Addis Ababa University

Addis Ababa Institute of Technology

School of Civil and Environmental Engineering

USING PLASTIC WASTE IN ROAD CONSTRUCTION, AN ECO-FRIENDLY WAY OF PLASTIC WASTE DISPOSAL

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Thesis Submitted to Addis Ababa Institute of Technology, School of Post Graduate Studies in partial fulfillment of the requirements for the Degree of Master of Science in Civil Engineering under Water Supply and Environmental stream.

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Certification

The undersigned certify that she has read the thesis entitled: Recycling of waste plastic to use as asphalt road binder, and hereby recommend for acceptance by the Addis Ababa University in partial fulfillment of the requirements for the degree of Master of Science.

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ABSTRACT

The rapid increase in the use of plastic materials in the recent years led to the accumulation of extreme amounts of plastic waste. Thermoplastics such as PET, PE, PP, PS and PVC as well as materials that derived from these are the type of plastic most used and consequently create environmental problems.

Landfill, incineration and recycling remains the primary options for solid waste management. One critical determinant of the acceptability of these options is the different health risks associated with each.

The plastic waste that burnt and dumped in landfill sites can be recycled and used for different purpose. This includes the use of waste plastic in construction of asphalt road. By recycling waste plastic, it is possible to protect the environment from contamination.

Using waste plastic in asphalt road construction as an aggregate binder is one of the recent plastic waste approach. This will help us to avoid the environmental pollution from open-air burning and landfill of plastic waste.

In this research the applicability of the waste plastic as a binder, together with Bitumen has investigated, for this purpose, the plastic (Polyethylene terephthalate) and bitumen mix was checked for certain quality that needed to be a good binder. The natural bitumen had modified by adding Polyethylene Terephthalate (PET) in different percentage by weight of bitumen. The tests that conducted on the modified bitumen quality are Ductility, Penetration, and Softening point of the plastic modified bitumen mix. Also the load bearing capacity of the modified bitumen asphalt (aggregate with modified bitumen mix), had been tested.

The research had conducted the two methods of asphalt road making using plastic waste.

After doing the quality test, the research identified what percentage by weight of plastic that should be mixed with bitumen to give a good quality of modified bitumen, accordingly 8% by weight in wet process and around 16% by weight of Polyethylene Terephthalate(PET) in dry process were able to give good binding property. This can enable us to recycle around 52.4 tons of PET waste (per kilometer of road) that would have gone to landfill and/or to open air burning and Incineration.

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LIST OF ACRONYMS

AACA	**Addis Ababa City Administration**
AASHTO	**American Association of State Highway and Transportation Officials**
AAPT	**Association of Asphalt Paving Technologists**
ABS	**Acrylonitrile butadiene styrene (ABS**
GDP	**Gross domestic production**
HDPE	**High-density polyethylene**
LDPE	**Low density Polyethylene**
MSW	**Municipal solid wastes**
PE	**polyethylene**
PET	**Polyethylene terephthalate**
PMB	**Polymer modified bitumen**
PS	**polystyrene**
PP	**Polypropylene**
PVA	**Polyvinyl Acetate**
PVC	**Polyvinylchloride**
QC	**Quality control**
TRRL	**Transportation Road Research Laboratory**
UNEPA	**United nations Environmental Protection**
WHO	**World Health Organization**

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Chapter 1
Introduction

1.1 Background

1.3 billion tons of solid waste is being generate per year. This waste is likely to increase to 2.2 billion tons per year by 2025 (World Bank 2012). World Health Organization (WHO) states that more than 1.5 million people die annually due to poor solid waste management. Waste poses severe hazard to public health through blocking of drainage system, formation of standing ponds, and creating breeding grounds for mosquitoes and flies. In addition, because of lack of proper dumping sites, most of the collected waste ends up in open pits, ponds, rivers, dumping grounds, and agricultural l ands. Wastes that did not managed properly, especially solid waste from households and the community, are a serious health hazard and lead to the spread of infectious diseases. Unattended wastes lying around attract flies, rats, and other creatures that, in turn, spread diseases (United Nations Environment Program Agency UNEPA, 2006).

A part of waste could have decomposed in the environment at dumpsites but non-biodegradable waste stays there for years. Plastic is one form of waste formed in domestic, commercial and social activities. Plastic is everywhere in today's lifestyle and its disposal is a great problem. Plastic waste handling is one of the major problems that the developing countries are facing today. Plastics are so durable that they do not decay or cannot destroy naturally, and immense amounts of discarded waste plastic products accumulate and it has become a threat to our environment. The managements of plastic wastes is intended to decrease the environmental impact according to the following order- waste minimization, reuse, recycling, energy recovery, and land filling. Since It is a non-biodegradable product due to which these materials pose environmental pollution and problems like breast cancer, reproductive problems in humans and animals and genital abnormalities (Verma, S.S. 2008).

Because of the pollution and all kinds of health, problems associated with plastic waste banning of plastic product can be an option but banning of plastic would bring much higher cost. Since Plastic covers large portion in our day-to-day activity. Materials in hospitals and in our house and all the electronic equipments and vehicles made from different forms of plastic. Therefore banning of plastic would be difficult. Because plastic are the best in some purposes and of their fair price. Therefore, the question must not be to use or not to use plastic products. There must be a balance. Use plastic material and reuse the waste in Flexible Pavements can be a better solution.

1.2 Statement of the Problem

Currently the plastic waste management options we have in our country could not handle all the plastic wastes generated, and the amount of the plastic waste generated is increasing. In addition, the plastic waste disposal methods have been polluting the environment and affecting human and animal lives. In another area, there is much need for materials in road construction industry, for the construction of pavements one of the construction material is binder. Bitumen is used as a binder in road pavements. This study undertakes to use the plastic waste that has been creating a big problem to our environment, in the road construction as a binder together with bitumen.

The existing solid waste management system of our country not well designed. From the wastes generated collected around 9% is plastic waste, from this plastic waste, large amount of its portion is water bottles (Polyethylene terephthalate PET). This waste burned in open air and dumped in land filling or incinerated for power generation. These methods have negative influence to the health of human and to the environment because of the toxic gases released.

The most dangerous health effect of burning plastic is the release of **Dioxin** into the atmosphere. Dioxins are extremely toxic to humans and animals. They cause **Cancer** and **hormonal birth defects** that passed from generation to generation. The dioxin also ends up in the soil poisoning food for humans and animals.

1.3 Research Questions

This research aimed to answer the following research questions:

- Is it possible to use plastic waste in road construction?
- What composition of plastic waste, optimally fulfill the requirement of good pavement?
- Which method of plastic waste and bitumen mixing would be better?
- Will it be environmentally friendly?

1.4 Objective of the study

The main objective of this paper is to study the use of plastic waste as asphalt binder to improve performance of the road, which could serve as eco-friendly way of plastic waste disposal.

1.4.1 Specific objective

- To determine the percentage (%) of plastic waste used in road making
- To compare the strength of plastic road and natural bitumen road
- To investigate the environmental effect of using plastic waste in road
- To minimize carbon footprint of bitumen production and its transportation

- To compare plastic waste consumption of the two process types (Dry process and Wet process)

1.5 Scope

An experimental work proposed to improve the properties of pavement using plastic Waste and to look for better way of plastic waste disposal. Plastic waste (PET) is grinded and mixed with hot bitumen and plastic modified bitumen is prepared. Laboratory studies carried out on plastic waste modified asphalt mixtures to evaluate engineering properties of the binder like that of penetration, ductility, and softening point. Also using marshal stability, the load bearing capacity of the plastic waste, bitumen, and aggregate mix checked.

1.6 Research Organization

This research paper is composed of six chapters. Chapter one discuss about the overall importance of the problem and an introduction to the project. It deals with background of the study, statement of the problem, basic research questions, and objective of the study. Chapter two of this paper deals with literature reviews on the basic pavement concepts. Materials mix design, and past studies and works on, plastic waste in the road construction industry. Chapter three describes how the experimental work is done with detailed procedures. Chapter four discusses in detail about the results of the experimental works. The conclusions and recommendations regarding this experimental work described clearly in chapter five. The final chapter, chapter six contains the references.

Chapter 2
Literature review

2.1 Solid waste

Waste is any material that does not have any value to the holder. This waste can be from domestic, public, commercial, or from industrial areas. According to World Bank, 1.3 billion tons of solid wastes are generate in the world. This waste is likely to increase to 2.2 billion tons per year by 2025(World Bank, 2012).

The understanding of the society and the relationship between them and the waste management problems is critical. We have been observing several problems in the collection transportation and in the final disposal process and methods of waste.

Classification of Solid wastes can be broad, this classification is in municipal (residential and commercial), industrial, construction and demolition wastes. The municipal solid wastes (MSW) are the most non-homogeneous since they consist of the residues of nearly all materials used by humanity: Food and other organic wastes, papers, plastics, fabrics, leather, metals, glass and other inorganic materials.

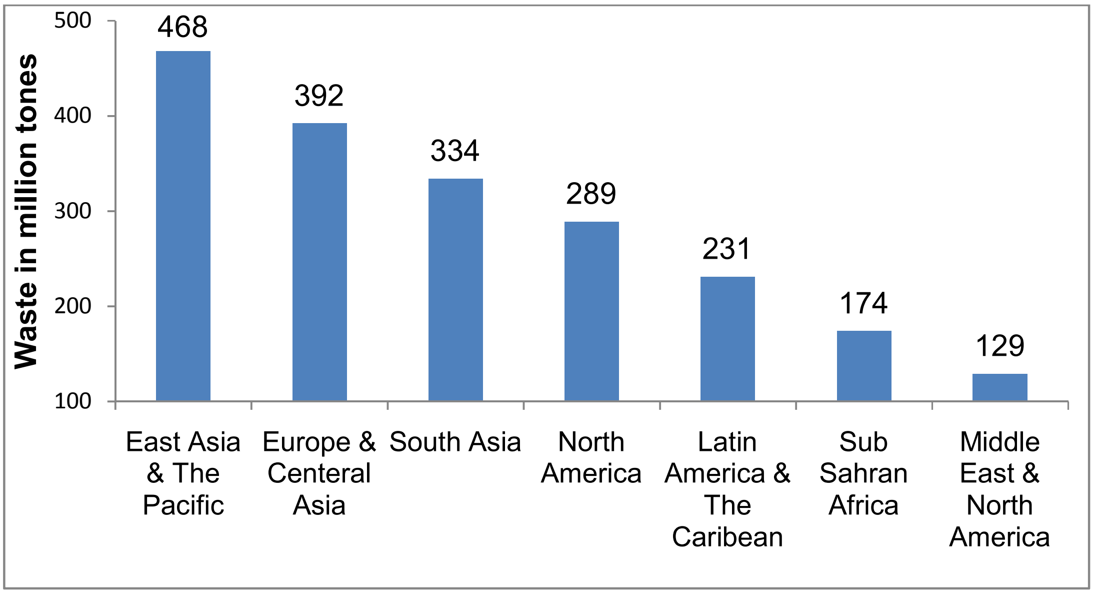
2.2 Solid waste management

2.2.1Global Solid waste generation and its composition

The world generates 2.01 billion tones of municipal solid waste every year. From the total waste generated more than 33% not managed in an environmentally safe manner (World Bank's).

The practice of managing wastes may differ between developed and developing nations, urban and rural regions and residential and industrial sectors.

Figure 1: Regional Annual waste generation

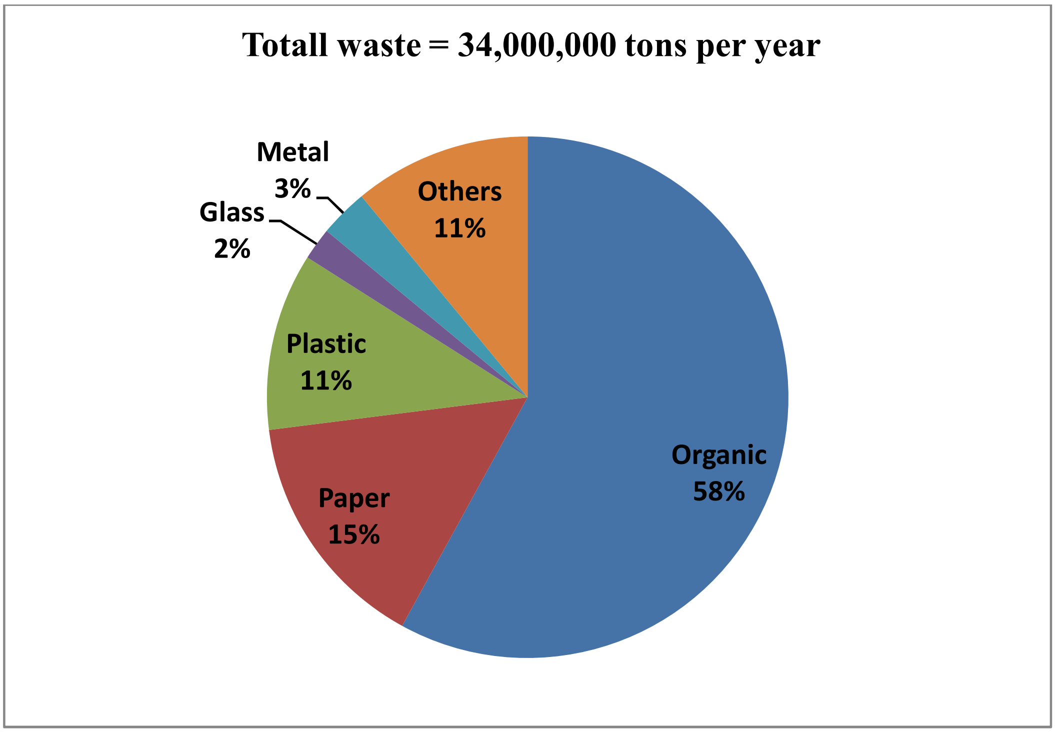


Source: World Bank 'what a waste 2' report.

Waste management is all about the steps and activities required to manage wastes from the initial to the final disposal point. This process includes all the actions of collecting, transporting, disposing, and controlling of waste materials. Usually the term relates to all kinds of waste materials; whether they are formed during the production, processing or final utilization stage of raw materials or by other human activities including municipal, household and agricultural wastes as well. Waste management, is designed to minimize the negative influence of waste on the environment, health and economy of the world. The management of waste can include solid, liquid, gaseous, hazardous or organic substances, which have a harmful impact on the society.

