was mixed with PCA, the portion of bitumen diffuses through the plastic layer and binds with aggregate. The plastic layer has already bonded strongly with aggregate. During this process three dimensional internal cross linked network structure results between polymer molecules and bitumen constitutes. Therefore the bonding becomes stronger and the removal of bonded bitumen becomes difficult. Dry process showed that the bonding between stone aggregate and bitumen is improved due to the presence of polymers [22].

The unit weight of the fiber-reinforced specimens is lower than that of plain specimens and the volume of air voids increased with increase in the content of polypropylene fibers along with significant improvement in stability and flow values. They blended fibers with aggregates at the optimized dosage of bitumen rather than conventional procedures. The experimental results show that adding polypropylene fiber increases the Marshall stability by 26% and the air voids by 67% while reducing the flow properties by 38%. The polypropylene fibers were found to increase the Marshall Stability by almost 25% [37].

At the same air-void content, the compacted Plastiphalt mix has lower bulk density than that of the conventional control mix. A 30% aggregate replacement by volume with the LDPE, results in a reduction in bulk compacted mix density of 16%. This reduction in density is advantageous in terms of haulage costs. LDPE partial aggregate replacement also results in a 250% times increase in the Marshall Stability (strength) value and an improved Marshall Quotient value (resistance to deformation). The plastic pellets obtained were predominantly composed of LDPE of single size (5-2.36 mm). It was decided in this investigation to replace by volume the mineral aggregate fraction having the same size as the plastic pellets in the original AC mix with LDPE pellets. The aggregate gradation of the resultant Plastiphalt mix would therefore be very similar in terms of volumetric proportions to the original AC control mix. Plastiphalt mixes are much stronger than the control mix. This strength can be achieved because the Plastiphalt is mixed and compacted at the correct preselected temperatures. The flow value of the Plastiphalt mix is also higher than the control mix due to the more flexible plastic component of the mix. Although the stability value of the Plastiphalt mix at OBC may at first instance seem unrealistically high, it must be noted that recent advancements in bituminous mix design have created very high performance mixtures. Conventional dense graded mixes normally combine high stability with low flow values and hence high MQ values indicating a high stiffness mix with a greater ability to spread the applied load and resist creep deformation [24].

By using Marshall Stability and Flow test, the result shows that the aggregate replacement of 20% fine aggregate (2.36-4.75mm) by volume with PET granulates (5% total weight of the asphalt mixture) was the effective use to get the highest Marshall Quotient with the lowest flow and the highest of stability. The ACW14 recommends that the optimum bitumen content should be obtain range 3 to 5% air void, 65 to 78% void filled with bitumen and 14 to 15% void mineral aggregate (VMA). It was tested to use waste plastic bags by conversion into recycled plastic waste aggregate (RPWA) in asphalt mixture. RPWA could be applied both in surface course and base course of pavement. The optimum bitumen content of control asphalt mixture was determined from bitumen content ranges from 4 to 6 by Marshall Compactor. All the results are obtained from an average of three test samples. The result indicates that the optimum bitumen content of control sample is 5% of mass of asphalt mixture. The lab testing reveals the maximum permanent deformation at 20% replacement with recycled PET. In term of economic value, it shows that this recycled PET could reduce cost of road construction because this recycled material is cheaper [26].

Using of waste plastic and/or waste rubber in hot aggregate forms a coating around the aggregate. When these aggregates are mixed with bitumen, mixture is found to give higher strength, durability and better water proofing properties. This technique of utilizing solid waste improves the engineering properties of bituminous mixes and also helps in the development of eco-friendly pavements for future generation. Some of the major objectives of the study are to analyze the effect of plastic and rubber waste on Stability-Flow & Volumetric characteristics of Bituminous Concrete Mix and to develop binary and tertiary Bituminous Concrete mix having better engineering properties than Controlled Mix [28].

The more asphalt and PET content increase, the more the Marshall Stability decrease. With the same asphalt content, the samples without PET have Marshall Stability lower than ones using PET. Asphalt mixture with fine type is better than one with fibrous type in terms of Marshall Stability. As a result, PET mixtures are better than original mixture without PET.
When asphalt content of three mixtures increase, their flows also increase. Research concentrates on discovering change task in Marshall test index (Marshall Stability, flow index) with different PET content and contribute to decrease pollution of environment due to applying discarded plastic. Asphalt mixtures modified with PET are better than original mixture without using PET based on Marshall Stability and flow values. Fine PET mixture could be a promising material in comparing with fibrous PET in this study. For reinforced influence evaluation of PET in mix, a sample was conducted with experiments which define value of strength (Marshall Stability and flow). Test results show that using PET in asphalt mixture could be a promising material. As a result, finding a necessary replacement material with low cost is a challenge for researchers nowadays. PET is a type of thermoplastic, belongs to polyester family which is used in fibrous industry, water bottles, food and liquid. PET is also a waste material that exists in form of water and coke bottle. It was cleaned and cut into two forms such as fibrous type 30x1.5mm and 1.5x1.5mm that used in asphalt concrete [29].
The optimum bitumen content for the Plastiphalt mix was determined at 6.0%. The compacted densities of the Plastiphalt mixes were lower than that of the control mix. A 29.7% coarse aggregate replacement by volume with the lower specific gravity LDPE, results in a 16% reduction in bulk density of the compacted mix. The reduction in bulk compacted density is accompanied by a reduction in the VMA, which indicates a tighter, more dense aggregate skeleton. This result would give an advantage in terms of haulage costs. The

results show that the Plastiphalt mixes have superior Marshall Stability values compared to the control mix. A stability increase of nearly 2.5 times indicates that the Marshall Stability value of controlled mix (6% by weight of aggregate) is 9.06 kN, which satisfies the minimum stability requirement of BC mix. The maximum stability value was obtained for BM9 (84%B + 6%P + 10%R), followed by BM6 (90%B + 10%R) and BM3 (92%B + 8% P). The stability value of tertiary mix, BM9 (53%), binary mix, BM6 (45%) and BM3 (16%) is significantly higher than the non-modified mix. These results prove that modified binder mix having rubber and/or plastic wastes provides better stability as compared to conventional bituminous mix. Stability values obtained for almost all the modified mixes are better than non-modified mix. Flow value of bituminous mixes is found to be increasing in each series with an increase in percentage replacement by waste additives. Flow value of non-modified mix is 3.8 mm, while flow value of tertiary optimum modified mix, BM9 is 3.9 mm, which lies within specified limit of 2–4 mm. Flow value of optimum binary modified mix which mean BM3 (3.35 mm) and BM6 (3.7 mm) is also within specified limit. Exceptionally high flow values are observed for the mixes containing greater than 10% replacement of rubber content.

Bulk density of non-modified mix is 2.320 g/cc. In binary series A, the maximum value of bulk density was obtained around 2.362 g/cc (BM3) for 8% replacement of bitumen by waste plastic, while in series B, maximum value of bulk density was achieved around 2.328 g/cc (BM6) for 10% replacement of bitumen by waste rubber. In series C of tertiary mixes, maximum density obtained was found to be 2.331 g/cc (BM9) for 16% replacement of bitumen by combination of waste plastic (6%) and rubber (10%). All these values were found to be higher than the density of non-modified mix. Air voids in the non-modified BC mix were found to be 3.72%, which is well within the allowable limits. Overall air voids' percentage escalates with escalation in the partial replacement percentage of waste materials with bitumen in all modified mixes. This is due to variation in density of waste additives blended in BC design. Voids in mineral aggregate is found to be 12.07% in non-modified mix, which is well within the specified limits that depend upon nominal maximum size of aggregate and design air voids. Overall voids in mineral aggregate escalate with escalation in the partial replacement percentage of waste additives in all three modified mixes. Research findings of the study indicate that use of rubber tyres and waste plastic bottles improves the strength and overall durability of the BC mix by increasing its overall performance manifold. Therefore with application of these waste materials in the fixed proportions, targeted characteristics of BC can be achieved. Use of discarded waste materials like rubber tyres and discarded plastic bottles in bituminous concrete mix may aid in minimizing the construction cost of the roads. Moreover it may also contribute in preventing the environmental pollution caused by the dumping of such waste materials in ground [28].

2.6 Determination of Optimum Plastic Content

To determine the optimum fiber content, the average of the following three fiber content is taken: the fiber content corresponding to maximum stability values, the fiber content corresponding to maximum unit weight, the fiber content corresponding to the median of the percentage of air voids in the total mix. The addition of PP fibers to bituminous mixtures increased the Marshall Stability value, decreased the flow value a fiber content of 5.33%, a binder content of 4.83% provide good stability volumetric properties. The variation in stability and flow values improves the structural resistance of bituminous concrete to distresses occurring in flexible pavements [42]. The optimum modifier content which satisfied the criteria of having maximum Marshall Stability, maximum bulk density, minimum air-voids, and maximum VMA is 12 % by weight of bitumen, polyethylene modified asphalt mixtures reduce permanent deformation, raise fatigue resistance and give better bond between the bitumen and the aggregates [43].

2.7 Determination of Optimum Bitumen Content

To determine optimum binder content, marshal specimens are prepared for bitumen content varying from 3.5-6.0% of the blended aggregates at an interval of 0.5%. The marshal stability value, flow value, unit weight and VFB are evaluated. Based on the graphs obtained, the optimum binder content is decided [41].

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Study Area

The administrative center of the Wolaita Zone of the Southern Nations, Nationalities, Peoples Region, it has a latitude longitude of 6°54′N 37°45′E with an elevation between 1,600 and 2,100 meters (5,200 6,900 feet) above sea level. Based on the 2007 Census conducted by the CSA, this town has a total population of 76,050, of whom 40,140 are men and 35,910 women. The majority of the inhabitants were Protestants, with 54.61% of the population reporting that belief, 38.43% practiced Ethiopian Orthodox Christianity, 4.76% were Muslim and 1.28% were Catholic. The 1994 national census reported this town had a total population of 36,287 of whom 18,863 were men and 17,424 were women.

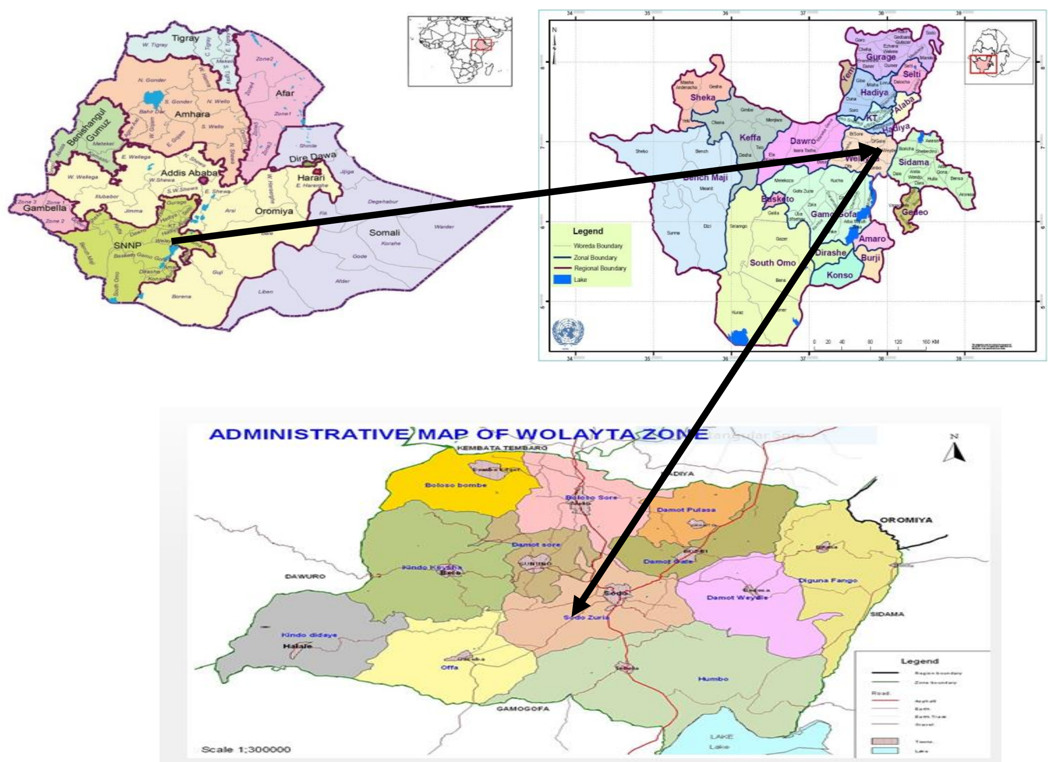

Figure 3.1 Study area

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3.2 Research Design

Experimental research was applied in this study area of the research; the required materials for this research work were collected such as waste plastic bottle, aggregate and bitumen. Testing of materials was held by the Hunan Huanda road and bridge Construction Company in order to check the materials (aggregate and bitumen) physical properties whether/not they fulfill the requirements as standard specifications. The mix was held through dry process since it is difficult to attain uniform mix in wet process.

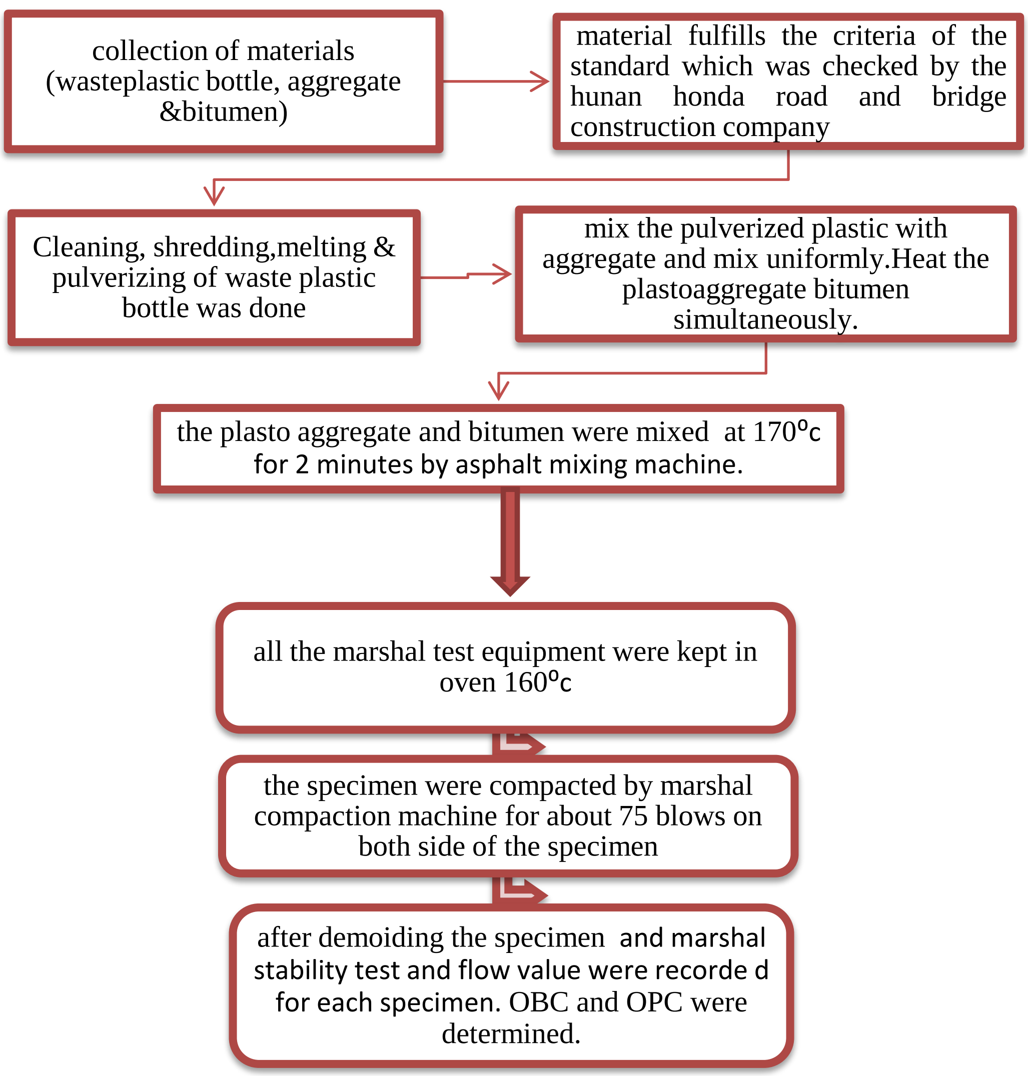

Figure 3.2 Research Design

3.3 Source of Data

The data were collected from two sources, those primary data were from the laboratory investigation and secondary data were gathered from literatures review of previous studies, books, journals, laboratory manuals and specifications of international and national standards such as (ASTM, AASHTO, ACRA and ERA).

3.4 Study Population

The study populations of this research were the waste plastic bottle and materials to be used to produce hot mix asphalt.

3.5 Sample Size and Sampling Technique

Sampling is perhaps the most important step in assuring that good quality aggregates are being used. Since a sample is just a small portion of the total material, the sample should be the representative of the material being delivered and should not be overemphasized. The total sample must be reduced to a sample size that can be quickly tested. Time did not allow for running the total sample. This method is called reducing the sample size (splitting sample).

The samples of aggregate were taken by purposive sampling technique from hot bin to study the effect of waste plastic bottle as partial replacement of aggregates as modifier on Hot Mix Asphalt concrete properties. The plastic bottles were highly available in everywhere in our surrounding environment and highly workable. Clean water bottles waste plastic were used to reduce the effect of the content during the sampling procedure of this research. The plastics bottles were added at different percentage by weight of aggregates. The required penetrations grade 60/70 bitumen's was selected based on climate zone of the study area and as per ASTM standard in order to determine physical characteristics.

For investigation of effects of waste plastic bottles on hot mix asphalt concrete properties, the required types of aggregates as specifications of engineering properties and the required penetration grade binder's properties were be selected and provided by the company. Finally the marshal stability tests and flow value were conducted; volumetric properties were computed to determine the OBC and OPC of hot mix asphalt concrete prepared by different percentages of waste plastic bottles added to the samples by weight of aggregates. For each percentages of waste plastic content three sample specimens were be prepared and the average of the three test result were taken.

3.6 Study Variables

There are both dependent and independent variables. The dependent variable is:

- ✓ The performance of HMA with plastic as partial replacement of aggregate.

Independent variables were the laboratory results of:

- ✓ Marshal stability
- ✓ flow value
- ✓ Volumetric properties of bituminous concrete mix.
- ✓ OBC
- ✓ OPC

3.7 Materials

The Components of bitumen concrete mixture were Bitumen, Aggregate mix (Coarse Aggregate & Fine Aggregate) and Modifier (waste plastic bottles) size. The volumetric properties of bituminous mixes prepared with varying amount of waste plastic bottle were computed, the marshal stability, flow value of plain bitumen and plastic modified bituminous mixes were compared.

3.7.1 Collection of Bitumen

Asphalt binder of required grade was selected according to the nature of environmental condition since there are many types of asphalt grade 40/50, 60/70, 80/100. For this study 60/70 penetration grade was used. The selected bitumen should fulfill the requirement requested by ASTM standard.

3.7.2 Collection of Aggregate

Aggregates either artificial or natural could be used. Aggregates can be further classified as coarse aggregates like crushed rocks, gravels, and fine aggregate. And also it could be from wastage from different industrial products. Coarse aggregate used for road construction should be hydrophobic to the bituminous surface. Other than this it should be hard, tough and durable. Sand should be well graded and free from organic matter, silt and clay. An aggregate which was collected from the hot bin of the company fulfilled the requirement requested by ASTM standards as tested by the company which made it desirable for road construction.

Figure 3. 3 preparing aggregate for the preparation of the specimen

3.7.3 Aggregate Gradation

Aggregate gradation analysis and the combining of aggregates to obtain the desired gradation are important steps in hot mix asphalt design. The aggregate gradations met the gradation requirements of the project specifications and yield a mix design that meets the criteria of the mix design method. To determining the proportion of aggregates to achieve a gradation within the specification limits, it was done so many trial and errors. It is desirable to initially plot the sieve analysis for all aggregate to be used. The aggregates gradation curve used for this study is found to be satisfying the ERA standard technical specification (2002, 6400/8.)The following procedures were followed to determine the gradation curve:

- After drying all aggregate samples to a constant weight at 105^{0}c to 110^{0}c. Separate pans were used for each aggregate sample.
- Washed sieve analyses were performed on representative samples including filler from each aggregate source.
- After computing a blend of aggregate to produce the desired mix gradation. A starting point for preliminary mix design were an aggregate gradation that approaches the median of the specification limits.
- After separating each dried aggregate into fractions (sizes) based on washed sieve analysis, size separation were done depending on the amount of material in each for a

specific aggregate and fraction were combined in to five parts such as 10-20mm, 5-10mm, 3-5mm, 0-3mm and filler.

- Blend proportion were computed and batch weight of the sized aggregates and filler required to produce batch mixes of the desired gradation were determined. For a matter of practical convenience the same weight of for each batch in trial mixes were used. After so many trial and errors, the blend proportion of 36%, 8%, 14%, 37% and 5% were used for combined aggregate of 10-20mm, 5-10mm, 3-5mm, 0-3mm and filler respectively. Then after combined aggregate were computed by using the blend proportion determined and it was fall within range of specification.
- Mix design test specimens were prepared.

3.7.4 Cleaning, Shredding, Melting and Pulverizing of Waste Plastic Bottles

Waste plastic bottles were collected from surrounding environments such as solid waste disposal sites, streets, market areas, hotels, roads, garbage trucks, temporary solid waste storage tanker and from public and non-public meeting halls and so on. It is abundantly accessible in everywhere since we use it in our day to day activity. The collected plastic bottles were washed because it should be free from dust and was cut to small parts less than or equal to 9mm using scissors. Then small pieces of plastic were melted at 180^0c for 30 minutes in oven. Then the melted plastic was cooled down and became solid which was finally pulverized using hammer. Pulverized waste plastic bottle was used in different percentages for the laboratory experiments 0%, 4%, 6%, 8% and10% by weight of aggregate particles. The figure 3.4 below depict that how to prepare the plastic bottles.

Figure 3. 4 Preparation of Plastic Bottles

3.7.5 Preparation of Plastoaggregate

Plastoaggregate mean that the plastic coated aggregate. The pulverized plastic was weighed and added over the aggregate in powder form less than or equal to 2.36mm and thoroughly mixed to form uniform distribution of plastic over the whole aggregate and then heated at 160^0c for two hours. This gives uniform distribution of plastic over aggregates as plastic gets soften and form a coat around aggregate. The resultant coated aggregate was mixed with hot bitumen of 60/70 grade bitumen which was also heated at 160^0c.

3.7.6 Plastoaggregate Bitumen Mix

Both Plastoaggregate and bitumen at heat state were mixed at 170^0c by automatic mixing machine which was adjusted for two minutes. The plastoaggregate remains in the softening state and bitumen was also at heat state was added which mean that both plastic and the bitumen are in a liquid state which enables easy diffusion. This increases the surface area of contact which helps the interaction process. As soon as bitumen is added to plastic coated aggregate a quantity of bitumen diffuses through plastic layer causing its bonding with aggregate. The aggregate is already bonded with plastic. This results in strong bond between polymers of plastic, aggregate and bitumen, which was very difficult to break as we see the marshal test result and volumetric properties.

3.7.7 Preparation of the conventional mix (without plastics) and marshal tests

- Aggregate of each percentage from 96% - 94% by 0.5 decrement from total the weight of the sample from each sieve sizes were measured according to the blend ratio. The required weight of aggregate was heated at temperature of 160^0c for two hours and filler was heated on separate pan for only 30 minutes because it became burnt if it were burnt together with the whole aggregate together.
- The compaction mould assembly and hammer were pre-heated at 160 ^{0}c.
- Bitumen of 60/70 penetration grade was heated at 160^0c and it was added in to the aggregate at the appropriate percentage.
- Aggregate mixture at heat state and the bitumen at heat state were transferred to mixing chamber adjusted at a temperature of 170°C for 120 seconds (2 minutes).
- Lastly the heated aggregate and bitumen was filled in casting mold which was heated in the oven up to 160°C and the casting mold was taken to marshal compaction

machine at a temperature of 140-150°C (compaction temperature) which was adjusted to 75 numbers of blows were given on each sides of the sample.

- Each sample was marked and kept separately for each percentages of bitumen (4%, 4.5%, 5%, 5.5% and 6%) and for each percentage of bitumen; three samples were prepared. After de molding the specimen and putting it in to water bath adjusted to a temperature of 60^0c for 30 minutes; the marshal test were done. Thickness should be 63.5mm otherwise correction factor should be applied for the measured marshal stability. Hence the average test values of three samples were taken. After determining weight of specimen in air, SSD and in water, the volumes of the samples were determined. Bulk specific gravity and maximum theoretical density, bitumen volume, different volumetric properties such as VA, VMA, VFA, were determined to decide the optimum bitumen content which was finally decided as 5.33 %.