Integrated solid waste management refers to the strategic approach to sustainable management of solid wastes covering all sources and all aspects, covering generation, segregation, transfer, sorting, treatment, recovery and disposal in an integrated manner, this process give much weight for efficient use of resource.

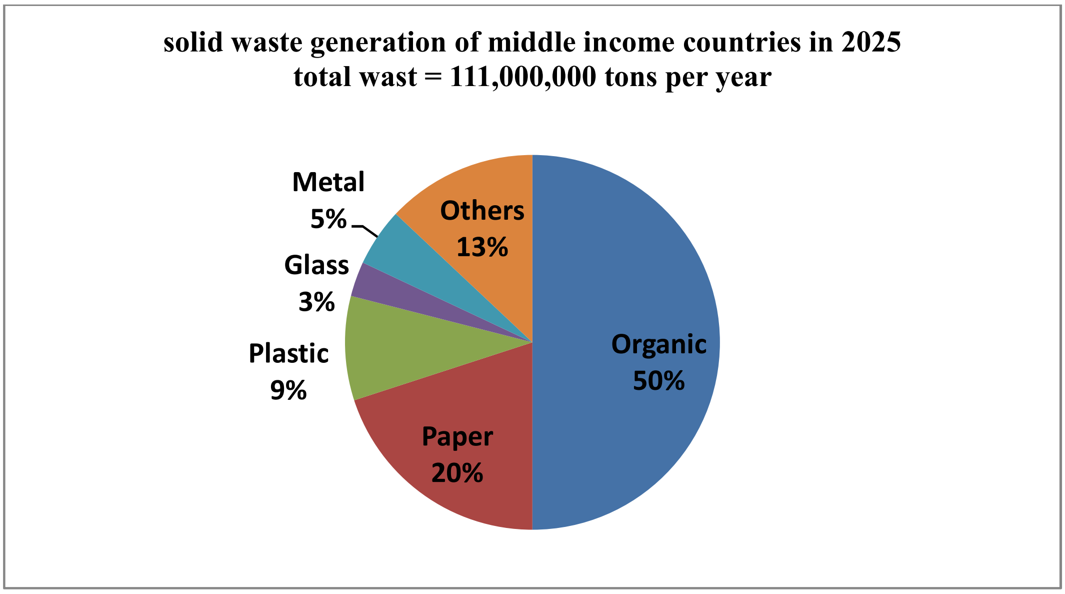
Figure 2: Solid waste generation of middle-income countries (1999).



Source: (MushtaqAhemd, integrated solid waste management).

This study predicts that the waste generated in these middle income countries become three folds of the base data in the coming year of 2025.

Figure 3: Future solid waste generation of middle-income countries.



Source: (Mushtaq Ahemd, integrated solid waste management)

As we can see in the above chart, the solid waste productions increased to 111,000,000 tons per year. Even though the portion of the plastic waste generated decreases from 11% to 9% but the amount of it is highly increased. That tells us we will have big problem coming a head of as concerning with plastic waste and its method of disposal. Therefore, we need much better way of disposing it in a way that will not have effect on our environment and in a way that will not be a challenge to human and animal health.

Solid waste management is a serious issue in most of Europe and developed countries like that of USA.

Waste incineration is popular in Europe, where nearly one quarter of all municipal solid waste incinerated. France has 126 waste-to-energy plants; Germany has 121 and Italy 40. (United Nations Environment Program)

2.2.2 Solid waste generation and composition in Ethiopia

In our country Ethiopia, most of the regions are affected by the lack of proper waste management. Most of the cities like Bahirdar, Hawasa, Adama, Mekele, and the capital city Addis Ababa have a better waste management system than the suburb towns. Despite these cities having better solid waste management, the production of solid waste is beyond the capacity of the management system to collect and dispose it properly. As a capital city of Ethiopia, Addis Ababa has modern economic activities, social and infrastructural services relatively in a better situation than other cities of Ethiopia. Due to the population growth in the city because of natural population growth and migration from all the rural areas to the city, the existing socio-economic and infrastructural development of Addis Ababa is unable to meet the demands of the increasing population.

Among other many urban problems, the poor solid waste management system existing in Addis Ababa or other cities of the country is the main one of which our city residents are suffering from.

The waste generated in the city managed in two stages starting from collection to disposal. These waste management system carried out, formally and informally all over the country.

In the capital city of Ethiopia Addis Ababa, waste collection executed by the City government of Addis Ababa in the formal way of waste collection. In this waste management system, the waste collected from the residential areas and transported to the dumping sites, which is a landfill area. Waste is also being disposed in huge amount in the informal way of waste management; this way of waste management is done by, people who use the waste as a source of income generation. By selecting the recyclable wastes and sell it for recyclers who are mostly located around Merkato. In this place, there is one recycling market locally called "MinaleshTera", in which scavengers sell materials collected from waste sites and some artisans made furniture from those materials (Wondafrash and Ehite, 2017).

A lot of studies and projects have undertaken on the problem of solid waste management in Addis Ababa. These studies provided solutions for different aspects ranging from problem of collection to institutional management and assessment of community based projects. All contributed to the gradual improvement of the system. Even though the system of SWM is getting better and better than before, the problem caused by increasing generation of waste is still there.

The source of waste in Addis Ababa city are numerous, and have different percentage of contribution to the waste generated, from these sources some of them are: households, street, commercial institutes, industries, hotels and hospitals. From total generated, solid waste households' account for 71%, street 10%, commercial institutions 9%, industries 6%, hotels 3% and hospitals 1% (Cointreau-Levine S, 1994).

The waste generated from the residential or commercial and industrial areas have not handled in proper way. Most of the solid waste materials produced by households are disposed without adequate care. A study made by the Addis Ababa City Administration shows that, the collection coverage has been constantly increasing from 38 percent in 2000 to 40 percent, in 2001, 53% in 2002, 53.9% in 2004 and 78% in 2005 (AASBPDA, 2005). Improper solid waste management of collection and disposal is creating a huge health and environmental problem in the city of Addis Ababa (Dierig, 1999).

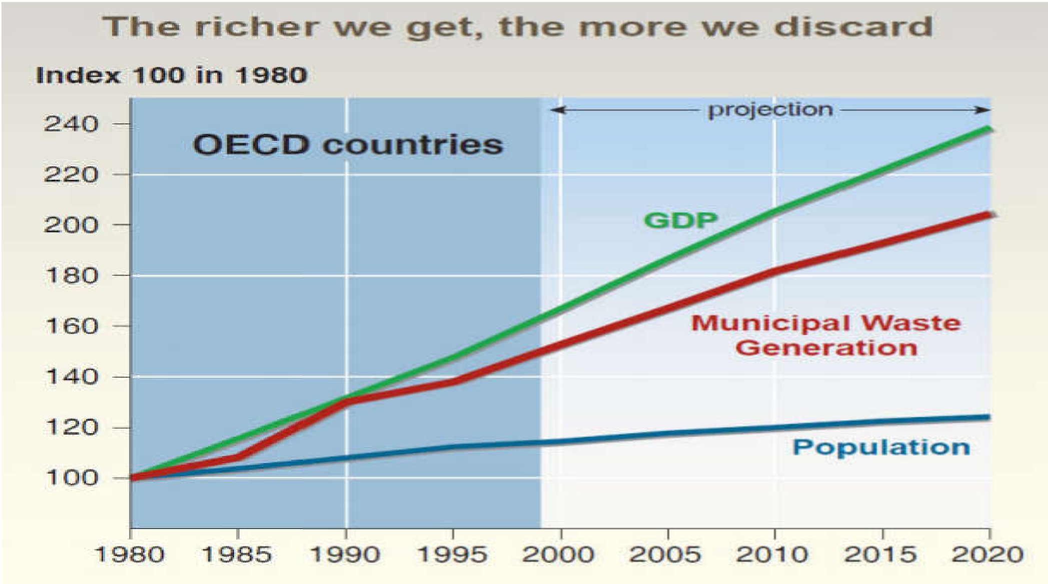
When the work of Solid waste management are carried out in the proper way of handling solid waste it will promote public health; improver hygiene; recycle materials; avoid waste; reduce waste quantities, and reduce emissions and residuals.

(KAPB, 1999) found that there were different types of diseases caused by improper handling of solid waste in the city.

Different study by UN in 2010 estimated that only 65% of the waste generated in the Addis Ababa city is collected, with the rest deposited in open sites, drainage channels, and rivers (UN, 2010). The city is home to major landfill sites; Repi Landfill and Korah dump are the two most prominent. Both landfills are open, unlined dumps. The Korah dump is located adjacent to the community of Korah, home to some 80,000 of the city's poorest people: many in this community reportedly use the dump as a food source (Cox, 2010).

The solid waste generation of a country and its gross domestic production is directly related. When the country's gross domestic production (GDP) increases the solid waste generated would be increased as well (OECD 1999).

Figure: 4 chart that shows the relation between GDP and waste generation.



source : (OECD 1999)

2.3 Plastic waste

These days we accompanied with Plastic in our day today activity. Plastics used for packaging, protecting, serving, and even disposing of all kinds of consumer goods. With the industrial revolution, mass production of goods started and plastic seemed to be a cheaper and effective raw material. Today, every vital sector of the economy starting from agriculture to packaging, automobile, building construction, these has revolutionized by the applications of plastics.

The following are some of the benefits we can get from plastic:

- Plastic wrapping protects foods and goods, from being contaminated, plus contaminated and in that way, it saves resources.
- The lightweight packaging material saves fuel and decreases emissions during transportation.
- Plastic water supply systems and storage containers/tanks provide clean water.

- Light plastic materials (replacing metals) in cars and aircraft save fuel and decreases emissions.
- Efficient plastic insulation materials in buildings save energy and provide climate protection.
- Plastic protective clothing and safety equipment (Fireproof materials, helmets, air bags) protects form injury.
- Plastic products for medical applications are very important and contribute to improved heath (disposable syringes, blood pouches, tubing, , prosthesis).
- Solar heaters and solar panels, in parts made of plastics, provide renewable energy (PlasticsEurope, 2009).

Plastic is made of a wide range of synthetic or semi-synthetic organic substances that are soft and it is capable of molded into solid objects of diverse shapes. Plastics are typically organic polymers of high molecular mass and they often contain other substances. They are usually synthetic, most commonly derived from petrochemicals and many are partially natural (LCPP 2011).

Plastics classified as thermoplastic and thermosetting materials, because of physical properties.

Table 1: Examples of thermoplastic and thermosetting materials

Thermoplastic	Thermosetting
High density polyethylene (HDPE)	Bakelite
Low density Polyethylene (LDPE)	Epoxy
Polypropylene (PP)	Melamine
Polyvinylchloride (PVC)	Polyester
Polyethylene terephthalate (PET)	Polyurethane
Polystyrene (PS)	urea-Formaldehyde
Polyvinyl Acetate (PVA)	Alkyd

Thermoplastics:

These types of plastics become soft when it get heat and can be molded or shaped with pressure when in plastic state and, when cooled; they solidify and retain the shape or mold. Some common thermoplastics with their uses and properties are as follows: -

Polyethylene Terephthalate (PET):

PET (also abbreviated PETE) is short for polyethylene terephthalate, the chemical name for polyester. PET is a clear, strong, and lightweight plastic that is widely used for packaging foods and beverages, soft drinks, juices and water. soft drinks and water sold in Ethiopia are bottled from PET.

PET is also popular for packaging salad dressings, peanut butter, cooking oils, toothpaste, shampoo, liquid hand soap, window cleaner, different kinds of playing balls. Special grades of PET used for carry-home food containers and prepared food trays that can warmed in the oven or microwave. The basic building blocks of PET are ethylene glycol and terephthalic acid, which combined to form a polymer chain. The resulting spaghetti-like strands of PET are extruded, quickly cooled, and cut into small pellets, the resin pellets then heated to a molten liquid that easily be molded into items of practically any shape.

PET, it first synthesized in North America in the mid-1940s. Today, more than half of the world's synthetic fiber made from PET, which is polyester when used for fiber or fabric applications. When used for containers and other purposes, it called PET or PET resin (Polyethylene terephthalate Resin Association).

Common properties of PET

i. Toughness, clear, good strength, and stiffness chemical and heat resistant, good barrier properties for oxygen and carbon dioxide
ii. It is used in-packaging, soft drink and mineral water bottles, fibers for clothing, films, food containers, transport, building and appliance industry (as it is fire resistant), etc.

High-density polyethylene (HDPE): Some common properties:

i. Good process ability, excellent balance of rigidity and impact strength, excellent chemical resistance, crystalline, melting point (130-1350C), and excellent water vapor barrier properties.
ii. Used for making blow molded products (various types of containers, water bottles), pipes, injection molded products (storage bins, caps, buckets, mugs), films (carrier bags), etc.

Polyvinyl chloride (PVC): Its properties are

i. Versatility, energy saving, adaptability to changing time and environment, durability, fire resistance
ii. It is used in industries such as building and construction, packaging, medical, agriculture, transport. Also used for making wires and cables, furniture, footwear, domestic appliances, films and sheets, bottles, etc.

Low density polyethylene (LDPE): Characteristics of LDPE are:

i. Easy process ability, low density, semi crystalline nature, low melting range, low softening point, good chemical resistance, excellent dielectric properties, low moisture barrier, poor abrasion and stretch resistance.
ii. It is, used for making carrier bags, heavy-duty bags, nursery bags, small squeeze bottles. Also used in milk packaging, wire and cable insulation, etc.

Polypropylene (PP): Properties are:

i. Low density, excellent chemical resistance, environmental stress resistance, high melting point, good process ability, dielectric properties, low cost, creep resistance
ii. Used for making bottles, medical containers, pipes, sheets, straws, films, furniture, house wares, luggage, toys, hair dryer, fan, etc.

Polystyrene (PS): Some of the properties of polystyrene are:

i. Glassy surface, clear to opaque, rigid, hard, high clarity, affected by fats and solvents
ii. Used for making electrical and communication equipment e.g. plugs, sockets, switch plates, coil forms, circuit boards, spacers and housings. Also used for making containers, toys, wall tiles, baskets, cutlery, dishes, cups, tumblers, dairy containers, etc.

Others plastics: There are many other types of plastics except these six types, often used in the engineering sector. Examples include polycarbonate (PC), nylon, and acrylonitrile butadiene styrene (ABS).

Thermosetting:

Thermosetting materials are those, which once set cannot be remolded /softened by applying heat. It includes phenol, melamine and urea formaldehyde, unsaturated polyester, epoxy and polyurethanes. These materials are not recyclable.