Table 3.1 material used in conventional bitumen concrete mixes

specimen	% of aggregate content by total mix	% of bitumen content by total mix	Weight of bitumen (gm.)	Weight of aggregate (gm.)	Weight of total sample in (gm.)
A	96	4.0	50.00	1200.00	1250.00
B			50.00	1200.00	1250.00
C			50.00	1200.00	1250.00
A	95.5	4.5	56.25	1193.75	1250.00
B			56.25	1193.75	1250.00
C			56.25	1193.75	1250.00
A	95	5.0	62.50	1187.50	1250.00
B			62.50	1187.50	1250.00
C			62.50	1187.50	1250.00
A	94.5	5.5	68.75	1181.25	1250.00
B			68.75	1181.25	1250.00
C			68.75	1181.25	1250.00
A	94	6.0	75.00	1175.00	1250.00
B			75.00	1175.00	1250.00
C			75.00	1175.00	1250.00

3.7.8 Optimum bitumen content

The proportion of binder in the HMA is critical and is required to be accurately determined in the laboratory and then precisely controlled at the plant. The binder content for a particular

HMA is established by the mix design. The optimum binder content of the HMA is highly dependent on aggregate characteristics such as gradation and absorptiveness. Aggregate gradation is directly related to optimum binder content. The finer the HMA gradation, the larger the total surface area of the aggregate and the greater the amount of binder required to uniformly coats the aggregate particles. This is why surface HMA requires more binder than base HMA.

The absorptiveness (ability to absorb binder) of the aggregate used in the HMA is critical in determining optimum binder content. Enough binder is required to be added to the HMA to allow for absorption and also coat the particles with an adequate film. Total binder content and effective binder content are the terms normally used. Total binder content is the amount of the binder that is required to be added to the HMA to produce the desired HMA qualities. Effective binder content is the volume of binder not absorbed by the aggregate, which mean that the amount of binder that effectively forms a bonding film on the aggregate surfaces.

To determine optimum binder content, in this study there were marshal specimens for bitumen content of various percentages from 4-6% by 0.5 increment was established without plastic (conventional method). After marshal test (stability and flow value) were recorded and volumetric properties (VMA, VFA, VA, bulk density) was computed and evaluated. Lastly the optimum bitumen content was obtained as 5.33% by weight of total mix. This was obtained at an average of percentage of bitumen at the highest stability, high bulk density and air voids of 3-5%.

3.7.9 Mixing Procedure for plastic modified bitumen concrete mixes and Marshal Tests

a) Plastic waste bottles were cleaned and cut into a size between less than or equal to 9mm using scissor. Then it was melted in oven at 180°C for 30 minutes and after cooling it becomes solid. Then the solid plastic was pulverized in to small plastic aggregates $\geq$ 2.36mm. Finally the required percentage of pulverized plastic and aggregate was weighed and mixed to form uniform plastic aggregate mixture.

Figure 3. 5 Melting, Pulverizing, Adding and Mixing of Plastic Respectively

b) The plastic and aggregate mixture was taken by iron pan heated together at 160°C for two hour. During this time the plastic became liquid and becomes good binder to the aggregate. It gave an oily coat to the aggregate. Since the filler became burnt if it was heated for long time with the course aggregate; the filler was heated by separate pan for up to 30minutes. Simultaneously the 60/70 bitumen was heated at 160^0c, and then both the plastoaggregate mixture at heat state and the bitumen at heat state were transferred to mixing chamber. This is done so as to obtain a good binding and to prevent weak bonding. During this process the temperature is under control by using pocket thermometer which was mostly ranges between 140-150°C.

Figure 3. 6 plastoaggregate in oven, mixing machine and pocket thermometer

c) The plastoaggregate mixture and bitumen both at heat state were mixed in asphalt mixer adjusted at a temperature of 170°C for 120 seconds (2 minutes).

d) lastly the heated aggregate and bitumen was filled in casting mold which was heated in the oven up to 160°C and the casting mold was taken to marshal compaction machine which was adjusted to 75 numbers of blows were done on each sides of the sample and the compaction temperature was up 140-150°C then each sample was marked with white chalk and kept separately.

Figure 3.7 compacted modified specimen and automtic marshal compaction machine

e) Each sample was marked and kept separately for each percentages of plastic (0%, 4%, 6%, 8%, and 10%) by weight of aggregate and for each percentage of plastic, three samples were prepared. Hence the average test values of three samples were taken. After de molding the specimen and putting it in to water bath adjusted to a temperature of 60^0c for 30 minutes; the marshal test were done to determine both marshal stability and flow value. Thickness should be 63.5mm otherwise correction factor should be applied. After determining weight of specimen in air, SSD and in water, the volumes of the samples were determined. The volume of sample is calculated as weight of sample in SSD minus weight of sample in water. Bulk density (bulk specific gravity) of a sample is the ratio of weight of a sample in air to the corresponding volume of sample. Bulk specific gravity, maximum theoretical density, bitumen volume and different volumetric properties such as VA, VMA, VFA, were determined to decide the optimum plastic content which was finally decided as 5.33%.

Figure 3. 8 Measuring height, Specimen in Water Bath and Marshal Test Respectively

Table 3. 2 Material used for plastic bottle modified BC mixtures

specimen	% of plastic bottles	Wt. of plastic in bottle (gm)	Weight of aggregate (gm)	Weight of bitumen(gm)	Wt. of total sample in (gm.)
A	0	0	1200	66.63	1266.63
B		0	1200	66.63	1266.63
C		0	1200	66.63	1266.63
A	4	48	1152	66.63	1266.63
B		48	1152	66.63	1266.63
C		48	1152	66.63	1266.63
A	6	72	1128	66.63	1266.63
B		72	1128	66.63	1266.63
C		72	1128	66.63	1266.63
A	8	96	1104	66.63	1266.63
B		96	1104	66.63	1266.63
C		96	1104	66.63	1266.63
A	10	120	1080	66.63	1266.63
B		120	1080	66.63	1266.63
C		120	1080	66.63	1266.63

3.7.10 Optimum Plastic Content

Marshall Specimen with various percentage of waste plastic content by weight of aggregate was formed and marshal tested was done. Three samples were prepared for each percent of plastic and the average test result was taken. According to marshal test results and volumetric properties, the average plastic content at maximum stability, maximum bulk density and 3-5% air voids were considered as optimum waste plastic content which was finally selected as 4%. The maximum stability was obtained at 4% plastic which was 20.66 KN, maximum bulk density of (2.59gm/cm$^{3)}$ was obtained at 0% plastic because plastic bottle have less specific gravity than aggregate, and 3.25% air voids were obtained at 8 % plastic which was tolerable and within in ranges of specification limit. The optimum plastic content was selected at the average of (4%+0%+8%) = 4 % of plastic bottle.

CHAPTER FOUR

RESULT AND DISCUSSION

In this chapter the analysis of all laboratory results and discussions were included. The analyses were categorized in two divisions. The first one was analyzing marshal test result and volumetric properties of conventional (plain) BC mix to determine the optimum bitumen content (OBC). The second one was investigating the effects of replacing the aggregate with waste plastic bottle (PET/PETE) in modified BC mix was experimented and analyzed to determine the optimum plastic content (OPC).

In Hot Mix Asphalt, binder and aggregate are blended together in precise proportions. The relative proportions of these materials determine the physical properties of the HMA and ultimately how the HMA performs as a finished pavement.

In this investigation the Marshall tests such as stability, flow value were measured and volumetric properties such as bulk density, voids in mineral aggregate, voids filled with asphalts and air voids were computed to obtain optimum bitumen content on conventional asphalt mixture which was 5.33% after laboratory results. In similar manner it was done for modified asphalt concrete mixture to determine the optimum plastic content (OPC) which was finally selected as 4% by weight of aggregate.

4.1 Aggregate Gradation Curve for the Mix Design

Asphalt mix requires the combination of fine and course aggregates, having different gradations, to produce an aggregate blend that meets the gradation specifications for a particular asphalt mix.

All AASHTO sieve size were used, those are 25mm, 19mm, 13.2mm, 9.5mm, 4.75mm, 2.36mm, 1.18mm, 0.6mm, 0.3mm, 0.15mm, 0.075mm and filler. The Table 4.1 below shows that, the final proportion of each aggregate material in asphalt binder surfacing. The proposed aggregates gradation curve is found to be satisfying ERA standard technical specification (2002, 6400/8). All aggregate pass through the first sieve size two sieve sizes which mean that 100% pass and zero percent retained. After so many trial and errors, the blend proportion of 36%, 8%, 14%, 37% and 5% were used for combined aggregate of 10-20mm, 5-10mm, 3-

5mm, 0-3mm and filler respectively. Then after combined aggregate were computed by using the blend proportion determined and it was fall within range of specification.

Table 4. 1 percentage retained results after sieve analysis

Sieve size in (mm)	**% retained**	**Total aggregate weight (gm)**
26.5	0.0	0
19	0.0	0
13.2	17.3	208
9.5	16.5	198
4.75	9.5	114
2.36	13.9	166
1.18	11.4	137
0.6	10.2	122
0.3	7.9	95
0.15	4.0	48
0.075	4.3	51
Pan (filler)	5.08	61
Total	**100 %**	**1200 gm**

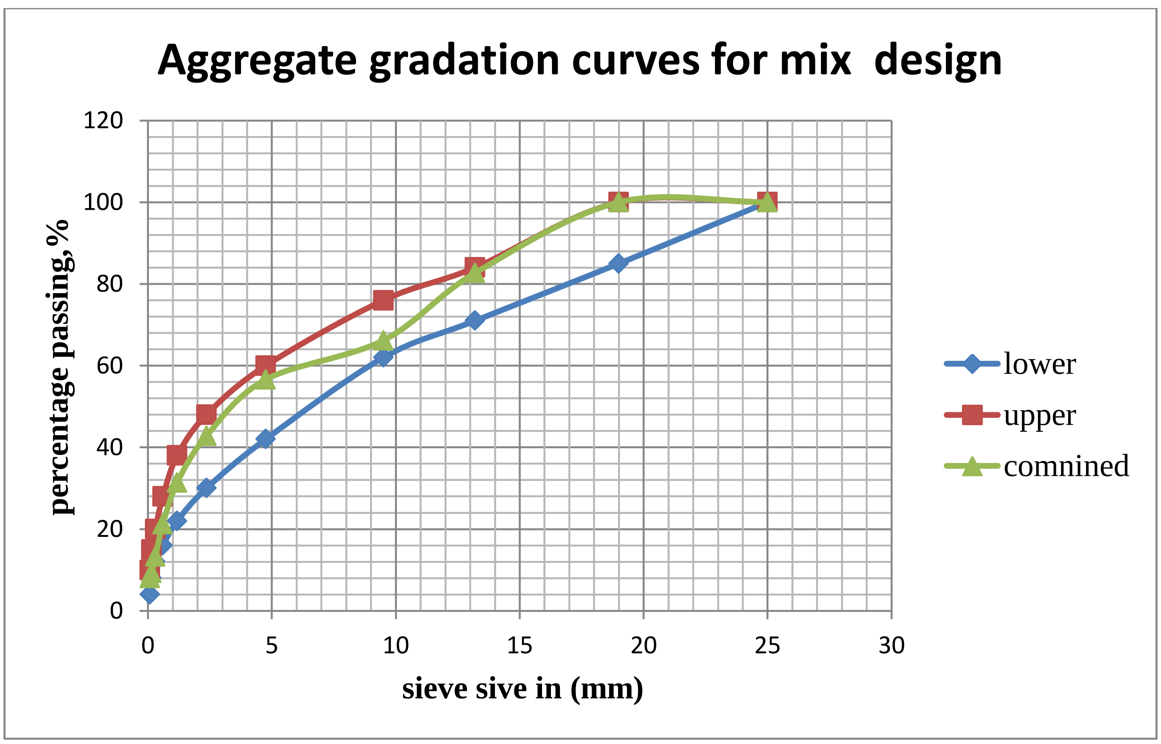

Figure 4. 1 Aggregate gradation curve for the mix design.

4.2 Marshal test results and volumetric properties of conventional BC mixes

4.2.1 Bulk density

As depicted in Table 4.2 below, bulk density increase with increase in bitumen content up to 5% and but further increase in bitumen content decreases bulk density. The maximum bulk density was attained at 5% of bitumen which was 2.51g/cm^3.

4.2.2 Marshal stability

As shown in Table 4.2 below, the asphalt mixture with bitumen content of 5% by weight of total mixture gave maximum stability of 20.03 KN and which fulfills the specification requirements of stability should be $\geq$ 9KN. The stability of mixture increased with increase in bitumen content up to 5% and then it was suddenly decreased after 5% of bitumen.

4.2.3 Flow Value

As represented in Table 4.2 below, the maximum flow value of bitumen concrete mixture was attained at 5.5% of bitumen content by total weight of mixture and it was recorded as 3.53mm and the minimum flow value was attained at 4% of bitumen as 2.41mm which was within specification limit. The specification requires flow value of 2mm-4mm.

4.2.4 Air voids

As rendered in Table 4.2 below, the percentage of air voids of BC mix decreased with increase in bitumen content up to 5.5% and then started increasing with increase in bitumen content. The nearest to minimum required air void of 4% was obtained at 6% of bitumen which was 3.84% which was within specification requirements of 3-5%.

4.2.5 Void Filled With Mineral Aggregates (VMA)

As shown in Table 4.2 below, VMA decreased with increase in bitumen content but it attains its peak VMA point at 6% of bitumen which was finally computed as 13.89% which fulfills the requirements of specification that states voids in mineral aggregate should be $\geq$13%.

4.2.6 Void Filled With Asphalt (VFA)

As depicted in Table 4.2 below, VFA increased continuously with increase in bitumen content. The VFA value of 72.77% at 4% of bitumen fails within range the range of specifications limit which is 65-75%.

4.2.7 Optimum Bitumen Content (OBC)

As represented in Fable 4.2 below, the optimum bitumen content was determined at the average percentage of bitumen content which fulfilled the criteria of maximum marshal stability, maximum bulk density, and minimum air voids, 20.03 at 5% bitumen, 2.51 at 5% bitumen and 3.84% at 6% respectively. The average of three percentage of bitumen (5%, 5% and 6%) was taken as OBC which was finally taken as 5.33%.

Table 4. 2 Marshal Test Results and Volumetric Properties of Conventional BC Mixes

% Bitumen (gm)	Stability(KN)	flow v.(mm)	VMA	VFA	VA	Bulk d.(gm/cm^3)
4.0	18.02	2.41	13.11	72.77	5.78	2.46
4.5	19.81	3.26	12.85	84.20	4.32	2.48
5.0	**20.03**	2.93	12.39	98.06	3.12	**2.51**
5.5	17.66	3.53	12.38	108.56	2.21	2.50
6.0	17.64	3.30	13.89	103.02	**3.84**	2.46

4.3 Marshal Test Results and Volumetric Properties Modified BC Mixes

As shown in Table 4.3 below, various percentages of plastic content (0%, 4%, 6%, 8% and 10%) by weight of aggregate was used to partially replace aggregates and the marshal test results of conventional asphalt mixtures mean that zero percentages of plastics compared with plastic modified one. Hot mix asphalt (HMA) with pulverized plastics bottles, when replacing 10% of aggregates, by plastic bottle reduced the mix density from 2.51 to 2.28, increased flow values from 2.93mm to 4.10mm, decreased the VFA from 98.06 to 49.46 and when 8% of aggregates was replaced by plastic bottle, increased the VMA from 12.39 to 22.32 when compared to the results of conventional mix. The marshal stability decreases as the percentages of plastic increases but maximum stability was obtained at 4% plastic (20.66KN) which was greater than the marshal stability of conventional one 20.03KN. The stability of BC mixture modified with PET decreased with increase in polyethylene content, but it attains maximum at 4% modifier content. The best thing is that the marshal stability results at any percentage replacement fulfills the specifications standards which requires $\geq$ 9KN. This tells that bitumen concrete mix with partial replacement of aggregate by plastic has maximum load carrying capacity at the standard test temperature of 60^0c.

The flow value of modified BC mixtures increased with increase in PET proportion by weight of aggregate in BC mixtures. Almost all percentage replacement fulfills the specification standards which require the flow value of 2mm-4mm. This implies that as the percentage of plastic increases, the resistance to deformations under heavy wheel loads increases. The percentage of air voids in BC mixtures decreased with increase in in PET bottles but the optimum air voids tolerable according to the standard, which requires percentage air voids of (3-5%) was attained at 8% of PET bottles by weight of aggregate which was as 3.25%. As conclusion the percentage of air voids of unmodified mixture was better than the PET modified bitumen because the plastic fills the void space even if still the air voids was tolerable. This has its own advantage in order to reduce the water absorption. The PET modified BC mixture with partial replacement of aggregate by PET gave the lowest bulk density than the conventional BC mixture. This has also its own advantage in order to reduce the hauling cost. The voids filled with mineral aggregate (VMA) increased with increase in proportion of PET bottles. Again surprisingly almost all percentage replacement of aggregate by plastic bottle attained the specifications requirements of VMA value $\geq$13%. The voids filled with asphalt decreased with increase in proportion of PET bottles as partial replacement of aggregates but 4% replacement of aggregate by plastic attained fails with in specification ranges of 65-75%.

Table 4. 3 Marshal Test Results and Volumetric Properties Plastic Bottle Modified BC Mixes

% plastic	Stability(KN)	flow v.(mm)	VMA	VFA	VA	Bulk d.
0	20.03	2.93	12.39	98.06	3.12	2.51
4	20.66	3.59	17.70	66.24	2.16	2.42
6	19.34	3.31	19.51	58.80	2.21	2.37
8	19.90	3.83	22.76	49.54	3.25	2.32
10	18.58	4.10	22.32	49.46	2.37	2.28

4.4 Percentage of plastic vs. stability

The Marshall Stability' of the bituminous mix is defined as maximum load carried (kg) at the standard test temperature of 60^{0}c.

Marshal stability (MS) value increases by using polymer coated aggregate; however, at higher plastic contents it decreases [5]. The asphalt mixture containing 4% recycled plastic and 1% recycled glass exhibit higher values of Marshall stability compared to the control sample, indicating that these asphalt mixtures have high load-withstanding strength [16]. It is observed that Marshall Stability value increases with polyethylene content up to 4% and thereafter decreases [31].

Reinforcing the previous study, maximum marshal stability value was obtained at 4% plastic, but as the whole the stability decrease as the proportion of aggregate increases which was shown in Figure 4.2.

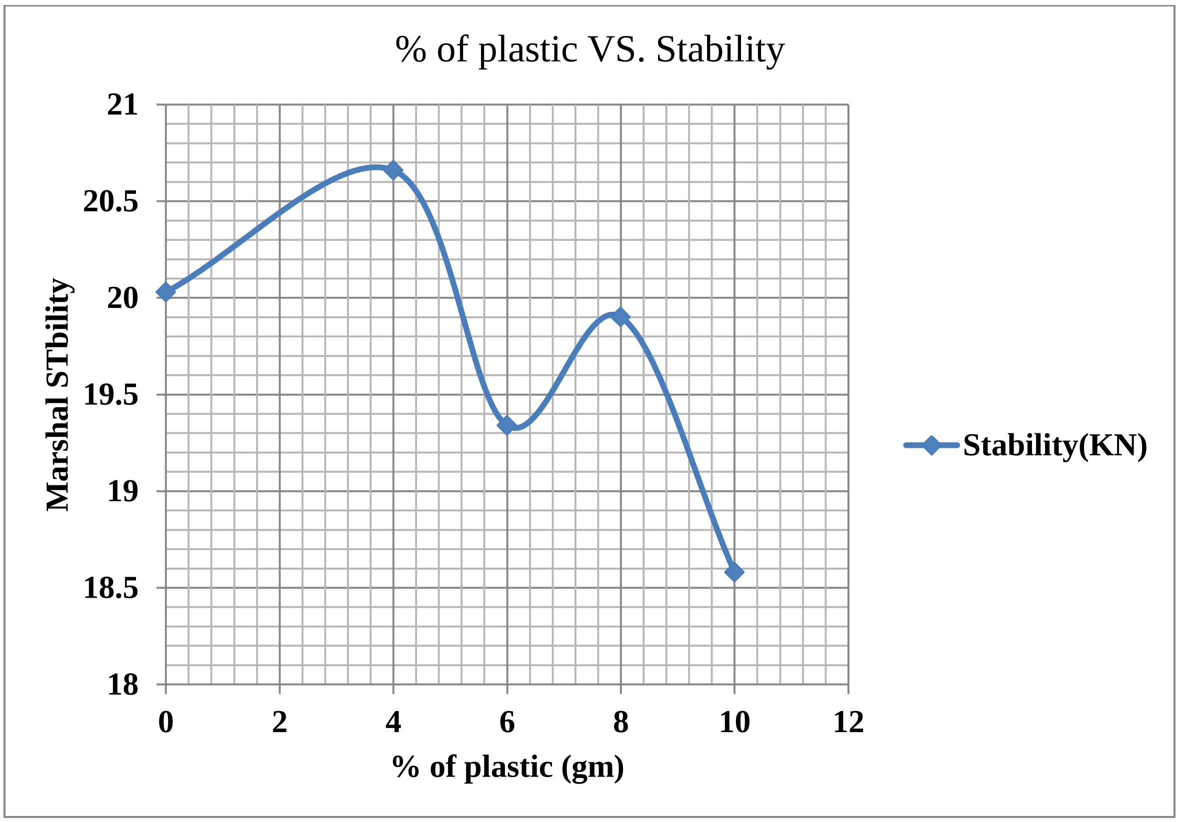

Figure 4. 2 Percentage of plastic vs. stability.

As depicted in Figure 4.3 below, the trend line decreases from upside down from left to right and negative slope which mean that the two variables (percentage of plastic and stability) have strong inverse relationship and according to the trend line for casted the value of stability still decreases as the percentages of plastic of increases. The r-squared value implies that there is somewhat strong linear relationship between stability values and percentage of plastic.

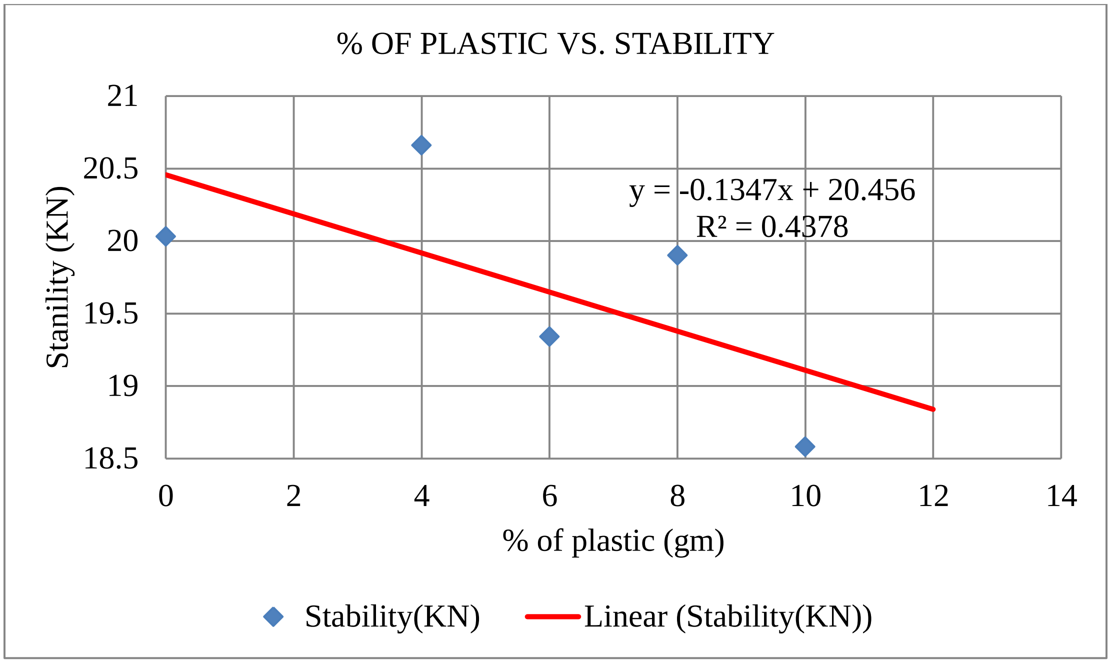

Figure 4. 3 Linear Regression Models for Stability and Percentage of Plastic.

4.5 Percentage of plastic vs. Flow values

Flow is the total amount of deformation which occurs at maximum load.