Table 2: Physical properties of some plastic

Full name	Abbreviation	Examples of use
High density polyethylene	HDPE	Bottles and films
Linear low density polyethylene	LLDPE	Film
Low density polyethylene	LDPE	Film
Polypropylene	PP	Containers, film
Polyvinylchloride	PVC	Blister packs and bottles
Polyethylene terephthalate	PET	Bottles for soft drinks,films etc.
Polystyrene	PS	Pots, thermo-Cole, trays, toys etc.

2.3.1. Plastic waste generation

The plastic bottles and plastic bags use is increasing in various purposes and their waste generation are increasing more than ever. As well, the problem of this plastic waste has grown up very rapidly. The plastic waste is not any more, just a matter of waste management. The hazards it can cause to the health of human beings and to their environment is becoming a worldwide concern. Environmental groups estimate that between 500 billion and 1 trillion plastic bags used globally each year (CBC News 2007).

Table 3: Import of plastic to Ethiopia (Tons)

Type/ year	**2009**	**2010**	**2011**	**Average**	% share
Polyethylene and related	27006.1	27006.1	27839.1	27283.8	40.58
Polypropylene and related	9,270.3	13,071.0	16,955.7	13,099.0	19.48
Polyvinyl chloride and related	14,836.3	9,251.2	8,928.2	11,005.2	16.37
Ethylene-vinyl acetate and related	5,484.7	5,647.7	7,990.2	6,374.2	9.48
Other polyethers	3,042.2	2,454.9	2,447.8	2,648.3	3.94
Poly(ethylene terephthalate)	1,215.0	1,971.3	4,081.5	2,422.6	3.60
Polyesters	828.7	1,152.7	1,143.9	1,041.7	1.55
Polymers of halogenated olefins	935.3	491.4	944.6	790.4	1.18
Alkyd resins	446.1	555.5	1,154.5	718.7	1.07
Polystyrene and related polymers	29	1,152.7	349.2	510.3	0.76
Acrylic	1,011.7	156.8	292.6	487.1	0.72
Polyamides	167.0	980.4	130.3	425.9	0.63
Epoxide resins	343.2	12.6	887.5	414.4	0.62
Poly carbonates	5.5	0.3	16.7	7.5	0.01
Poly(methyl methacrylate)	0.6	5.9	10.7	5.8	0.01
Total	64,622	63,911	73,172	67,235	100.00

Source: – Ethiopian Revenues & Customs Authority

These issues are, characterized in the following points (Macur andPudlowski, 2009).

- Plastic bags are a real hazard for the environment and especially today when they are in mass production – between four to five trillion is produced globally each year – there is no universal regulation about their disposal and their afterlife threat to the natural environment.
- If waste plastic bottles and plastics bags end up as litter in waterways they choke drainage systems, and force the flood to flow out of the

system. This brought different contaminants to the land area. In addition loss of life, and losses to the economy

- Lots of rubbish with plastic bag content is floating across oceans.

Table 4: Waste Plastic and its Source

Waste Plastic	**origin**
Low Density Polyethylene (LDPE)	Carry bags, sacks, milk pouches, bin lining, cosmetic and detergent bottles.
High Density Polyethylene (HDPE)	Carry bags, bottle caps, house hold articles etc.
Polyethylene Teryphthalate (PET)	Drinking water bottles etc.,
Polypropylene (PP)	Bottle caps and closures, wrappers of detergent, biscuit, vapors packets, microwave trays for readymade meal etc.,
Polystyrene (PS)	Yoghurt pots, clear egg packs, bottle caps. Foamed Polystyrene: food trays, egg boxes, disposable cups, protective packaging etc
Polyvinyl Chloride (PVC)	Mineral water bottles, credit cards, toys, pipes and gutters; electrical fittings, furniture, folders and pens, medical disposables; etc

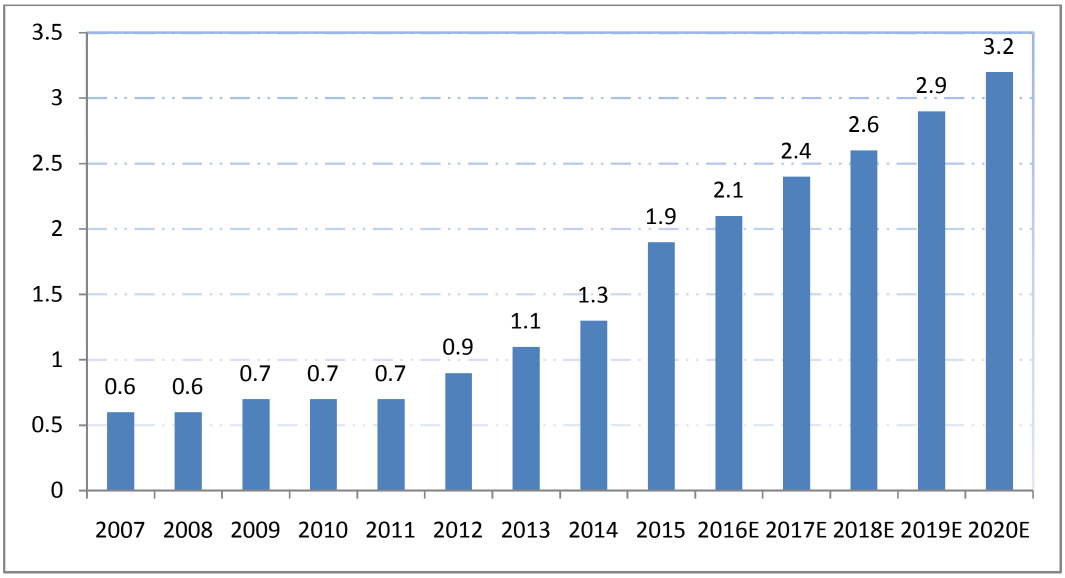
The population of Addis Ababa City is increasing very fast in the resent years and the production of solid waste also growing along with the population and modernization. The city generates a solid waste of 0.4kg/c/day. From the solid waste that generated, more than 200,000 tons/day of solid waste collected each year in the formal way of waste collection. The municipality has to increase the collection rate from 60% to 80%, because of the amount dumped around the streets and any open places are getting bigger in amount and the problems it causes to the city dwellers. About 550 tons/day, 80% of the total waste collected. The collected wastes have differed in kind and portion. Around 9% of the solid waste collected by weight is plastic waste (Tesema, 2010).

Similar study done in Bahirdar shows that, the total of 24.87 tons of plastic bag waste generated annually (Ayana, 2007). This is equivalent to more than 12 million Plastic bags per year enter into the environment as the waste.

Our ambition as a developing county is to achieve a middle income ranking countries in the near future. If we can succeed in achieving our plan it will need our much effort to tackle the much increased production of solid waste in general and plastic waste in particular, that grows along with our GDP.

Ethiopia has shown an annual of 15% increase in per capital consumption of plastic, in the past ten years. It was 0.6 kg in the year 2007 and become 2.4 kg in 2017. In the year 2020, it is estimate to be 3.2 kg per capital per year (plastprintpack Ethiopia).

Figure 5: Per capital consumption of plastic in Ethiopia from 2007 to 2017, and future prediction.



Source: plastprintpack Ethiopia

The country's plastics consumption has grown by 17.5% annually over the past ten years, from 44 KT in 2007 to 220 KT in 2017 and it estimated to be 308 kT in 2020. (plastprintpack Ethiopia).

Plastics are cost-effective, require little energy to produce, and are lightweight and biocompatible. This makes them an ideal material for single-use disposable devices.

The nature of plastics like its softness, transparency, and flexibility makes it preferable than other metal or glass products.

Durability of plastic

Plastics can last longer than most materials under any types of environmental condition. It is resistance against decomposition makes it preferable. Permanent shopping bags are durable than bags made from clothes, plastics and other natural materials.

Cost

Cost of plastic bottles, plastic bags, and any plastic made utensils are chipper in cost. These low costs of plastic products increase the demand for it. One of the factors that affect its demand is its cost. For instance, the costs of plastic bag determine the demand of the consumers for the plastic bags, as the cost of plastic bag increases the demand for the plastic bag decreases (Alexander, 2012).

Easy to use

Plastic materials are easy to handle and they are not heavy to carry them. If we take Plastic bags, they are convenient for handling and carrying goods. Moreover, they are accessible at any place and time in the shops.

2.3.1.1 Plastic waste collection

In these days, it is very common to see plastic bags and plastic bottles in our way to work, to school, to every corner of the town. Most of the plastic waste in domestic level waste generation is plastic bags, from the total of plastic waste generated plastic bag generated at each household accounts 92% by weight and 89.4% by volume. For that of packing plastic materials it take an account of 8% by weight and 10.6% by volume from total plastic waste (Ayana,2007).

As a solid waste plastic wastes also collected in three different mechanisms of solid waste collection. Municipalities to collect solid waste establish these systems. These are:

Collection through municipal containers: this system of waste collection is for municipalities living near main road. Container for solid waste collection placed in an open area center to the residents so that they can put the wastes from their house to the container. When the metal containers are full, the municipal tracks take the container to land fill site.

Collection from different institutions: this kind of plastic waste and solid waste collection is done by giving access to the institutions to use the collection containers and it requires the institutes to pay for the disposal.

House-to-house collection: This plastic waste collection currently practiced in most part of the country. The residents store the waste in their compound until collectors came to take the waste. The waste collectors have small car or two-wheel pushcart that pushed by hand.

2.3.1.2 Plastic waste sorting

These days' plastic wastes sorted from the source where they generated. In House-to-house solid waste collection, plastic wastes and recyclable wastes are sorted alone to sell it to recycling company.

House to house collectors will not take the waste if the recyclable wastes are not sorted out.

2.3.2 Plastic waste management options

Plastic polymers and products are extremely diverse, in terms of chemical composition, properties and applications. Several hazardous substances maybe released during the life cycle of a plastic product; and considering the large and growing global consumption of plastic products, and their long life in the environment without degradation, there must be a good way of managing it.

The first and most effective method of solving problems is by trying not to create that problem. If we use Plastic the wastes we create are so difficult to manage and can create health problems we cannot reveres.

Some of the countries in the world have prefers not to create the problem in the first place, France has banned plastic cups and plates, Italy and France are banning plastic cotton buds, the UK have ban straws, Brussels region recently, and other countries like Ireland and Portugal are considering measures. Not only banning the plastic products but also is searching for alternative materials (European commission, 2018).

The decision to ban bottled water is partly due to opposition to a proposed water extraction plant, and partly to concern related to the environmental and health impacts

More than 15 African countries in the continent either, have banned the use of plastic bags completely or charge a high tax on them or as of our country Ethiopia has band importing or producing them in domestic companies based on the thickness of the plastic bag. Importing or producing of plastic bags above a thickness of 0.3mm is band in Ethiopia.

The table below is some of African countries in which have band or charge higher tax on the use of plastic.

Table 5: List of African countries banned or put high tax on plastic use

Benin	Benin reportedly banned plastic bags in November 2017
Botswana	Botswana introduced a levy on plastic bags that became effective in 2007. This led to many retailers charging a fee on plastic bags and consequently a reduction in plastic bag use.
Zimbabwe	Styrofoam pollution is a serious problem in Zimbabwe. The government is set to ban the ubiquitous material for use in food containers and to promote greener alternatives.
Cameroon	Cameroon outlawed disposable plastic in April 2014. There are problems considering black market activities
Chad	There is a plastic bag ban in N'Djamena
Eritrea	Eritrea banned plastic bags in 2005.
Ethiopia	Ethiopia has banned the production of certain types of plastic bags
Gabon	Gabon has had a plastic bag ban since 2010
Guinea-Bissau	Guinea-Bissau banned plastic bags in 2016, but the legislation has been poorly enforced
Kenya	Kenya tried to ban manufacture and import of plastic bags in the year 2007 and 2011 as a way to protect the environment.
Madagascar	Madagascar introduced a plastic bag ban in 2015.
Malawi	Malawi introduced a plastic bag ban in 2015
Mali	Mali has banned plastic bags
Mauritania	Mauritania banned the use, manufacture and import of plastic bags from January 2013 to protect the environment, livestock, and marine species

Mozambique	Mozambique has had a plastic bag charge since 5 February 2016
Niger	Niger has a plastic bag ban in force
Senegal	Senegal has banned plastic bags in April 2015
Somalia	Plastic bags were banned in the self-declared Republic of Somaliland on 1 March 2005

Source: (Wikipedia Global List of Countries with Plastic Bans)

The biggest move comes from the European countries in the fight against plastic and minimizing the production of plastic waste. To reach this goal more than 30 European countries have band or put a higher tax on importers and producers.

Table 6: List of European countries banned or put high tax on plastic use

European Union	In November 2013, the European Commission published a proposal aiming to reduce the consumption of lightweight (thickness below 50 microns) plastic carrier bags. Under the proposal, EU member states can choose the most appropriate measures to discourage the use of plastic bags.
Austria	Austria has a voluntary agreement in place whereby retailers apply a charge to bags
Belgium	Belgium has plastic bag bans in place in Wallonia and Brussels, with bans set to also be introduced to Flanders.
Bulgaria	Bulgaria has seen a significant reduction in use since applying a charge to plastic bags
Croatia	Croatia is planning on introducing a plastic bag charge in 2019
Denmark	In 2003, Denmark introduced a tax on retailers giving out plastic bags.
Estonia	Estonia introduced a bag tax in July 2017
Finland	Finland applies a tax to plastic bags through a voluntary agreement
France	Following a National Assembly vote on 11 October 2014, France banned plastic carrier bags under 50 microns starting 1 July 2016
Georgia	Georgia has reportedly banned plastic bags, as of 2017
Germany	Germany imposes a fee on excess packaging through its Green Dot program, which included plastic bags.
Germany	Germany imposes a fee on excess packaging through its Green Dot program, which included plastic bags. In addition, all stores in Germany that provide plastic bags must pay a recycling tax.

Source:(Wikipedia Global List of Countries with Plastic Bans).

The amount of plastic waste produced is increasing in Ethiopia as well as in Africa and the rest of the world, because of its harm to the environment and to human health some of the countries like France, Kenya are banning the use of plastic bag. Still most of the countries of the world are using plastic bags and other plastic products. Therefore, there must be a way to handle the waste produced.

Plastic waste handling is more difficult for countries in which are developing. Plastics are so durable that they do not decay. As a result, great amounts of discarded waste plastic products accumulate and it has become a threat to our environment. The management of plastic waste intends to decrease the environmental impact in the following order- waste minimization, reuse, recycling, energy recovery, and land filling. Waste minimization and reuse are options with limited applicability. Hence, recycling and energy recovery are alternatives to be consider. Energy recovery by incineration seems to be a suitable solution that takes advantage of the high-energy content of plastics, but presently questioned because of the possible emission of toxic compounds such as dioxins, furans (Kanti and Shahidul, 2016).

2.3.2.1 Open dumping

Solid waste disposal in Open dumpsite is a primitive stage of solid waste management in many parts of the world. It is one of the most poorly rendered services by municipal authorities in developing countries as the systems applied are unscientific, outdated and inefficient. Solid waste disposal sites found both within and on the outskirts of developing urban cities. With increase in the global population and the rising demand for food and other necessities, there has been a rise in amount of waste generated daily by each household. These wastes are mostly, thrown into municipal disposal sites and due to poor and ineffective management, the dumpsites turn to sources of environmental and health hazards to people living around that dumping site. These health treats comes because of the wastes contaminating the land in which we used to crop, air we breathe in and the water we drink.

Community live around the dumpsite are highly exposed to a disease causing vectors since the dumpsite can be the breeding place for disease vectors. Malaria is one of the diseases that people suffer from the most. In addition, for that plastic bottles and bags create good opportunity for the breading of mosquito.

2.3.2.2 Landfills

The Population of our country is increasing from time to time and showing impressive economic growth trend. With this population increase and economic growth, the municipal solid waste is highly increasing in the same rate the plastic waste is also increasing.

The way municipal solid waste of Addis Ababa city currently managed is becoming challenging, with a big landfill laid in 33 hectares of land for the last five decades (Regassa et al., 2011).

Land filling is the easiest way of solid waste handling and disposing of waste plastic. It has considered traditionally as an easy and cheap method for disposing off all material generated by society and therefore has been and remains the dominant waste disposal option. Disposing waste plastic in landfill can elongate the decomposition of degradable materials and even cause for the ground water contamination because of leached toxic substances (Ayana, 2012).

2.3.2.3 Incineration

Incineration is one way of waste plastic disposal; it is burning of the waste until the plastic waste is burned-out and turns to ashes. This method of plastic disposal has many health risks to the human and animal. Incineration results in the release of carbon dioxide, a greenhouse gas, and of other air pollutants, including carcinogenic polycyclic aromatic hydrocarbons (PAHs), and dioxins (Shemwell and Levendis, 2011). Polystyrene is harmful to Central Nervous System. Burning of plastic leads to severe health risks such as heart diseases, aggravates respiratory ailments such as asthma and emphysema and cause rashes, nausea or headaches, damages in the nervous system kidney or liver, in the reproductive and development system.

Table 7: Compounds generated during incineration of PVC and their harm

Name of compound	**Health effects**
Acetaldehyde	It damages the nervous system, causing lesions.
Acetone	Irritates the eyes, the respiratory tract
Benzaldehyde	Irritates the eyes, skin, respiratory system, limits brain function
Benzole	Carcinogenic, adversely affects the bone marrow, the liver, the immune system.
Formaldehyde	Serious eye damage, carcinogenic, may cause pulmonary oedema.
Phosgene	Gas used in the WWI. Corrosive to the eyes, skin and respiratory organs
Polychlorinated dibenzo-dioxin	Carcinogenic, irritates the skin, eyes and respiratory system. It damages the circulatory, digestive and nervous system, liver, bone marrow.
Polychlorinated dibenzofuran	Irritates the eyes and the respiratory system, causes asthma
Hydrochloric acid	Corrosive to the eyes, the skin and the respiratory tract
Salicyl-aldehyde	Irritates the eyes, the skin and the respiratory tract It can also affect the central nervous system.
Toluene	Irritates the eyes and the respiratory tract, can cause depression.
Xylene	Irritates the eyes, It can also affect the central nervous system. Reduces the level of consciousness and impairs learning ability.
Propylene	Damages the central nervous system by lowering of consciousness

Vinyl chloride	Carcinogenic, irritating to eyes, skin and respiratory system, Effect on the central nervous system, liver, spleen, blood-forming organs

Source: **(**Agnes and Rajmund (2016) the Environmental impact of Plastic Waste Incineration)

Incinerating waste to Energy has begun in our country Ethiopia probably the first African country to use waste to produce electric energy. The cost it takes to build waste to energy facility is so expensive for most developing countries and that was why we did not have one in our continent until now. These facilities established in the periphery of the capital. Expected to have a processing capacity of approximately 1400 tons of waste a day, The project came to reality with the partnership of the Ethiopian Electric Power, Cambridge Industries Energy and the China Urban Construction Design and Research Institute, to complete this project it took four years to and needed around USD 3 billion (Samuel Getachew 25 August 2018)

2.3.2.4. Recycling

Recycling is reusing of the waste material for as its original function or for different purpose. The nature of plastic is compatible for the idea of reusing, because plastics can reshape, molded so that they can have real use.

Some of western countries like USA send its plastic waste to other countries, which recycle and use the plastic waste.

Figure 6: Countries where America sends its plastic waste

Recycling or recovery of plastic in Ethiopia performed in two ways these are formal and informal way of reusing.

Informal plastic recovery system in Addis Ababa brings several benefits to the society, from these:

- Employment opportunities to several thousands of unemployed people, which in turn reduces poverty
- Reduces the amount of waste needed to be collected, transported and disposed at the landfill
- It supplies low cost raw materials to industries, which makes the plastics factories more competitive on the market and it saves the environment from the extraction of natural resources.

In the informal plastic recovery system the collection and recovery of waste plastic performed by the workers in this system, the municipal waste management agency benefited highly from the informal way of plastic waste recovery, because municipality is not taking any action in recovery activities.

Benefits of the informal plastic recovery recycling activity in the city summarized as follows:

- Employment of people who would otherwise be unemployed
- Saves the city expenses for waste collection, transport and disposal
- Reduces the amount of waste materials requiring collection
- Supplies/substitutes raw materials for the industry
- Reduces the production costs of plastic products would otherwise have been lost.
- Environmentally beneficial in the form of reducing the amount of extracted raw materials, reducing the amount of waste in the landfill, and extending the life span of materials.
- Improves the health and safety conditions in the city(Camilla Louise Bjerkli, 2005)

It is possible to produce energy from waste plastic at the same time it reduces the amount of waste plastic that goes to land fill or incineration site.

Table 8: Annual plastic waste consumption of recycling factories in Addis Ababa

	Name of Companies			
Year	WeidongJia Plastic Recycling Co.	Asia Chemical fiber PLC	Great Wall Packing Materials Plc.	AISAI recycled plastic manufacturing Plc.
year 2012	40 tons		105 tons	
year 2013	84 tons		170 tons	
year 2014	1075 tons	175 tons	2010 tons	
year 2015	1112 tons	178 tons	2030 tons	240 tons
year 2016	1213 tons	930 tons	2080 tons	360 tons

source: Yohannes, 2017

2.3.3 Health threats of plastic waste

There are several problems associated with plastic bag and other plastic wastes. From these Varity of issues animal death, blockage of sewage systems, deterioration of natural beauty of environment and human health problems were some of the health and environmental threats (Legesse and Diriba, 2011).

If people knew how harmful burning plastic was, they would think twice before burning the waste from their house. For whatever reason our culture about wastes is to burn it, this culture has to stop. The effects of burning plastic on the environment have serious health consequences for everyone. Combustion of waste plastic could be a source of human and environmental health problems, the outcome of plastic combustion are airborne particulate emission soot and solid residue ash. Several studies have demonstrated that soot and solid residue ash possess a high potential of causing health and environmental concerns, especially Volatile organic compounds (VOCs), semi- VOCs, smoke (particulate matter), particulate bound heavy metals, polycyclic aromatic hydrocarbons (PAH's), polychlorinated dibenzo furans (PCDF's) and dioxins (Valavanidid et al 2008). This can travel thousands of kilometers, depending on prevailing atmospheric conditions and enter our food chain. Significant amount of pollutants of environmental and health concern including carcinogens such as PAH's, nitro-PAH's and dioxins have been identified in the airborne particulate emission. These particulates are highly mutagenic (Lee et al., 1995). PAHs in the range of 8-340ppm have observed in the soot, which is significant enough to cause cancer (Valavanidid et al 2008).

The most dangerous health effect of burning plastic is the release of dioxin into the atmosphere. Dioxins are extremely toxic to humans and animals. They cause cancer and hormonal birth defects that passed from generation to generation. The dioxin also ends up in the soil poisoning food for humans and animals.

Other dangers of burning plastic are as follows.

- increases risk of heart disease
- aggravates respiratory ailments such as asthma and emphysema
- causes skin rashes, nausea, or headaches
- damages the nervous system
- damages the kidneys and liver
- Disrupts the reproductive, endocrinal and development systems

2.3.4. Benefits of plastic waste

These days the new motto we are having about waste is, "waste is wealth". Waste plastic can be use repeatedly for different purposes. Waste plastics have a number of vital properties, which make them fit in different construction works. (Shweta et al,2015). Not only for construction, but also to regenerate energy from waste plastic is one of the benefits we can get.

Waste to energy recovery is the transformation of degradable and non-biodegradable waste resources to serviceable heat, electricity, or fuel by different methods, comprising combustion, gasification, pyrolysis, anaerobic digestion and landfill gas recovery. Population growth, urbanization and economic progress are likely to yield growing amounts of waste overloading on the waste disposal system (Rajasekhar et al, 2015).

On the LDPE waste plastic such as milk container cap a study to gat kerosene grade fuel was done in the process called thermal degradation. From that research the outcome was approximately 30% of the total obtained product was similar with the commercial kerosene (MoinuddinSarker et al, 2012).

2.3.5 Plastic waste for road construction

Making the road out of bitumen and waste plastic will be a huge solution to protect the environment from hazards that the plastic waste produce as well as from the carbon emission from bitumen production. Since Bitumen is a petroleum product by replacing bitumen with waste plastic, we can minimize the carbon emission. The carbon footprint of asphalt is 1.6 million tons of carbon dioxide per year, so using recycled plastic instead could help cut down on some portion of these emissions (VolkerWessels 2015).

We see roads stop giving service with in short time of their construction because of the bond between the binder and the aggregate bondage brakes easily; this is and the binding nature of plastic and being accessible as a waste is an opportunity to use it in hot asphalt mix.

Problems with using natural bitumen hot asphalt mix.

- The performance of road reduced at high temperature due to bleeding of bitumen.
- Cracking phenomenon takes place due to oxidation of bitumen.
- Potholes easily formed as bitumen strips off from the aggregate, as it is water repellent material. This reduces the life of the road constructed.
- The maintenance costs are high.

The durability of the roads lay out with a mix of shredded plastic waste much more compared with roads with asphalt with the ordinary mix. The use of modified bitumen with the addition of processed waste plastic of about 5-10% by weight of bitumen helps in substantially improving the Marshall stability, strength, fatigue life and other desirable properties of bituminous concrete mix, resulting which improves the longevity and pavement performance with marginal saving in bitumen usage(Gawande, et al 2012).

Below are the advantages of plastic-bitumen roads over natural (plain) bitumen roads.(Centre for Innovations in Public Systems (CIPS).2014)

- Overall reduction in bitumen consumption by 6-8%
- Enhanced load carrying strength and road strength (Increased Marshall Stability Value)

- Limited wear and tear thus longer life of the roads
- Prevents release of 3 tons of CO_2 (through disposal by burning) into the atmosphere
- Excellent resistance to water and water stagnation
- No stripping and potholes have been reported on sections studied
- Enhanced binding and better bonding of the mix
- Less rutting (vertical deformation of a pavement surface) and raveling (loosening of aggregate from the surface)
- Improved soundness property
- Negligible maintenance cost of the road
- No leaching (removing of substance through a chemical reaction) of plastics
- No effect of Ultra-violet radiation
- No new machinery required so any additional infrastructure or cost is not required for this technology implementation.

Many experiments at laboratory level shows that the bituminous concrete mixes prepared using the plastic treated bitumen binder satisfied all the specified Marshall Mix design criteria for surface course of road pavement. Plastic mix of bitumen asphalt road shows a significant increase in Marshall Stability value of the asphalt mix, up to two to three times advanced value in comparison with the natural or ordinary bitumen. In addition to that, the plastic mix asphalt could withstand adverse soaking conditions under water for longer duration (**Dr. S. S. Verma**2008)

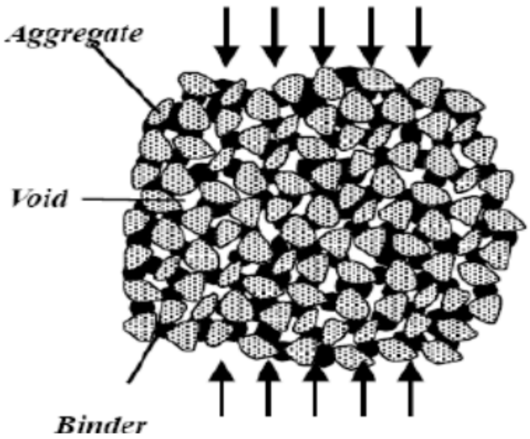
Waste plastic and bitumen mix asphalt helps to avoid the usual ways of solid waste disposal technique especially for waste plastics, which are open air burning and land filling, which have a well-known negative effect on the natural environment. In these methods of using plastic waste in a road construction it is a better way of plastic waste disposal at the same time, a better road is also constructed (Avula, 2013).

The use of waste plastic in road construction technology not only strengthened the road construction but also increased the road life as well as will help to improve the environment and also creating a source of income for the waste plastic collectors (Ahmed, April 2017).

2.4 Hot-Mix Asphalt

Hot-Mix Asphalt (HMA) is the most widely used paving material around the world. It's known by many different names: HMA, asphaltic concrete, plant mix, bituminous mix, bituminous concrete, and many others. It is a combination of two primary ingredients aggregates and asphalt binder. Aggregates include both coarse and fine materials, typically combination of different size rock and sand. The aggregate weights about approximately 95% of the weight of asphalt mix.(ASHITO, 2000b).