The Marshall Flow value decreases upon addition of polythene i.e. the resistance to deformations under heavy wheel loads increases [31]. With the addition of plastic waste, flow values are less than that of conventional values [1]. Flow value of bituminous mixes is found to be increasing in each series with an increase in percentage replacement by waste additives [28].

From Figure 4.4 depicted below, in contradiction to the above conclusion of [31] and confirming [28], marshal flow values increases continuously with the addition of plastic. And almost all the values falls under the specifications range 2mm-4mm.

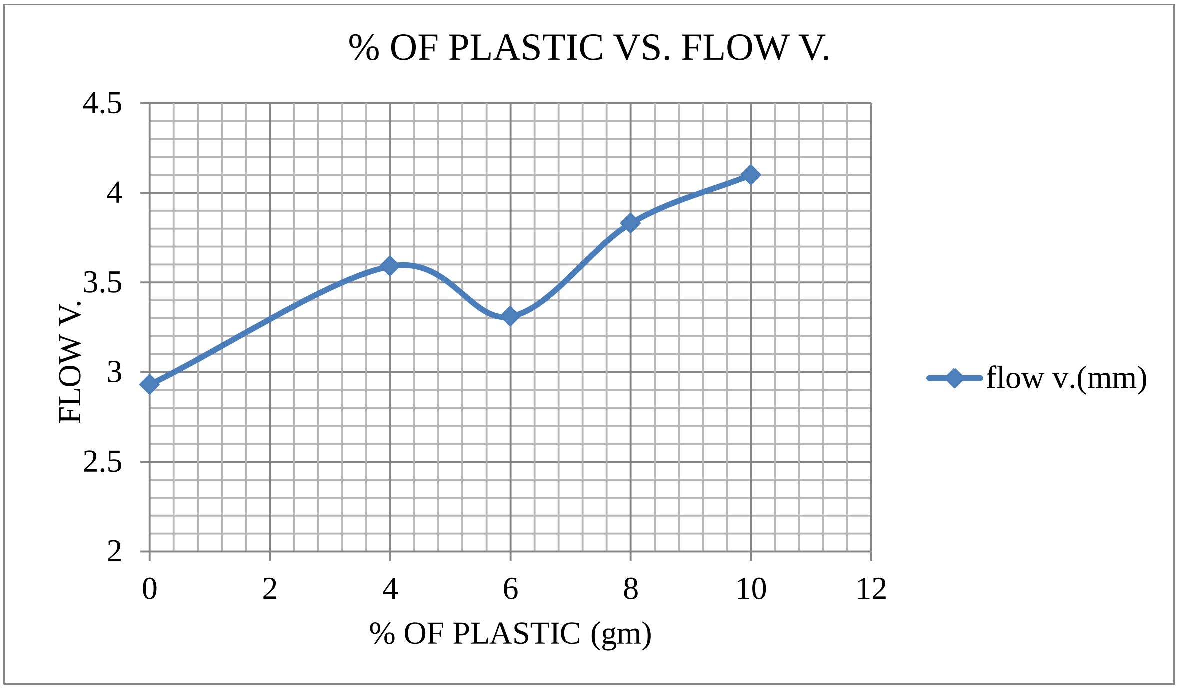

Figure 4. 4 Percentage of Plastic vs. Flow Value.

As portrayed in Figure 4.5 below, the marshal flow value and percentages of plastic have direct relationship which means that as the percentages of plastic increases the marshal flow values also increases. Since the trend line is up from left to right indicate that there is positive slope (direct relationship) between flow value and percentage of plastic. According to the trend line forecasted the value of flow values for the future increase of percentages of plastic it still increases. As the r-squared value is nearest to one, imply that there is strong linear correlation between flow value and percentage of plastic. Since the data points lay down near the trend line.

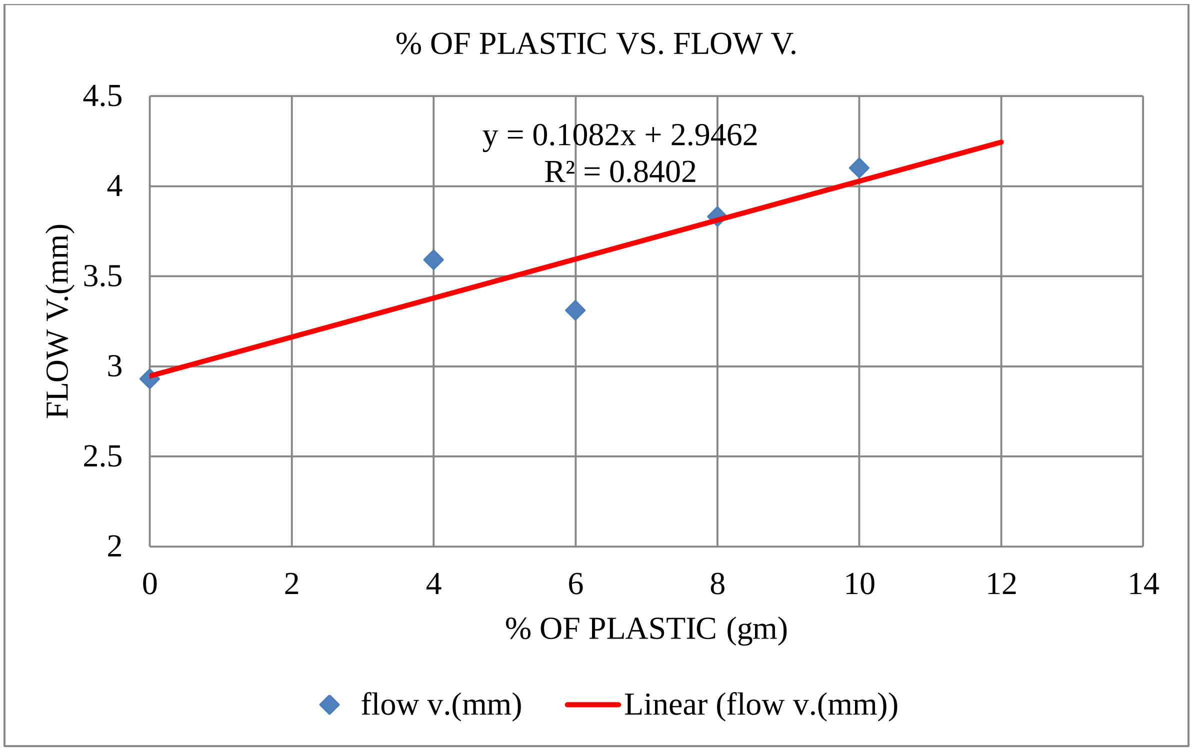

Figure 4. 5 Linear Regression Models for Flow Value and Percentage of Plastic.

4.6 Percentage of plastic vs. Voids filled with mineral aggregates (VMA)

It is the volume of inter-granular void space between the uncoated aggregate particles of a compacted paving mixture that includes the air voids and effective bitumen content. VMA is expressed as the percentage of the total volume of the compacted paving mixture. It is the void spaces that exist between the aggregate particles in the compacted paving HMA, including the space filled with the binder. VMA represents the space that is available to accommodate the effective volume of binder (i.e., all of the binder except the portion lost by absorption into the aggregate) and the volume of air voids necessary in the HMA. The more VMA in the dry aggregate, the more space is available for the binder.

With addition of plastic, VMA values are increasing to that of convention mix [1].

Depending on the Figure 4.6 below, confirming the previous study [1], the value of VMA increases as the percentages of plastic increases but further increment of amount of plastic decreases the value of VMA.

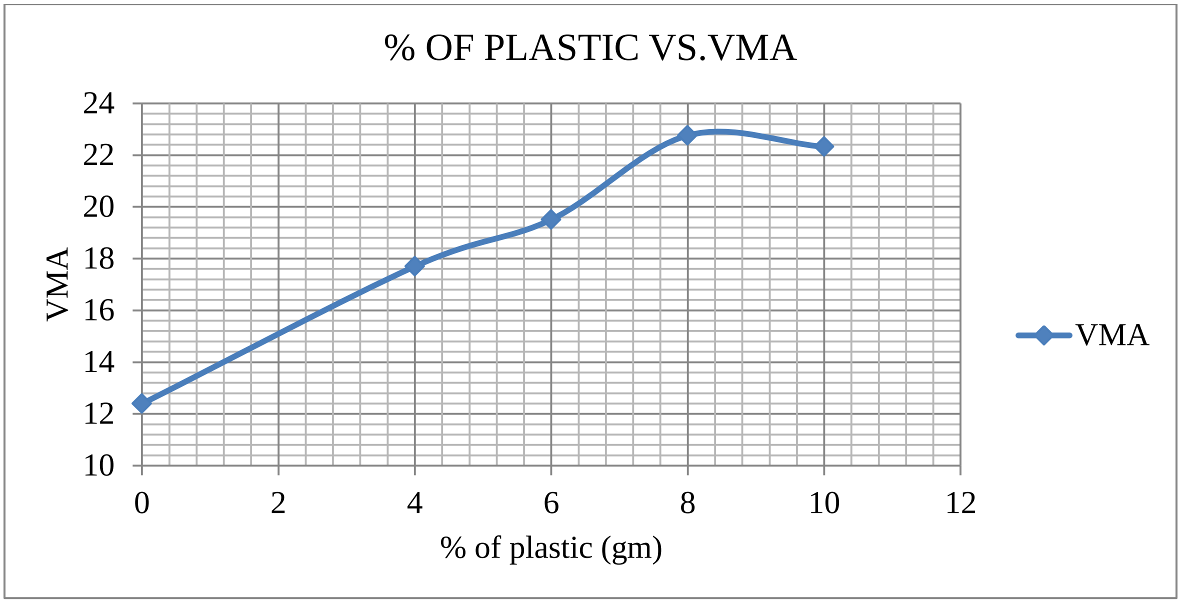

Figure 4. 6 Percentage of plastic Vs. VMA.

As shown in Figure 4..7 below, Since the trend line is up from left to the right (the positive slope) imply that there is direct relationship between the variables (percentages of plastics and VMA) which mean that as variable increases the other increases and the reverse is true. R–squared value (0.9451) which is nearest to one implies that there is strong linear correlation between voids in mineral aggregate and percentages of plastic.

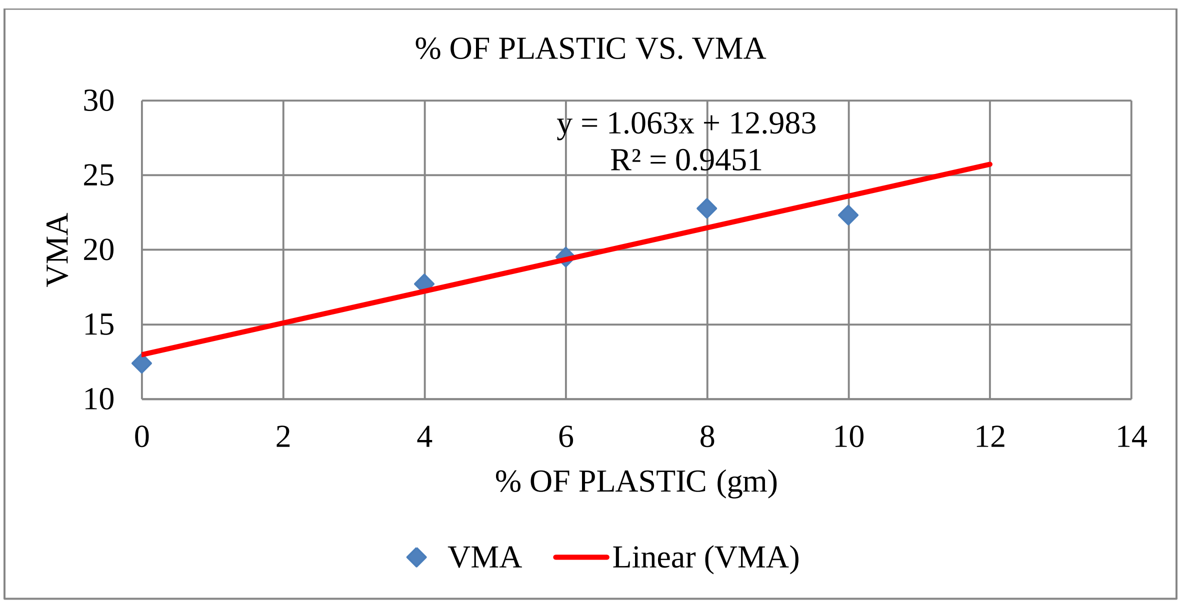

Figure 4. 7 Linear Regression Models for VMA and Percentage of Plastic.