Figure 7: Schematic of Asphalt Mixture Materials



Binder (Bitumen)

Bitumen is a sticky, black and highly viscous liquid or semi-solid, in some natural deposits. It consisting essentially of hydrocarbons and their derivatives, which is soluble in trichloroethylene and is substantially nonvolatile, and softens gradually when heated. Possesses waterproofing and adhesive property, It is obtained by refinery processes from petroleum, and is also found as a natural deposit or as a component of naturally occurring asphalt, in which it is associated with mineral matte. It is the residue or by-product of fractional distillation of crude petroleum.

In modern integrated refinery it is a common practice to blend multiple crude oils to produce consistent quality high-grade bitumen that meets precise engineering specifications.

Bitumen manufactured from crude oil; Crude petroleum is a mixture of hydrocarbons of different molecular weights. In the petroleum refineries the individual components like naphtha, Kerosene, Diesel etc. separated through the process of fractional distillation. The heaviest material obtained from the fractional distillation process is further treated and blended to make different grades of paving grade bitumen (**Kavita and Sumesh,**2017).

Bitumen Composed primarily of highly condensed polycyclic aromatic hydrocarbons, containing 95% carbon and hydrogen 87% carbon and 8% hydrogen, up to 5% sulfur, 1% nitrogen, 1% oxygen and 2000-ppm metals. Also bitumen is Mixture of about 300 - 2000 chemical components, with an average of around 500 - 700. It is the heaviest fraction of crude oil, the one with highest boiling point (525ºC)

Bitumen is the binding agent of the asphalt mix in the asphalt concrete mix. The quality of the bitumen always affects the strength and quality of the road. Bitumen can be different in quality.

Bitumen Characteristics

Asphalt binder has the following key characteristic properties.

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

Elasticity
Elasticity is the ability of a deformed material body to return to its original shape and size when the forces causing the defamation are removed. The response to relatively small stress results in a directly proportional strain as described by Robert Hooke in Hooke's law in 1660.

Plasticity
when temperature rose as well as when a load applied to bitumen, it will flow, but will not return to its original position when load removed. This condition referred as plastic behavior.

AGGREGATE

Aggregate is one of the main components of the asphalt road, which carry the load of vehicles. **Construction aggregate**, or simply "*aggregate*", is a broad category of coarse to medium grained particulate material used in construction, including sand, gravel, crushed stone, slag, recycled concrete and geo-synthetic aggregates. Aggregates are the most mined materials in the world. Aggregates are a component of composite materials such as concrete and asphalt concrete; the aggregate serves as reinforcement to add strength to the overall composite material. Due to the relatively high hydraulic conductivity value as compared to most soils, aggregates are widely used in drainage applications such as foundation and French drains, septic drain fields, retaining wall drains, and roadside edge drains. Aggregates are also used as, base material under foundations, roads, and railroads. It helps prevent differential settling under the road or building or as a low-cost extender that binds with expensive cement or asphalt to form concrete.

Sources for these basic materials can be grouped into three main areas: Mining of mineral aggregate deposits, including sand, gravel, and stone; use of waste slag from the manufacture of iron and steel; and recycling of concrete, which is itself chiefly manufactured from mineral aggregates. In addition, there are (minor) materials that used as specialty lightweight aggregates clay, pumice, perlite, and vermiculite.

Aggregate Gradation Terms

Fine aggregate:-

Sometimes referred as "fines" Defined as natural or crushed sand passing the 4.75mm and mineral particles passing the 75um sieve (AASHTO M 147).

Coarse aggregate:-It defined by AASHTO M147 as hard durable particles or fragments of stone, gravels or slags retained on the 4.75mm sieve. Usually coarse aggregate has a toughness and abrasion resistance requirement.

Mineral filler:-

It defined by the Asphalt Institute as a finely divided mineral product at least 65 percent of which would pass through 75um sieve. Pulverized limestone is the most commonly manufactured mineral filler, although other stone dust, silica, hydrated lime, Portland cement and certain natural deposits of finely divided mineral matter are also used (Asphalt Institute, 1962).

Aggregate should have the following characteristics;

i. Be angular and not excessively flaky, to provide good mechanical interlock;
ii. Be clean and free of clay and organic material;
iii. Be strong enough to resist crushing during mixing and laying as well as in service;
iv. Be resistant to abrasion and polishing when exposed to traffic;
v. Be non-absorptive - highly absorptive aggregates are wasteful of bitumen and also give rise to problems in mix design; and
vi. Have good affinity with bitumen - hydrophilic aggregates may be acceptable only where protection from water guaranteed or a suitable adhesion agent is used (Ethiopian roads authority ERA, 2013).

Hot mix asphalt" is a term used generically to describe various types of mixtures of asphalt and aggregate that are produced using heat at a mixing plant. Different mixtures used to satisfy different performance criteria strength and waterproofing is among these. The composition of the Bitumen by mass is around 5% to 6 % (ASHITO, 2000b).

The desirable properties of Asphalt mixes are:

1. Resistance to permanent deformation: The mix should not distort or be displaced when subjected to traffic loads. The resistance to permanent deformation is more important at high temperatures.
2. Fatigue resistance: the mix should not crack when subjected to repeated loads over a period of time
3. Resistance to low temperature cracking, this mix property is important in cold regions.
4. Durability: the mix should contain sufficient asphalt cement to ensure an adequate film thickness around the aggregate particles. The compacted mix should not have very high air voids, which accelerates the aging process.
5. Resistance to moisture-induced damage
6. Skid resistance.
7. Workability: the mix must be capable of being place and compacted with reasonable effort.

8. Low noise and good drainage properties: If the mix is to be use for the surface (wearing) layer of the pavement structure

2.4.1 Modified bitumen preparation

The wet process can employ; Samples prepared, using melt-blending technique. By heating Bitumen in oven until fluid condition and adding polymer slowly, Between 160 C and 170 C. The concentration of PP and HDPE, ranged from 0.5% 3% by weight of blend with an increment of 0.5%. Mixing continued for 30mins-1hr to produce homogenous mixtures. The polymer modified bitumen (PMB) then Empirical test such as penetration, softening point and viscosity conducted on the prepared samples (Johnson , et al, 2017).

In the construction of asphalt pavement, hot bitumen coated over hot stone aggregate mixed, laid and rolled. Bitumen acts as a binder. Yet when water is stagnated over road, it penetrates and results in potholes, a defective spot on the pavement. The uses of anti-stripping agents are having limited use only and the process increases the cost of road construction (Shuler, et al1987). Use of plastic to modify the bitumen and the use of plastic coated aggregates studied to improve performance of the pavement. Bituminous mixes used in the surface course of the bituminous pavements are being improved in their performance by incorporating various types of additives to bitumen such as rubber latex, crumb rubber, styrene, butadiene styrene, styrene – ethylene –butylenes, recycled Polypropylene ,low density polyethylene, Polyethylene, Ethylene vinyl acetate (EVA) (5%) and polyolefin. Some of the properties improved are durability, fatigue life, resistance to rutting, softening point, elastic property (S.Rajasekaran, et al, 2013).

The polymer bitumen blend is a better binder compared to plain bitumen. Blend has increased Softening point and decreased Penetration value with a suitable ductility. When it used for road construction it can withstand higher temperature and load. The coating of plastics reduces the porosity, absorption of moisture and improves soundness. The polymer coated aggregate bitumen mix forms better material for flexible pavement construction as the mix shows higher Marshall Stability value and suitable Marshall Coefficient. Hence the use of waste plastics for flexible pavement is one of the best methods for easy disposal of waste plastics (**Avula, 2013)**. Use of plastic bags in road help in many ways like Easy disposal of waste, better road and prevention of pollution of the land and sea environment (Dr. R. Vasudevan, 2007).

2.4.1.1 Processes for making bitumen plastic mix

There are two main processes of making bitumen and plastic waste mix namely: Dry process and Wet process.

2.4.1.1.1 Dry process

In Dry process: The mixing of bitumen and plastic happened after the plastic coated over the heated aggregate. That means the addition of bitumen done after the mixing of the aggregate and plastic waste.

This process start with the waste plastic shredding cleaning and drying then the shredded plastic applied directly on the heated aggregate.

The temperature of the aggregate has to regulated, in order to prevent burning of waste plastic. Melting or softening of waste plastic is the way of coating the heated aggregate but not burning it. Burning of the waste plastic could force the toxic substances escape. Therefore, when we add the plastic the temperature of the aggregate heated should be approximate to 170^0c this would avoid the chance of burning the plastic. The bitumen that added on the top of plastic and aggregate mix has to be heat around 160^0c. After both plastic and bitumen mixed with aggregate should be laid on the road that we wanted to make a flexible asphalt road. The aggregate when coated with plastics improved its quality with respect to voids, soundness and moisture absorption and decreases porosity and thus the performance of the pavement is increased (Anzar, 2015).

Table 9: Toxic gases released above the deception temperature

Plastic	toxic gases released	T (0C)
Polyethylene Terehathalate (PET)	Light hydrocarbons (C5-C10)	>200
Polypropylene(PP)	C_2H_6	270-300
Poly vinyl Acetate (PVA)	CH_3COOH	>190
Poly vinyl chloride (PVC)	HCL	250
Polystyrene(PS)	C_6H_6	300-350
Low Density Polyethylene(LDPE)	CH_4C2H_6	270-350
High Density Polyethylene(HDPE)	CH_4C_2H7	270-350

Source: (Centre for Innovations in Public Systems (CIPS).2014)

Table 10: Softening point of waste plastic and toxic gas released at that temperature

Polymer	**Softening Temp (0C)**	**products reported**	**Decomposition temp (0C)**	**Examples**
Polyethylene	100-120	no gas	270-350	Bags, sacks, Detergent bottles
Polypropylene	140-160	no gas	270-300	Film wrapping of biscuits, chips
Polystyrene	110-140	no gas	300-350	Disposable glasses

Source (Menaria and Sankhla, 2015).

In Dry process, aggregate is, modified by coating with plastic and producing a new modified raw material for flexible pavement. Coating of plastic (PET) on the surface of the aggregate has resulted in many advantages and ultimately helps to improve the quality of flexible pavement. The coating of plastics over aggregate also improves the quality of the aggregate. In addition to the improvement of the quality of the road, this technology has helped to use the waste plastics obtained from domestic and industrial packing materials. By this technique, which is in-situ, waste polymer like, carry bags, foam, laminated sheets, cups used for road laying. Moreover, the use of polymers helps to reduce equivalent quantity of bitumen, thus reducing the cost of the road laying (S.Rajasekaran 2013).

"The dry process gives a blend with better binding property, a larger surface area of aggregate is available for mixing. Aggregate coated with plastic waste and plain bitumen show zero stripping even after 72h. Other properties like soundness, moisture absorption and voids formation are also minimized and no pot hole formation is observed on roads processed in this way" (Sandhya andDeepak, **2013**).

According to S.Rajasekaran 2013,In a net shell the Dry Process helps to

- Use higher percentage of plastics waste.
- Reduce the need of bitumen by around 10%.
- Increase the strength and performance of the road.
- Avoid the use of anti-stripping agents.
- 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.
- Develop a technology, which is eco-friendly.

Advantages of Dry process

- As the plastic coated over the aggregates, thus surface property of aggregates is improved.
- Binding property of aggregates doubled and aggregates show increased strength.
- No degradation of roads even after years of construction
- It reduces need of bitumen by around 10%.
- Use of waste plastic more than 15% is possible.
- Flexible films of all types of plastics can be used
- No new equipment is required.
- Bitumen bonding is strong than normal.
- The coated aggregates show increased strength.

- Replacing bitumen to 15%, higher cost efficiency is possible (Gawande, 2012).

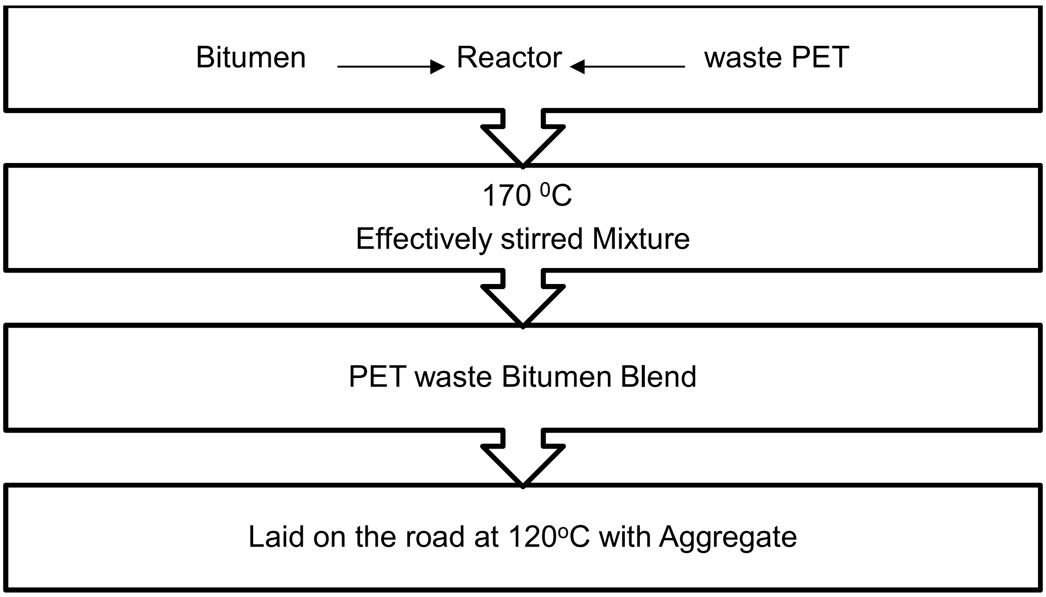
Disadvantage of Dry process

- only aggregate coated
- Bitumen is not modified

2.4.1.1.2 Wet process:

Wet process is the most common method of polymer modification of bitumen. This process used to mix the waste plastic and bitumen. This days many countries are using waste plastic in the making of asphalt road, and the method of mixing the plastic waste with bitumen is wet method. The wet process used mostly in Australia, South Africa and USA (Mohammad, 2012).

Figure 8: Flow chart for wet process



Advantages of Wet Process:

- This Process can be utilized for recycling of any type, size, shape of waste material like Plastics, Rubber and etc. (Anzar 2015,Gawande, 2012).

Disadvantages of Wet Process:

- Time consuming- more energy for blending.
- Powerful mechanical is required.
- Additional cooling is required as improper addition of bitumen may cause air pockets in roads.

Types of wet process: (Mohammad, 2012)

- Chemical reaction process,
- Gelatin process and
- Blending process

Chemical Reaction Process:

Polymer chemically reacts with bitumen and produces blend. The process is performing at the refinery. Obtained blend from this method has higher storage stability.