4.7 Percentage of plastic vs. Air voids (VA)

In MS-2 VA is the total volume of small pockets of air between coated aggregate particles throughout a compacted paving mixture, expressed as the percentage of the total volume of the compacted paving mixture. A certain percentage of air voids (3-5%) is necessary in all dense-graded mixes to prevent the pavement from flushing, shoving, and rutting. It can be increased or decreased by lowering or raising the binder content or controlling the amount of material passing the No. 200 sieve such as baghouse dust in the HMA. Air voids may be changed by varying the aggregate gradation in the HMA.

Air voids are decreasing but the value decreases with increase in plastic waste content [1].

According to Figure 4.8 below, the percentage of air voids decreases as the percentage of plastic increases but for further increment in plastic air voids also increases and attains optimum air voids at 8% of plastic, which was 3.25% and fulfills the requirements of specification standard of 3%-5% air voids.

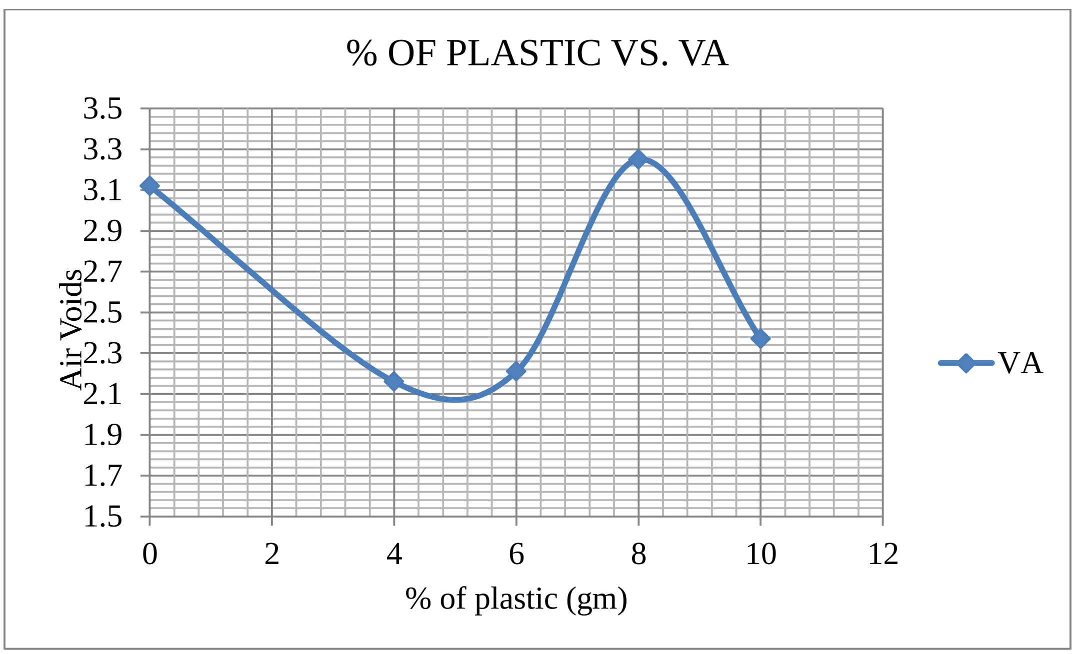

Figure 4. 8 Percentage of Plastic vs. Air Voids.

As rendered in Figure 4.9 below, the trend line in linear regression model is down from left to the right (the negative slope) to little extent imply that there is inverse relationship between the variables (percentages of plastics and VA) which mean that as one variable increases the other decreases and the reverse is true. R–squared value is near to zero (0.0512) implies that there is no linear correlation between percentage of air voids and percentages of plastic.

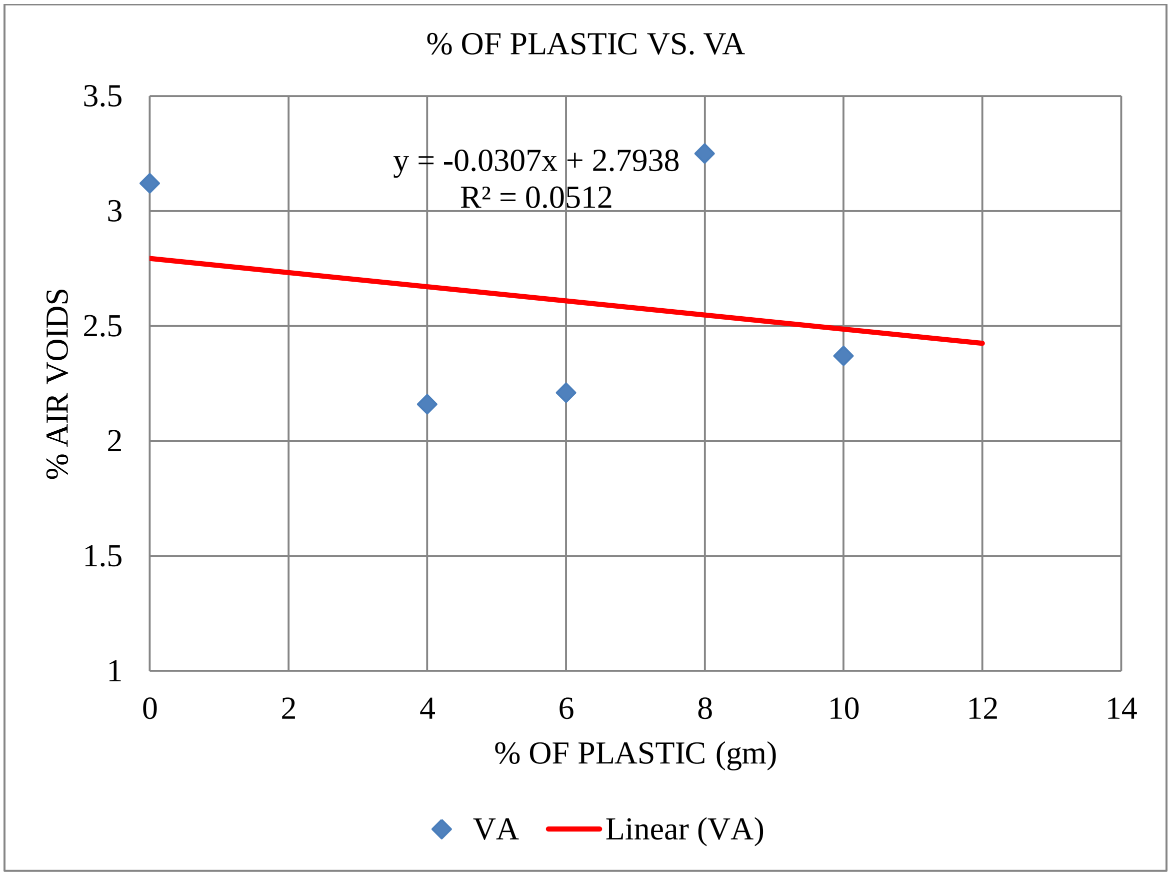

Figure 4. 9 Linear Regression Models for Air Voids and Percentage of Plastic.

4.8 Percentage of plastic vs. voids filled with asphalt (VFA)

In MS-2 VFA are defined as the void spaces that exist between the aggregate particles in the compacted paving HMA that are filled with binder. VFA is expressed as a percentage of the VMA that contains binder i.e., is the percentage of VMA that is occupied by the effective bitumen.

As the proportion of plastic increase the VFA value increase as compared to that of the conventional mix [1]. According to the Figure 4.10 below, contradicting to the previous study, the value of VFA decreases as the percentages of plastic increases and the reverse is true. i.e., the two variables (Percentage of plastic and voids filled with asphalt) inversely proportional. The VFA value of (66.24) at the 4 percent of plastic falls inside the standard specification ranges which is 65-75%.

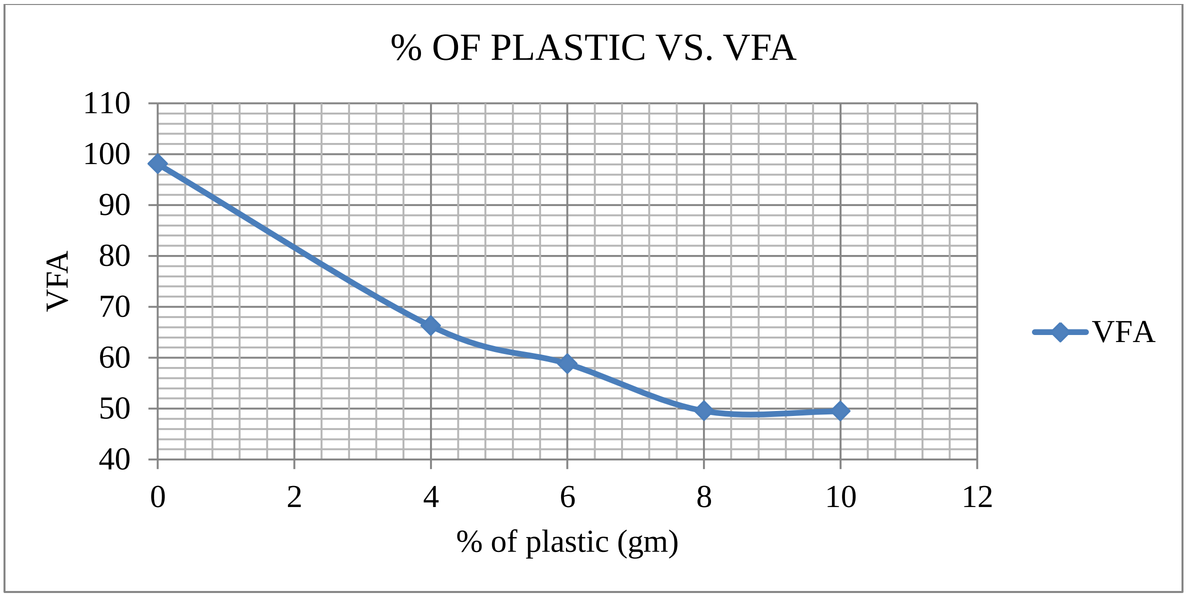

Figure 4. 10 Percentage of Plastic vs. VFA.

As portrayed in Figure 4.11 below, the trend line of linear regression model is down from left to the right (the negative slope) which implies that there is an inverse relationship between the variables (percentages of plastics and voids filled with asphalt) which mean that as one variable increases the other decreases and the reverse is true. R–squared value is almost equal to one (0.9126) implies that there is strong linear correlation between percentage of voids filled with asphalt and percentages of plastic.

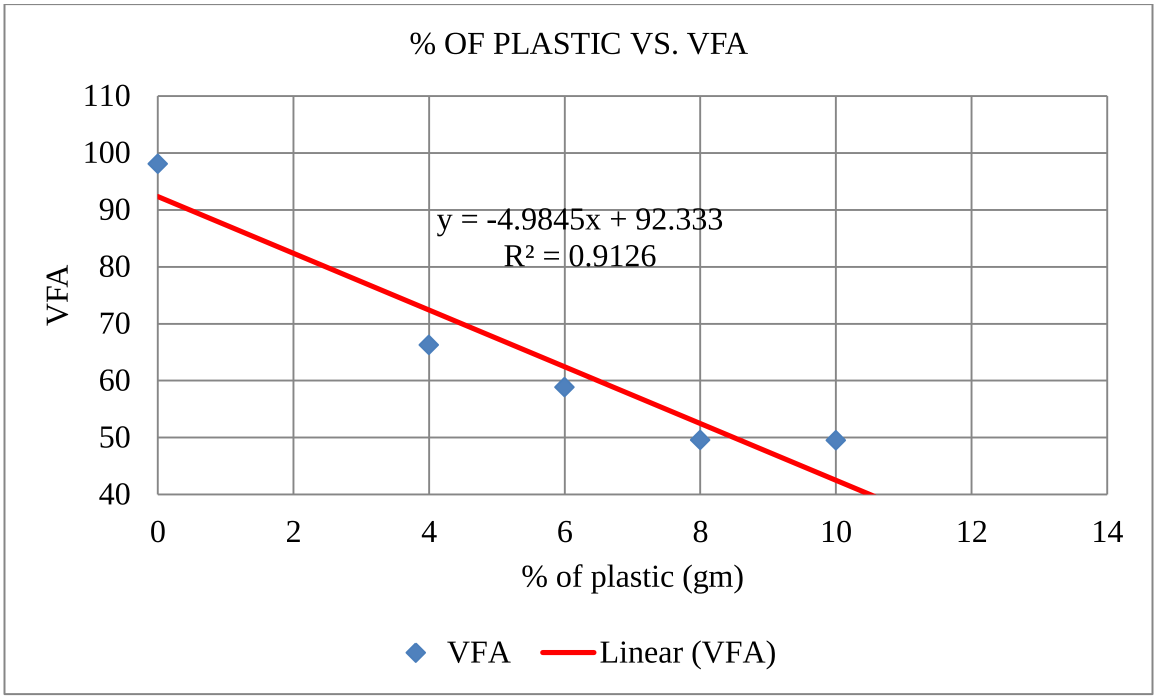

Figure 4.11 Linear Regression Models for VFA and Percentage of Plastic.

4.9 Percentage of plastic vs. Bulk Density

It is the ratio of weight in air of the specimen to the difference in weight of the specimen in air and water. The density of the compacted mix is the unit weight of the mixture (the weight of a specific volume of HMA). Density is important because proper density in the finished product is essential for lasting pavement performance. Mix properties are required to be measured in volumetric terms as well as weight. Density allows us to convert from units of weight to volume. In mix design testing and analysis, density of the compacted specimen is usually expressed in pounds per cubic foot (lb/ft3).

The values of bulk density are decreasing with increase in waste plastic content [1]. DBM with recycled plastics, mainly low density polyethylene (LDPE) replacing 30% of 2.36–5mm aggregates, reduced the mix density by 16% [12].

As depicted in Figure 4.12 below, the values of bulk density decrease as the percentages of plastic content increases. This indicated that the two factors are inversely related. The reduction of bulk density has the advantage of reducing hauling cost.

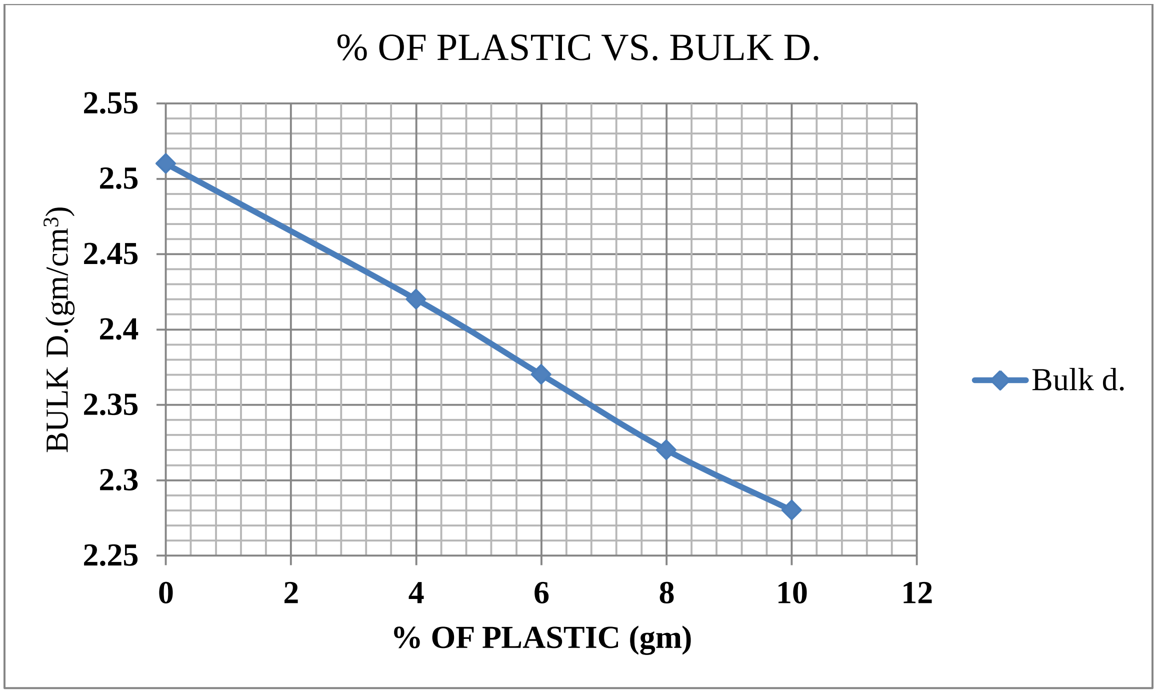

Figure 4. 12 Percentage of Plastic Vs. Bulk density.

As portrayed in Figure 4.3 below, the trend line of linear regression model is down from left to the right (the negative slope) which implies that there is an inverse relationship between the two variables (percentages of plastics and bulk density) which mean that as one variable increases the other decreases and the reverse is true. R–squared value is almost equal to one (0.999) implies that there is strong linear correlation between percentage of bulk density and percentages of plastic.

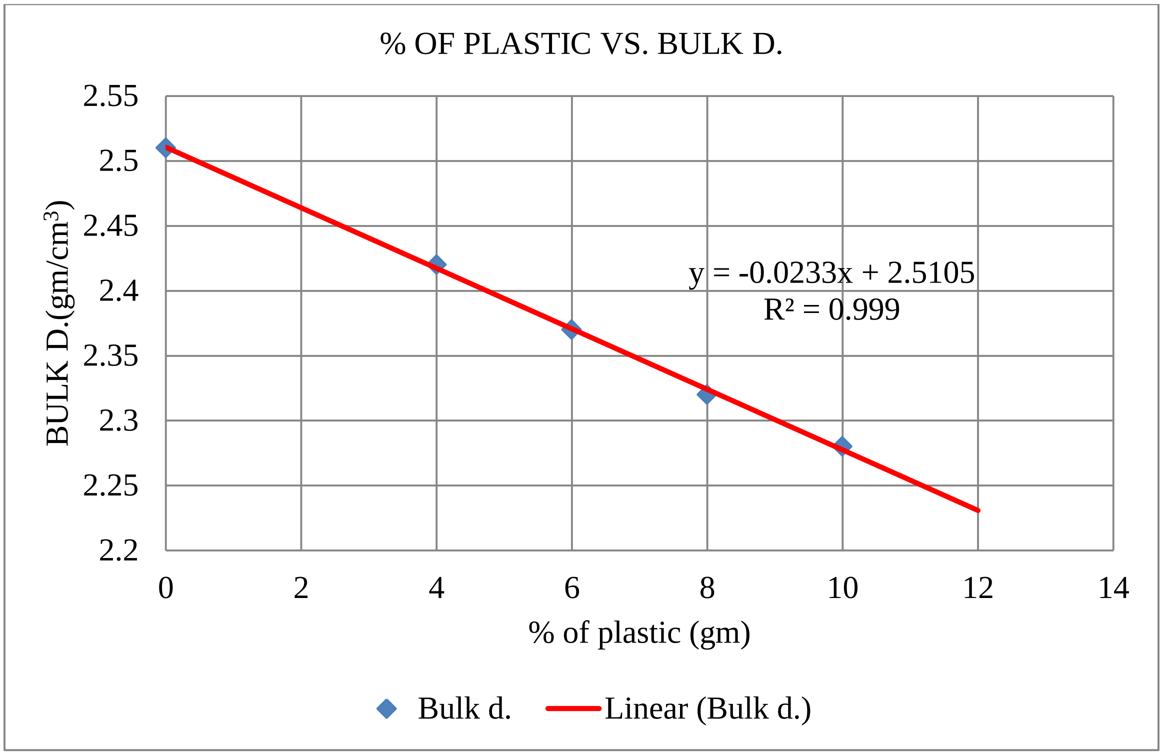

Figure 4. 13 Linear Regression Models for Bulk Density and Percentage of Plastic.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

As the laboratory results of marshal test indicate, application of waste plastic bottles in road construction especially in flexible pavement construction increases the performance of pavement since the overall performance of plastic modifies bitumen concrete mix are better than that of conventional one. And this reduces the aggravating negative impact of plastic bottle (PET/ PETE) on environment since the incineration and land filling does not solve problem because the plastic bottles can stay up to 500 years to decompose. According to the marshal test results and volumetric properties on conventional bitumen concrete mix the optimum bitumen content was determined as 5.33% by weight of total mix.

Then after the specimen were prepared to the modified BC mix with partial replacement of aggregate with waste plastic bottle by (0%, 4%, 6%, 8% and 10%) by weight of aggregate. The performance of BC mix according to marshal flow value and percentages of plastic have direct relationship which mean that as the percentages of plastic increase the marshal flow values also increases and there is strong linear correlation between flow value and percentage of plastic. And there is no constant increment or decrement of marshal stability values, but the marshal stability values fluctuate as the percentage of plastic increase. But there is maximum stability of (20.66KN) at the 4% of waste plastic bottle (PET/PET) was added as an aggregate which was higher than that of 0% plastic (conventional BC mixes) which was recorded as 20.00KN. As percentage of plastic increases the bulk density decreases; this has the advantage to reduce the hauling cost and there is strong linear correlation between the two. As percentage of plastic increases the VFA decreases and there is strong linear correlation between the two. There is direct relationship between percentages of plastics and VMA but further increment of amount of plastic decreases the value of VMA and there is strong linear correlation between voids in mineral aggregate and percentages of plastic. And there is no constant increment or decrement of percentage of air voids with increment of plastic, but the percentage of air voids fluctuate as the percentage of plastic increase. But to a little extent imply that there is inverse relationship between percentages of plastics and VA.

There is no linear correlation between percentage of air voids and percentages of plastic since r-squared value is near to zero.

According to the comparison of laboratory test result and the standard specification of AASHTO, the marshal stability value should be greater than or equal to 9KN, marshal flow value should be with in ranges of 2-4mm, voids filled with mineral aggregate should be greater than or equal to 13%, voids filled with bitumen should be within 65-75%, the optimum percentage of air voids should be 3-5% and all the test results at each percentage replacement of aggregate by plastic content fulfills the standard specification requirement of stability, flow value and voids filled with mineral aggregate. But only 4% replacement of aggregate by plastic fulfills the requirements of voids filled with mineral aggregate and air voids at 8% of plastic content was tolerable.

5.2 RECOMMENDATIONS

Depending on the laboratory results and the current situation of solid waste disposal problem especially plastic bottles; this study had great findings and becomes great congratulations for developing countries like Ethiopia which have poor solid waste management systems. This study has double advantages to improve the performance of flexible pavements and to reduce environmental pollution through non-biodegradable PET/PETE plastics. This non-biodegradability property of plastic was great advantage for application of plastic in BC mixes since it resist different climatic and harsh weather condition. The researcher recommends other researcher and organizations for the following points.

- Waste plastic bottles (PET/PETE) can enhance the performance of BC mixtures if it were used to partially replace aggregate. For this matter this study recommends different governmental (ERA and ACRA) and non-governmental organization involved in road construction works, it is better to include such waste material input as an important improving agent in flexible pavements at certain percentage as a new finding technologies on flexible pavement specially with high traffic volume. It is better to apply this new construction technology on the ground and to adopt it.
- Further studies are recommended to investigate the cost benefit analysis of using was plastic bottles as partial replacement of aggregate in BC mixes.

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APPENDIX

Appendix A

Laboratory Result of Physical Properties of Aggregate and Bitumen

Project: sodo tercha road upgrading project, lot 1

Material type: Bitumen and Aggregate

Tested by: Hunan Huanda road and Bridge Corporation

Approved by: International Consultants and Technocrats Ethiopia Private Limited Company

Table A1). Physical property of aggregate

No	Test types and standard method	Test results			
		00	01	02	Average
1	Soundness loss by sodium sulfate (AASHTO T-104)	5%	4%	2%	3.67
2	Loss angeles abrasion (AASHTO T-96)	-	-	14%,grade B	14%
3	Specific gravity (AASHTO T-85)	2.82	2.81	2.54	2.72
4	Water absorption (AASHTO T-85)	2%	2%	1%	1.67
5	Agregate crushing value (BS 812 part 110)	-	-	13%	13%
6	Agregate impact value (BS 812 part 112)	-	-	8%	8%
7	Flakiness Index (BS 812 part 112)	-	22%	10%	11%
8	Stripping and coating (AASHTO T-182)	-	-	95%	95%
9	Sand equivalent (AASHTO T-176)	88%	-		88%

Table A2). Physical properties of bitumen

NO	Test types	Test method	Test result
1	Flash point Cleveland open cup ^{0}c	AASHTO T 48	285
2	Penetration 100gm,5sec at 25 ^{0}c	AASHTO T 49	69
3	Ductility 5cm/min at 25 ^{0}c,cm	AASHTO T 51	100
4	Solubility in trichloro ethylene %	AASHTO T 44	99.68
5	Loss on heat %	AASHTO T 47	0.02
6	Thin film oven %	ASTM D 179	0.02

Appendix B

Marshal test results & volumetric properties of conventional & modified bitumen concrete mix respectively.