Gelatin Process:

Here polymers do not react with bitumen. Polymer dispersed in to the bitumen to form a two-phase homogeneous mixer.

Blending Process:

This process is suitable for scrap polymer and rubber. Polymer/rubber cooked in the bitumen in this process. This method requires a blending/cooking system. Major parts of the blending equipment are a container, a mechanical stirrer with shear blade and controlled heating facilities. Bitumen heated in the container to make it liquid. Then the polymer in particular form (powder, shredded, pellet, latex) added to the bitumen and stirring continued up to completion of blending. Required blending time, temperature and speed of stirrer depend on the type of polymer used. The drawback with these systems is that mixing uniformly is difficult and often the result is significant segregation of waste plastic.

In wet process Blending method, Plastic waste is grinded and made into powder 6 to 8%. Then the powder form or shredded Plastic added to the bitumen at 160’C. The process did not yield a homogenous mix with prominent separated solid deposits of mix therefore wet process was not adopted and another waste material (crumb rubber) has been adopted to add to it (Anzar, 2015).

2.4.2 Properties of Plastic waste road

- Resistance to permanent deformation: The mix should not distort or be displaced when subjected to traffic loads. The resistance to permanent deformation is more important at high temperatures.
- Fatigue resistance: the mix should not crack when subjected to repeated loads over a period of time
- Resistance to low temperature cracking, this mix property is important in cold regions.
- Durability: the mix should contain sufficient asphalt cement to ensure an adequate film thickness around the aggregate particles. The compacted mix should not have very high air voids, which accelerates the aging process.
- Resistance to moisture-induced damage

- Skid resistance.
- Workability: the mix must be capable of being placed and compacted with reasonable effort.
- Low noise and good drainage properties: If the mix is to be used for the surface (wearing) layer of the pavement structure, (Marshall Method Of Asphalt-Concrete Mix Design).

Studies on 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 (S.Rajasekaran, 2013).

The maintenance cost of the road will come down, as the road's life increased by 2 to 3 times .The durability of the roads lay out with PET is, more compared with roads with asphalt with the ordinary mix (Anzar, 2015).

2.4.3 Processes and methods of testing the sample

There are different techniques and steps for modified plastic asphalt road preparation. Starting from the sample collection and clearing the dirt on it, to the size the plastic waste has to shred since it affects the creation of a homogeneous mixing between the plastic waste and the bitumen. Different studies have shown the effective method for the use of plastic waste into bitumen for road laying and Polymer-bitumen mixtures of different compositions, (Sundaram&Rojasay2008).

The entire laboratory tests are, based on AASHITO and ASTM specification.

The following laboratory tests conducted to understand the nature of the modified bitumen (waste plastic and bitumen mix) and to find out the load bearing capacity of the modified asphalt.

1. Penetration test of Plastic Bitumen
2. Softening point of Modified plastic Bitumen, and finally
3. Ductility of Modified Plastic Bitumen
4. Marshall Stability test of Modified Plastic Bituminous aggregate Mixture.

To proceed the above tests, except the Marshal Stability test a wet process would be employed for preparation of modified bitumen. Wet method is a preparation of modified Bitumen mix by directly adding the shredded waste plastic on the heated Bitumen. Samples will be prepared, using melt-blending technique.

For Marshall Stability we use both Wet and Dry process, to find out the load baring capacity.

The following are the procedures for the modified bitumen preparation at laboratory.

- The first step will be heating Bitumen with a known weight in oven until it reach fluid condition
- Add the shredded plastic slowly. The added plastic waste has to be in some percent by weight of the Bitumen.
- Mixing the plastic and the bitumen until we get uniformity in the plastic distribution at temperature, between 160 C and 170 C, the polymer modified bitumen (PMB) then sealed in containers and stored for further testing.
- Empirical test such as penetration, softening point and viscosity and ductility will be conduct on the prepared samples.

2.4.3.1 Specimen Mixing

The Polymer Modified Bitumen (PMB) should be heated using indirect source of heat. The recommended heating temperature for binder is 177±5°C and for aggregate is150±3°C. Binder should stir to avoid local overheating. Mixing of the PMB and aggregate should performed using standard mechanical mixer. Vigorous manual mixing may be acceptable also. Mixing should perform immediately after the addition of binder to the aggregate. Maximum mixing time should not exceed two minutes. If complete coating of aggregate cannot be achieved within mixing time, one or more of the following parameters should be adjusted(Mohammad, 2012).

- The content of binder should be increased
- Increase binder temperature to reduce viscosity
- The rubber content in bitumen should be decreased

2.5 Results found from different literatures

The increase in percentage by weight of plastic decreased the penetration value of the bitumen plastic mix. This shows that the addition of polymer increases the hardness of the bitumen. The penetration values of the blends are decreasing depending upon the percentage of polymers and the type of polymer added. The ductility decreased by the addition of plastic waste to bitumen. The decrease in the ductility value is because of interlocking of polymer molecules with bitumen (**Avula, 2013**).

Table 11: Comparison between ordinary roads and plastic waste roads

Sr. NO	Properties	Ordinary roads	Plastic waste roads
1	tensile strength	Less	High
2	Softening point	More	Less
3	Binding property	Good	Better
4	Cost of pavement	Normal	Less
5	Seepage of water	Yes	No
6	Stripping (potholes)	More	No
7	Durability of road	Good	Better
8	Environment friendly	No	Yes
9	maintenance cost	More	Less
10	Marshall Stability Value	Less	More

source: (I. Ali, et.al, 2018).

Table 12: Compressive &Bending strength of asphalt concrete made from plastic waste and bitumen.

% of plastic coating over aggregate	Compressive strength (MPa)	Bending strength (MPa)
10%	250	325
20%	270	335
30%	290	350
40%	320	390

source: Shweta, et al. 2015

Table 13: Plastic road performance summery of Indian city

Roads	Year laid	Characteristics of the road
Jumbuligam road, chennel	2002	No pothole, cracking, deformation or edge flaw
Veerbadhra street road	2003	No pothole, cracking, deformation or edge flaw
vandiyurman road	2004	No pothole, cracking, deformation or edge flaw
vilachery main road	2005	No pothole, cracking, deformation or edge flaw
Canteen road	2006	No pothole, cracking, deformation or edge flaw
Thyagaraja college of enginering Madurai	2002	No pothole, cracking developed, road is in good condition
Lenin street, Kovilpatti	2002	No pothole, cracking , rutting developed,
Mannar college road Madurai	2002	No pothole, cracking developed, road is in good condition
Brindavanam street, Salem	2003	No pothole, cracking developed, road is in good condition
Bharat petroleum plant, Tanjiore	2004	Road functioning is satisfactory
Parry and Co,Ranipet,Chennai	2003	Road condition is good and stable
Asaripallam,Nagercoil	2003	Road condition is good and stable
Kuzhithuria,nagercoil	2003	No pothole cracking Road condition is good and stable
New prabhadevi road, Mumbai	2004	No pothole cracking Road condition is good and stable

Source:(Centre for Innovations in Public Systems (CIPS).2014).

Chapter 3
Materials and methodology

3.1 Materials

The materials used in this research are...

- Bitumen with grade of 60/70,
- Aggregate.
- Plastic waste (PET)
- cement

Each material in the above list has its own role in the asphalt road construction. The waste plastic and bitumen have the role of

- binding the aggregate together,
- waterproofing the surface of the road and
- Providing of additional stiffness is among their roles.

Selection of the appropriate aggregate blend is very important, even more important than the binder selection.

The structure of the aggregate plays very important role in carrying the load.

The aggregate must have high internal friction to develop the degree of inter lock to resist shearing or rutting, and the aggregates must be durable.

3.1. 1PLASTIC

The waste plastic used in this research is Polyethylene terephthalate (PET) which is collected from the local company called Roha pack located around Gerji. This company collects water bottles from the waste collectors around the city. After the waste plastic bottles reach in the company the collected Plastic waste (water bottle) sorted as per their color. Here the trade mark on the water bottle must be removed because the nature of the bottle and the tin film is different form of plastic which is Polyethylene Teryphthalate(PET) and Low density polyethylene (LDPE) respectively.

The company then shredded the waste bottles in to smaller pieces and put it in the big bathing thank for the final cleaning. After they let it dry, it would be pack for export. Mostly the company exports the shredded plastic bottles to china.

Figure 9: Inside of Roha pack shredding and bathing unit

3.1.2 BITUMEN

The bitumen used in this research is of grade 60/70. I have collected it from Ethiopian construction Work Corporation. Grade 60/70 chosen because it is the most used type of bitumen in our country. The grading of the bitumen is based on, the penetration value.

Various grades of bitumen used for pavement purpose.

- **Grade 30/40:** These are the thicker material having higher softening point and these are used in high temperature regions
- **Grade 60/70:** These are semi viscous material having moderate softening point. It is widely used because of its availability & cheaper cost. It is a best suitable material in roads and highways of Ethiopia.
- **Grade 80/100:** This type of bitumen is thinner material and used in tropical regions, It has lower softening point

Table 14: Properties of natural bitumen

Characteristic properties of natural bitumen	Grades of bitumen		
	30/40	**60/70**	**80/100**
Specific gravity	0.99	0.99	0.99
Water content	0.2	0.2	0.2
Softening point (^oC)	50-65	40-55	35-50
Penetration point (100 g/5 sec)	30-40	60-70	80-100
Ductility (cm)	50	75	75
Flash point ^oC	175	175	175
Solubility in CCl3	99%	99%	99%
solubility in CS2	99%	99%	99%

3.1.3 AGGREGATE

Natural mineral aggregate Granite was used in this research. The Average Specific gravity of this aggregate was 2.8

For each sample, we need 1200 gm of aggregates and filler to produce the desired thickness (Marshal Method of asphalt-concrete mix design Chapter 11).

The aggregate used in this research, collected from a local construction company called Ethiopian construction Work Corporation.

Aggregate size affects the amount of binder-needed in road construction. It also affects the load bearing capacity. To get the good aggregate gradation (size) lots of sieving and weighting has been done.

The shape of an aggregate also has effect on the compactness and coherence of the mix. Aggregates having shapes as below was where selected out and remover from the mix.

Round - loosing edges and corners

Angular - well defined edges and corners

Elongated- when length is considerably larger than the other two dimensions

Flaky or **flat**- when thickness is small relative to two other dimensions

Table 15: Aggregate used in the Marshall Mix

Sieve size	Total aggregate retained in grams (g)
25	12
19	42
9.5	249
4.75	237
2.36	224
0.3	334
0.075	52
Pan	30
Filler	20
Total Sum	1200

3.2 Methods

All laboratory studies had carried out at the highway lab of Addis Ababa institute of technology.

In this research, we have tried to see the quality of the modified bitumen, which is a mix of bitumen and waste plastic (PET). Therefore, we have performed a bitumen quality test on the modified bitumen.

To do so we have used different composition of PET by weight of bitumen. Which is starts from 2% and increased by two. So the composition by weight of the PET we used was 2%, 4%, 6%, and 8%.

We have also done the Marshall Stability test on the load caring capacity of the natural bitumen and on modified bitumen mix of asphalt concrete.

Finally we have performed the Marshall Stability test on a sample prepared in Dry and Wet methods of mixing PET. At 8% and 10% by weight of bitumen in wet and Dry, process respectively.

Therefore, The load baring capacity of the mix have checked at 8% PET by weight of bitumen in Wet process since it is the best result found on the binder quality test.

Then it was 10 % PET by weight of bitumen but this time it is in Dry process. This has given a chance to compare from the two methods.

Finally, stability at 12 gram of PET added checked. Which was done for further investigate the potential of this practice in consuming more PET.

3.2.1 Specimen mixing of bitumen and PET

To start the lab work shredded plastic waste (PET) was collected from the company called Roha Pack. Since the size of plastic from the company have different size, it needs sieving and take a sample that passes sieve size 2.36 mm. The fineness of the waste plastic the easier to make homogeneous mix, from experience taking of larger size waste plastic in my case PET, is not preferable since the bond in the PET is strong it makes it difficult to mix it with the bitumen.

Generally, polyethylene shredded as small as possible is better for the further process. Less micron plastic is easily mixable in the bitumen at higher temperature (160°c-170°c). It is clean by de-dusting or washing if required.

Firstly, Bitumen heated to the temperature about 160°c-170°c, which is its melting temperature. Pieces were added slowly to the hot bitumen of temperature around 160-170°c.The mixture was stirred manually for about 20-30 minutes. In that period, temperature was kept constant about 160-170°c.

PET-bitumen mixtures of different compositions were prepared and used for carrying out tests that shows the bitumen quality.

The following laboratory test where conducted to understand the nature of the modified bitumen (waste PET and bitumen mix) and to find out the load bearing capacity of the modified asphalt concrete.

Penetration test of Plastic Bitumen

Softening point of Modified plastic Bitumen, and finally

Ductility of Modified Plastic Bitumen

Marshall Stability test of Modified Plastic Bituminous aggregate Mixture.

The entire laboratory test, were based on AASHITO and ASTM specification since Ethiopian Road Authority ERA uses most of AASHITO and ASTM specifications.

To proceed the above tests, except the Marshal stability test a wet process had been employed for preparation of modified bitumen .Wet method is a preparation of modified Bitumen mix by directly adding the shredded waste plastic on the heated Bitumen. Samples with different plastic waste composition where prepared, using melt-blending technique.

The following are the procedures for the modified bitumen preparation at laboratory.

- The first step was washing the shredded PET to avoid a possible presence of dust particles since that alter the result.
- Let the washed PET to dry.
- Heat natural bitumen with a known weight in oven until it reaches fluid condition. 300 g of bitumen have used in each metal bowl that used to melt the bitumen.
- Add the shredded plastic slowly. Adding all the plastic waste all at a time would cause for the sticking of the powdered plastic PET together and make it difficult to separate them in the mixing process. That in turn makes it hard to get homogeneous mixture of the plastic and bitumen. The added plastic waste has to be in some percent by weight of the PET added. To avoid the sticking of PET together because of adding it once, add 25% at a time.
- Mixing the plastic and the bitumen until uniformity in the plastic distribution occur at temperature, between 160 ^{0}C and 170 ^{0}C.
- The polymer-modified bitumen (PMB) then sealed in containers and stored for further testing. Empirical test such as penetration, softening point and ductility where conducted on the samples that have been prepared in the above procedures.

Figure 10: Sample preparation

(A) Sieved PET (B) weighted samples

3.2.2 Penetration Test

Penetration measures the hardness or softness of the plastic and bitumen mixture by measuring the depth in tenths of a millimeter to which a standard loaded needle will penetrate vertically in 5 seconds.

The equipment, penetrometer consists of a needle assembly with a total weight of 100g and a device for releasing and locking in any position.

The bitumen softened to a pouring consistency stirred thoroughly to avoid the presence of any air voids in the sample and poured into containers at a depth at least 15 mm in excess of the expected penetration. The test conducted at a specified temperature of 25^0C.

It may be noted that penetration value is largely influenced by any inaccuracy with regards to pouring temperature, size of the needle, weight placed on the needle and the test temperature.

3.2.2.1 Procedure of Penetration Test

- Soften the modified bitumen above the softening point (between 75 and $100^{o}C$). Stir it thoroughly to remove air bubbles and water.
- Pour it into a container to a depth of at least 15mm in excess of the expected penetration.
- Cool it at an atmospheric temperature of 15 to $30^{o}C$ for 1 1/2 hours. Then place it in a transfer dish in the water bath at 25.0 + $0.1^{o}C$ for 1 1/2 hrs.
- Keep the container on the stand of the penetration apparatus.
- Adjust the needle to make contact with the surface of the sample.
- Adjust the dial reading to zero.
- With the help of the timer (stopwatch), release the needle for exactly 5 seconds.
- Record the dial reading.

  In hot climates, a lower penetration grade is preferred.

Figure 11: Penetration testing

3.2.3 Softening Point Test

Softening point denotes the temperature at which the bitumen attains a particular degree of softening under the specified condition of test.

If it is add more polyethylene, terephthalate (PET) in the sample for the softening point test the softening point also increased due to the high viscosity of the bitumen mix. Studies showed that polyethylene terephthalate (PET) modified bitumen has a higher softening point compared to natural bitumen or unmodified bitumen, also it showed better or higher softening point than sample modified with polypropylene (PP) (Mushtaq and MohamadApril 2015).

The test conducted by using Ring and Ball apparatus. A brass ring containing test sample of bitumen suspended in liquid like water or glycerin at a given temperature, a steel ball placed upon the bitumen sample and the liquid medium heated at a rate of 5^0C per minute. Temperature is noted when the softened bitumen touches the metal plate which is at a specified distance below.

Generally, higher softening point indicates lower temperature susceptibility and is preferred in hot climates.

The apparatus required for this test:-

i. Ring and ball apparatus
ii. Thermometer – Low Range: - 2 to 80^{o}C, Graduation 0.2^{o}C – High Range: 30 to 200^{o}C, Graduation 0.5^{o}C.

3.2.3.1 Preparation of sample

i. The sample should be just sufficient to fill the ring. The excess sample should be cut off by a knife
ii. Heat the waste plastic modified bitumen between 75 and 100oC. Stir it to remove air bubbles and water.
iii. Heat the rings and apply glycerin. Fill the material in it and cool it for 30 minutes.
iv. Remove excess material with the help of a warmed, sharp knife.

Figure 12: measuring the temperature of the modified bitumen sample

3.2.3.2 Procedure to determine Softening Point of Bitumen

Materials of softening point below 80^{o} C:

i. Assemble the apparatus with the rings, thermometer and ball guides in position.
ii. Fill the beaker with boiled distilled water at a temperature 5.0 ± 0.5^{o}C per minute.
iii. With the help of a stirrer, stir the liquid and apply heat to the beaker at a temperature of5.0 ± 0.5^{o}C per minute.
iv. Apply heat until the material softens and allow the ball to pass through the ring.
v. Record the temperature at which the ball touches the bottom, which is nothing but the softening point of that material.

Figure 13: preparation and measuring of softening point

(A) Measuring softening point **(B)** preparing for softening point test

3.2.4 Ductility Test

This test described in AASHTO T 51. Ductility is the property of bitumen that permits it to undergo great deformation or elongation. Ductility defined, as the distance in cm, to which a standard sample or briquette of the material will be elongated without breaking. Dimension of the briquette thus formed is exactly 1 cm square. The bitumen sample is heated and poured in to the mold assembly placed on a plate, these samples with molds are cooled in the air and then in water bath at 27^0C temperature. The excess bitumen cut and the surface leveled using a hot knife, then the molds with assembly containing sample kept in water bath of the ductility machine for about 90 minutes. The sides of the molds removed, the clips are hooked on the machine and the machine operated. The distance up to the point of breaking of thread is the ductility value, which reported in cm.

The ductility values affected by factors; such as pouring temperature, test temperature, rate of pulling etc. A minimum ductility value of 75 cm

3.2.4.1 Procedure to determine the Ductility of Bitumen

- Completely melt the Modified bituminous material to be test by heating it to a temperature of 75 to 100^oC above the approximate softening point until it becomes thoroughly fluid. Assemble the molds on a brass plate and in order to prevent the material under test from sticking, thoroughly coat the surface of the plate and the interior surfaces of the sides of the molds with a mixture of equal parts of glycerin and dextrin. While filling, pour the material in a thin stream back and forth from end to end of the molds until it is more than level full. Leave it to cool at room temperature for 30 to 40 minutes and then place it in a water bath maintained at the specified temperature for 30 minutes, after which cut off the excess bitumen by means of a hot, straight-edged putty knife or spatula, so that the molds is just level full.
- Place the brass plate and molds with briquette specimen in the water bath and keep it at the specified temperature for about 85 to 95 minutes. Remove the briquette from the plate; detach the side's pieces and the briquette immediately.
- Attach the rings at each end of the two clips to the pins or hooks in the testing machine and pull the two clips apart horizontally at a uniform speed, as specified, until the briquette ruptures. Measure the distance in cm through which the clips have pulled to produce rupture.
- While the test is being done, make sure that the water in the tank of the testing machine covers the specimen both above and below by at least 25mm and the temperature is maintained continuously within ± 0.5^oC of the specified temperature.

Figure 14: Ductility test preparation

(A) (B)

(C)

3.2.5 Marshall Mix design

Marshall Mix design is a practice used to find economical and applicable binder (Bitumen) content in the pavement mixture. Bituminous mixes (asphalt mixes) are used in the surface layer of road pavements. The mix is composed usually of aggregate and asphalt cements. The design of asphalt paving mix is largely a matter of selecting and proportioning constituent materials to obtain the desired properties in the finished pavement structure.

In this method, the resistance to plastic deformation of a compacted cylindrical specimen of bituminous mix measured when the specimen is loaded diametrically at a deformation rate of 50 mm per minute.

To do the martial mix design we need to consider the following, so that our design can fulfill the quality we wanted.

Stability

The ability to withstand traffic loads without distortion or deflection, especially at higher temperatures.

To get good stability, we need to use strong, rough, dense-graded, cubical aggregate with just enough binder to coat the aggregate particles. Excess modified bitumen or too much of plastic lubricates the aggregate particles and lets them slide past each other more easily (which reduces stability). But a thick asphalt coating provides good flexibility to resist cracking, which is desirable.

Workability

The ability to be placed and compacted with reasonable effort and without segregation of the coarse aggregate.

Too much of modified bitumen or plastic waste makes the mix weak. Too little of it also makes it hard to compact. Too much natural sand can also make the mix weak because natural sand has smooth, round grains.

Skid Resistance

Skid resistance is the capability of a pavement to resist the frictional force from vehicle's wheel when brake applied. Proper traction in wet and dry conditions to get good skid resistance, use smaller aggregate so there are many contact points, use hard aggregate that does not polish and make sure you have enough air voids to prevent bleeding. Some states now use an open-graded friction course (OGFC) that allows water to drain to the sides of the pavement, eliminating hydroplaning. However, OGFC is not very durable because of the open pores.

Durability

It is the ability to resist aggregate breakdown due to wetting and drying, freezing and thawing, or excessive inter-particle forces.

To get good durability, use strong, tough, nonporous aggregate and enough asphalt cement to completely coat all of the aggregate particles (to keep them dry) and fill all of the voids between particles (to slow the oxidation of the asphalt cement). However, this reduces stability.

Stripping

Separations of the asphalt cement coating from the aggregate due to water getting between the asphalt and the aggregate. To reduce stripping, use clean, rough, hydrophobic aggregate and add enough asphalt cement to provide a thick coating of asphalt on every aggregate particle. This improves durability but decreases stability.

Fatigue Cracking

Cracking resulting from repeated flexure of the asphalt concrete due to traffic loads.
To minimize fatigue cracking, use the proper bitumen grade and have a thick coating of binder over the aggregate to make the mix flexible. This improves durability but decreases stability.

Thermal Cracking

Cracking that results from an inability to acclimate to a sudden drop in temperature.
To minimize thermal cracking, use the proper binder grade.

3.2.5.1 Marshall Mix Design Steps

1. Create aggregate blend to meet gradation specifications.
2. Establish mixing and compaction temperatures from the viscosity-temperature chart.
3. Compact three specimens at each of five asphalt contents spanning the expected optimum asphalt content.
4. Measure the performance properties of each specimen at 60ºC (140ºF).

In the laboratory, the aggregate, binder and plastic were respectively mixed and compacted. The mixes were compacted with 75 blows on each side with the standard Marshall hammer to avoid disintegration of materials and to remove voids in the sample.

After compaction, the specimens removed from the molds by using sample extractor, and allowed to cool.

3.2.5.2 Marshall Stability of plastic modified Bitumen Mixture

The coarse aggregate, fine aggregate, and the filler material proportioned to fulfill the requirements of the relevant standards. The required quantity of aggregate mix 1200g, taken to produce compacted bituminous mix specimens of thickness around 63 mm approximately.

1200 gm of aggregates and filler are prepared for each specimen to produce the desired thickness of 63.5±3mm and around 10.16 cm of diameter.

The aggregates heated to a temperature to 170°C over the cores of 24 hours.

The compaction mould assembly and rammer are cleaned, and kept pre-heated to a temperature of 100°C to 145°C,

The bitumen has heated to a temperature of 160°C and the required amount of first trial of bitumen has added, to the heated aggregate and thoroughly mixed. The mix has placed in a mould and compacted with number of blows specified 75 in both faces of the sample.

The sample taken out of the mould after few minutes using sample extractor

This test has done to determine the Marshall stability of bituminous mixture. The principle of this test is the resistance to plastic flow of cylindrical specimens of a bituminous mixture loaded on the lateral surface. It is the load carrying capacity of the mix at $60^{o}C$ and it measured in KN.

Apparatus:

1) Mold Assembly: cylindrical molds of 10 cm diameter and 7.5 cm height consisting of a base plate and collar extension.
2) Sample Extractor: for extruding the compacted specimen from the molds.

3) Compaction pedestal and hammer
4) Breaking head
5) Loading machine
6) Water bath, thermometer

Figure 15: Mixing machine

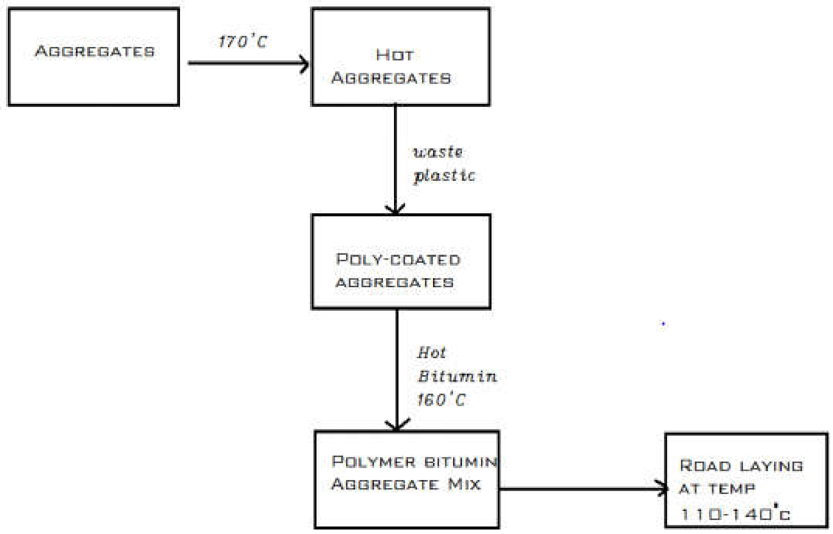
3.2.6 Procedure to determine Marshall Stability of natural bitumen asphalt mixture

I. Heat the weighed aggregates and the bitumen separately up to 170°C and 163°C respectively.
II. Mix them thoroughly, transfer the mixed material to the compaction mold arranged on the compaction pedestal.
III. Give 75 blows on the top side of the specimen mix with a standard hammer (45cm, 4.86kg). Reverse the specimen and give 75 blows again. Take the mold with the specimen and cool it for a few minutes.
IV. Remove the specimen from the mold by gentle pushing. Mark the specimen and cure it at room temperature, overnight.
V. A series of specimens are prepared by a similar method with varying quantities of bitumen content, with an increment of 0.5% (3 specimens) or 1bitumen content.
VI. Before testing of the mold, keeps the mold in the water bath having a temperature of 60°C for half an hour. Check the stability of the mold on the Marshall Stability apparatus.

3.2.7 Procedure to determine Marshall Stability of Plastic mixed on heated aggregate. (Dry process)

The above procedure is for natural bitumen and aggregate martial mixing. For Dry process of martial mixing, we follow same procedure except we add the waste plastic on the heated aggregate.

Figure16: Flow chart of Dry process of mixing aggregate, plastic and bitumen



I. Heat the weighed aggregates up to 170^{o}C.
II. Add the shredded waste plastic on the top of heated aggregate and mix it until the plastic melt and over coat the aggregate.
III. Heat the natural bitumen up to 160^{0}C and add on the plastic coated aggregate.
IV. Mix them thoroughly, transfer the mixed material to the compaction mold arranged on the compaction pedestal.
V. Give 75 blows on the top side of the specimen mix with a standard hammer (45cm, 4.86kg). Reverse the specimen and give 75 blows again. Take the mold with the specimen and cool it for a few minutes.
VI. Remove the specimen from the mold by gentle pushing. Mark the specimen and cure it at room temperature, overnight.
VII. A series of specimens have prepared by a similar method with varying quantities of bitumen content, with an increment of 0.5% (3 specimens) or 1bitumen content.
VIII. Before testing of the mold, keeps the mold in the water bath having a temperature of 60^{o}C for half an hour. Check the stability of the mold on the Marshall Stability apparatus.