Description	client	Test types	Date tested	Tested by
plastic modified BC mix	Hunan Huanda Raod and Bridge Corporation	Marshal stability and flow value	19/12/2018	Yetimgeta Mekonnen

Specimen No.	Asphalt content by total mix (%pb)	Aggregate content by total mix (%ps)	Weight of specimen			Volume of sample	Specific gravity of mix (gm/cm^3)		Bitumen volume	VA	VMA	VFA	stability	flow	Marshal quotient (KN/mm)
			In air (gm)	SSD wt. (gm)	In water (gm)		Bulk	Max theoretical density							
1	4.0	96	1236.8	1239.5	736.3	503.2	2.46	2.611	9.54	5.78	13.11	72.77	17.45	2.40	0.92
2		96	1229.7	1233.0	731.6	501.4	2.45		9.50	6.17	13.47	70.53	18.06	2.01	0.92
3		96	1241.2	1244.0	742.1	501.9	2.47		9.58	5.40	12.76	75.08	18.55	2.81	0.92
Avg.		**96**	**1235.9**	**1238.8**	**736.7**	**502.2**	**2.46**		**9.54**	**5.78**	**13.11**	**72.77**	**18.02**	**2.41**	**0.92**
1	4.5	95.5	1222.1	1223.5	733.2	490.3	2.49	2.592	10.86	3.94	12.50	86.88	19.97	3.41	0.92
2		95.5	1232.8	1233.8	737.1	496.7	2.48		10.82	4.32	12.85	84.20	20.22	3.33	0.92
3		95.5	1257.8	1259.1	750.5	508.6	2.47		10.78	4.71	13.20	81.67	19.23	3.04	0.92
Avg.		**95.5**	**1237.6**	**1238.8**	**740.3**	**498.5**	**2.48**		**10.82**	**4.32**	**12.85**	**84.20**	**19.81**	**3.26**	**0.92**
1	5.0	95	1242.2	1243.0	749.9	493.1	2.52	2.587	12.22	2.59	11.93	102.43	19.62	2.84	0.92
2		95	1240.6	1241.0	749.3	491.7	2.52		12.22	2.59	11.93	102.43	20.85	2.97	0.92
3		95	1222.4	1222.9	736.5	492.5	2.48		12.02	4.14	13.22	90.24	19.53	2.99	0.92
Avg.		**95**	**1235.1**	**1237.7**	**745.2**	**492.4**	**2.51**		**12.15**	**3.12**	**12.39**	**98.06**	**20.03**	**2.93**	**0.92**
1	5.5	94.5	1253.1	1253.2	756.4	496.8	2.52	2.577	13.44	2.21	12.38	108.56	18.47	3.18	0.92
2		94.5	1230	1234.2	745.1	493.0	2.49		13.44	2.21	12.38	108.56	16.71	3.78	0.92
3		94.5	1229	1232.4	743.4	493.5	2.49		13.44	2.21	12.38	108.56	17.79	3.63	0.92
Avg.		**94.5**	**1237.4**	**1239.9**	**748.3**	**494.43**	**2.50**		**13.44**	**2.21**	**12.38**	**108.56**	**17.66**	**3.53**	**0.92**
1	6.0	94	1254.4	1254.9	741.2	513.7	2.44	2.572	14.19	5.13	15.62	90.88	18.44	3.55	0.92
2		94	1262.1	1262.5	751.2	511.3	2.50		14.54	2.80	11.82	123.05	16.68	3.25	0.92
3		94	1251.9	1252.3	748.0	504.3	2.48		14.43	3.58	14.24	101.33	17.80	3.20	0.92
Avg.		**94**	**1256.1**	**1256.6**	**746.8**	**509.8**	**2.46**		**14.31**	**3.84**	**13.89**	**103.02**	**17.64**	**3.30**	**0.92**

Description	client	Test types	Date tested	Tested by
modified BC mix	Hunan Huanda Raod and Bridge Corporation	MSV and Fv	19/12/2018	Yetimgeta Mekonnen

Spec. No.	Plast. Cont't. by tot aggreg(%pp)	Asphal.cont,t by tot. mix (pb.)	Aggre.content by total mix (%ps)	Weight of specimen			Vol. of sample	Specific gravity of mix (gm/cm^3)		Bitumen vol.	VA	VMA	VFA	Stability (KN)	Flow (mm)	Marshal quotient (KN/mm)
				In air (gm)	SSD wt. (gm)	In water (gm)		Bulk	Max theor. density							
1	0.0	5.0	95	1234.9	1243.0	749.9	493.1	2.52		12.22	2.59	11.93	102.43	19.62	2.84	0.92
2			95	1240.6	1241.0	749.3	491.7	2.52		12.22	2.59	11.93	102.43	20.85	2.97	0.92
3			95	1222.4	1222.9	736.5	492.5	2.48		12.02	4.14	13.22	90.24	19.53	2.99	0.92
Avg.			**95**	**1235.1**	**1237.7**	**745.2**	**492.4**	**2.51**		**12.15**	**3.12**	**12.39**	**98.06**	**20.03**	**2.93**	**0.92**
1	4.0	5.0	91	1234.9	1235.4	721.4	514	2.40	2.47	11.64	2.83	18.26	63.70	18.91	3.13	0.917
2			91	1217.5	1217.9	714.4	503.5	2.42		11.73	2.02	17.58	66.70	20.36	3.78	0.917
3			91	1250.7	1251.1	735.8	515.3	2.43		11.78	1.62	17.24	68.32	22.54	3.87	0.917
Avg.			**91**	**1234.4**	**1234.8**	**723.9**	**510.9**	**2.42**		**11.72**	**2.16**	**17.70**	**66.24**	**20.66**	**3.59**	**0.917**
1	6.0	5.0	89	1264.3	1264.9	729.4	535.5	2.36	2.42	11.44	2.48	19.74	57.95	19.36	3.29	0.917
2			89	1234.5	1234.9	714.2	520.7	2.37		11.49	2.07	19.40	59.23	20.66	3.09	0.917
3			89	1248.2	1248.6	721.3	527.3	2.37		11.49	2.07	19.40	59.23	17.99	3.54	0.917
Avg.			**89**	**1249**	**1249.5**	**721.6**	**527.8**	**2.37**		**11.47**	**2.21**	**19.51**	**58.80**	**19.34**	**3.31**	**0.917**
1	8.0	5.0	87	1226.5	1227.2	689.9	537.3	2.28	2.40	11.05	4.92	24.09	45.88	19.71	3.54	0.917
2			87	1213.8	1214.1	696.9	517.2	2.35		11.39	2.00	21.76	52.35	20.14	4.03	0.917
3			87	1231.2	1232.5	703.7	528.8	2.33		11.30	2.84	22.42	50.40	19.85	3.93	0.917
Avg.			**87**	**1223.8**	**1224.6**	**696.8**	**527.8**	**2.32**		**11.25**	**3.25**	**22.76**	**49.54**	**19.90**	**3.83**	**0.917**
1	10.0	5.0	85	1237.0	1237.6	693.9	543.7	2.28	2.34	11.05	2.56	22.23	49.71	17.69	3.63	0.917
2			85	1232.0	1232.6	690.4	542.2	2.27		11.02	2.91	22.50	48.98	19.66	3.89	0.917
3			85	1234.0	1234.5	692.6	541.9	2.28		11.05	2.56	22.23	49.71	18.39	4.69	0.917
Avg.			**85**	**1234.3**	**1234.9**	**692.3**	**542.6**	**2.28**		**11.04**	**2.68**	**22.32**	**49.44**	**18.58**	**4.10**	**0.917**

Appendix C

Photos

19/12/2018

Weighing shredded plastic fot melting

19/12/2018

Shredded Plastic bottle inside oven at 180^0c

19/12/2018

Melted plastic bottle

19/12/2018

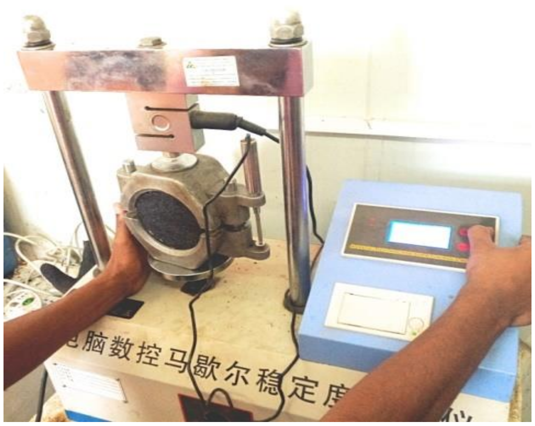
coarser plastic bottle after melting and pulverizing

19/12/2018

Fine plastic bottle aggregate after pulverizing

19/12/2018

Bitumen concrete samples without plastic



19/12/2018

marshal stability and flow value testing

19/12/2018

pulverized plastic added to aggregate

18/12/2018

Bubbling for Gmm

18/12/2018

Quartering equipment

18/12/2018

Sample for GMM

18/12/2018

Drying of specimen with clothes

19/12/2018 17/12/2018

specimens after marshal compaction mixing pulverized plastic with aggregate

18/12/2018 17/12/2018

pocket thermometer pulverized plastic over aggregate

17/12/2018

Aggregate mixed with pulverized plastic

16/12/2018

lubricating marshal stability mold

16/12/2018

Sample in water bath at 60^{o}c

16/12/2018

weight of sample in water

Specimens in water bath at 60^0c for 30 min

16/12/2018

samples inside water for SSD

Sample for calculating bulk density

16/12/2018

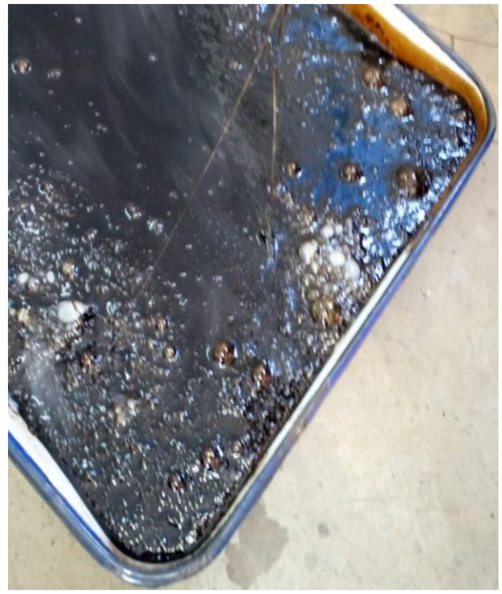
measuring the height of sample

19/12/2018

Pulverized plastic after melting

16/12/2018

vacuum pumping with pycnometer

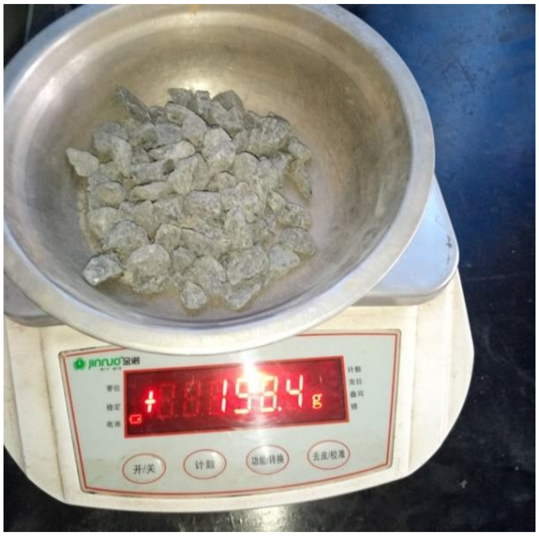


19/12/2018 16/12/2018

Pulverized plastic to be mixed with aggregate melted plastic

16/12/2018 14/12/2018

Drying aggregate inside oven @ 150^{0}c plastic to be melted @ 180^{0}c for 2 hrs



13/12/2018

Electric Balance with 0.1g accuracy

13/12/2018

preparing aggregate for sample

13/12/2018

Different sieve size aggregate

18/12/2018

Oven

18/12/2018

Asphalt mixture Mixer

18/12/2018

marshal compacter

19/12/2018

Sieving the aggregate for each sieve Size

19/12/2018

compaction molded sample