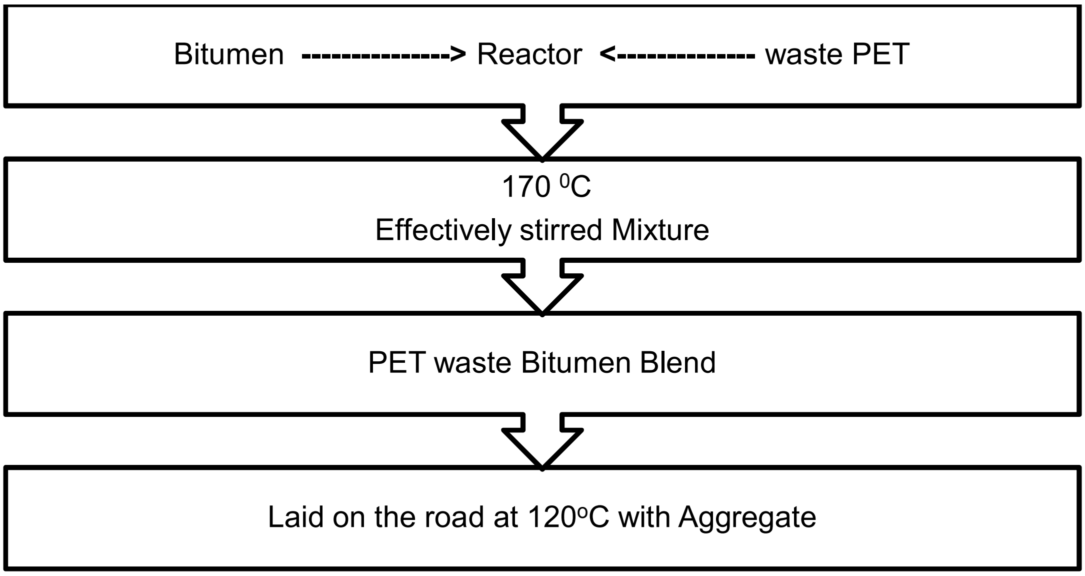
Binder should stir constantly to avoid local overheating. Mixing of the PMB and aggregate should have performed using standard mechanical mixer. Vigorous manual mixing may be acceptable also. Mixing should have performed immediately after the addition of binder to the aggregate. Maximum mixing time should not exceed two minutes. If complete coating of aggregate is not be achieved within mixing time, one or more of the following parameters should be adjusted.

- Increase the amount of binder.
- Reduce viscosity by increasing binder temperature
- The plastic content in bitumen should be decreased

3.2.8 Marshall mixing of PET modified bitumen and aggregate Wet process.
Here we follow the same steps like that of doing Marshall mixing of Aggregate and natural bitumen.
The Polymer Modified Bitumen (PMB) should be heated using indirect source of heat. The recommended heating temperature for binder is 177±5°C and for aggregate is170 C.
Binder should have stirred to avoid local overheating. Mixing of the PMB and aggregate should have performed using standard mechanical mixer. Mixing should be immediately after the addition of binder to the aggregate. Maximum mixing time should not exceed two minutes, otherwise cooling of the sample can occur and it would be difficult to cover the aggregate surface with the PMB.
If coating of aggregate surface with plastic modified bitumen cannot be achieved within mixing time, which is two minutes, as of the natural bitumen and aggregate mixing we should we should consider the following one or more parameters.

- The content of binder should be increased
- Increase binder temperature to reduce viscosity
- The plastic content in bitumen should be decreased

Figure 17: Flow chart of Wet process



There are two forms of resistance, frictional or interlocking and cohesive resistance. Frictional or interlocking resistance is dependent on the aggregate framework. Cohesive resistance develops in the bitumen-binder portion of the mixture. It depends on the rate of loading, load and temperature. High stability is undesirable if it is due to high density and low voids. Mixtures of this type have an excess of filler and are deficient in bitumen. Such surfaces will have low resistance to cracking, are brittle in the cold time of the year, and tend to scrambling under traffic.

Figure 18: Sample compacting machine

Figure 19: samples ready for stability test.

3.2.9 Stability test

Stability is a measure of resistance to deformation. The stability value increases with increasing asphalt content up to a maximum after which the stability decreases. Cases are common where no stability peak obtained. It is necessary to have sufficient stability to meet the requirements of traffic without mat distortion or displacement.

In the stability test, the specimens were prepared with the specified temperature by immersing in a water bath at a temperature of 60°C±1°C for a period of 45 minutes. Then it placed in the Marshall Stability testing machine and loaded at a constant rate of deformation of 50.8 mm/minute until the maximum load reached.

Figure 20: Samples socked under water for

45 min. at a temperature of 60^{o}c

Figure 21: Marshall Stability measuring

Table 16: weight of Sample

S. No	Bitumen content (%)	weight of mix (g)	weight in air (g)	Weight in water (g)
1	4	1248	1249	729
2	4.5	1253.5	1255	733
3	5	1259	1261	739
4	5.5	1265.5	1267	746
5	6	1272	1273	750

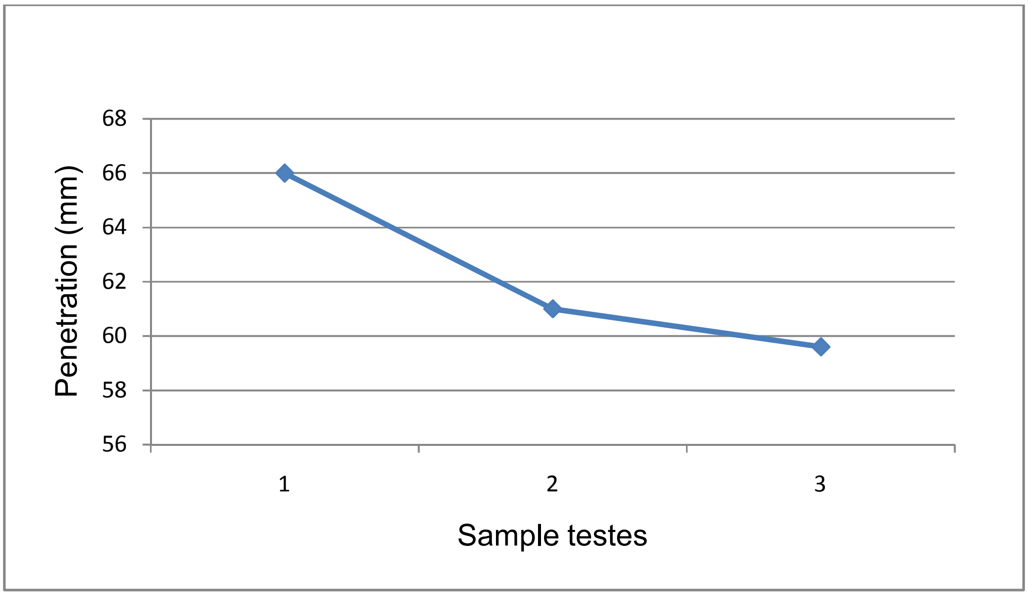
Chapter 4
Result and Discussion

4.1 Result

Increasing in percentage of plastic waste highly influences the penetration, Ductility and Softening point value of the modified bitumen.

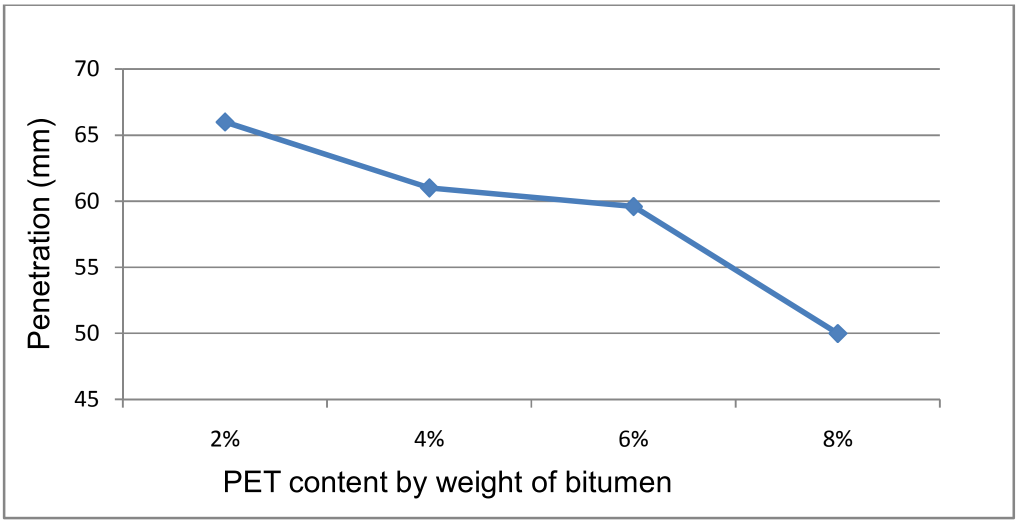
4.1.1 Penetration Test Results

Figure 22: Chart of penetration result on natural bitumen



For penetration test on natural bitumen, the sample had tested three times. These sample testes were from the same source and had same weight. As it seen on the chart, the penetration result is not the same, for all the three samples. This is because sometimes the temperature gradient along the sample will not be the same. When the sample tested on the center, the result would be less than the result when tested on the periphery of the sample container. This is because the temperature could be less at the center than that of the periphery of the sample. However, the penetration value of the 60/70 grade bitumen can range from 60mm to 70mm.

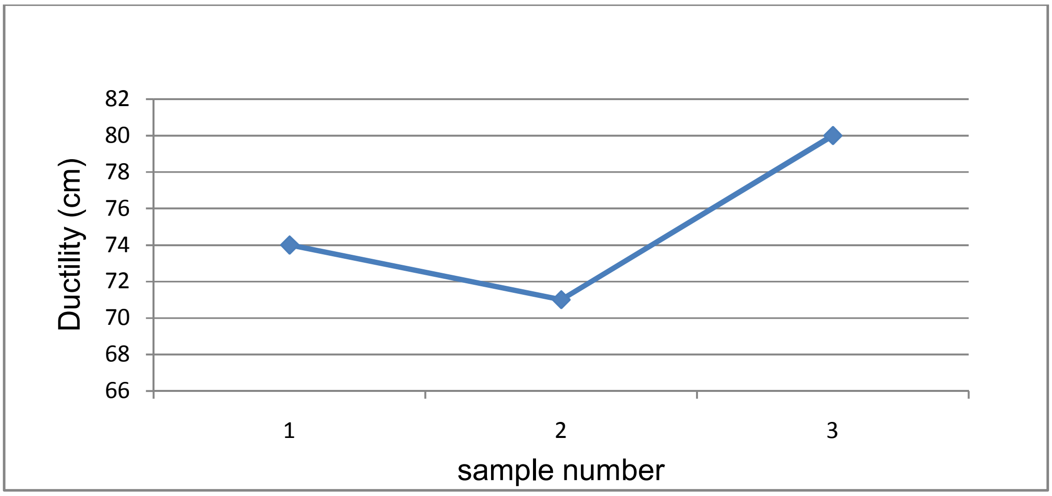
Figure 23: Chart of penetration result of PET and bitumen mix



The Penetration values are decreasing significantly, when 60/70 bitumen have mixed with the PET. Thus, there is a significant decrease in penetration values for modified blends, indication the improvement in their temperature susceptibility resistant characteristics. In which increasing the waste plastic percentage in the mix will decrease the penetration value of it. In another word, the addition of waste plastic increases the hardness of the modified bitumen. The penetration values of the blends are decreasing depending upon the percentage of PET. When 8% PET by weight of bitumen mixed, the penetration result become 50mm, which is closer to a good bitumen grade 30/40 which have a penetration value range from 30mm to 40mm.

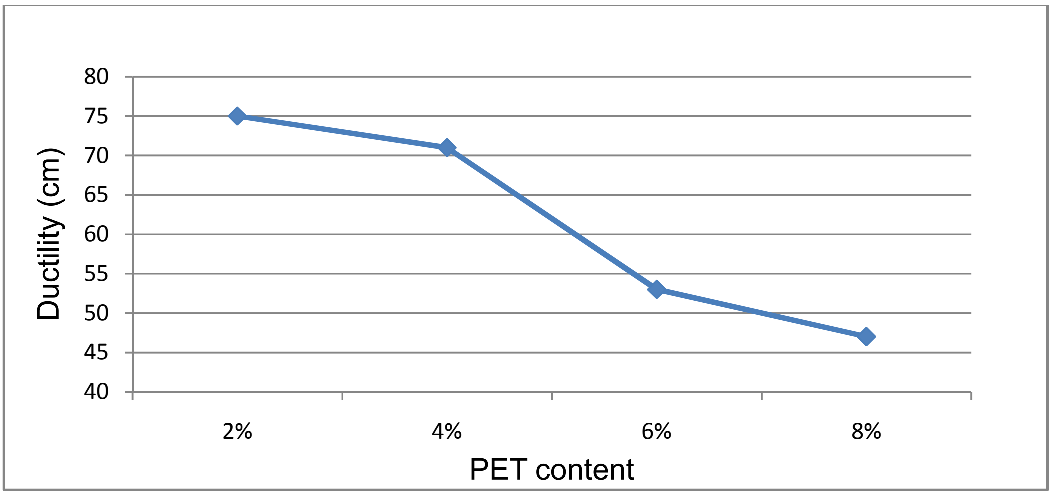
4.1.2 Ductility test results

Figure 24: Chart of Ductility test results on Natural bitumen



The binders possessing high ductility have good cementing qualities in the road surface and adhere well to aggregates. There were three samplings with similar natural bitumen and each of them shows different value. These difference in the ductility value could be a result of inconsistent temperature in the water where the bitumen sample is socked. If the ductility test value of a sample shows a result of above 75cm the ductility value taken as 75cm.

Figure 25: Chart of Ductility test results on PET and bitumen mix



It has seen in the above chart, the ductility of the plastic waste and bitumen mix decreased because of the addition of plastic waste. The decrease in the ductility value has seen in the modified bitumen, this is due to interlocking of plastic molecules with bitumen. The ductility in the presence of PET becomes 47cm at 8% addition. This shows that the amount of plastic waste added should not be more than 8% by weight of bitumen. Using more than 8 %, plastic waste would result for the asphalt mix (asphalt concrete) to be easily broken.

4.1.3 Softening point test results

Figure 26: Chart of softening point test results on natural bitumen

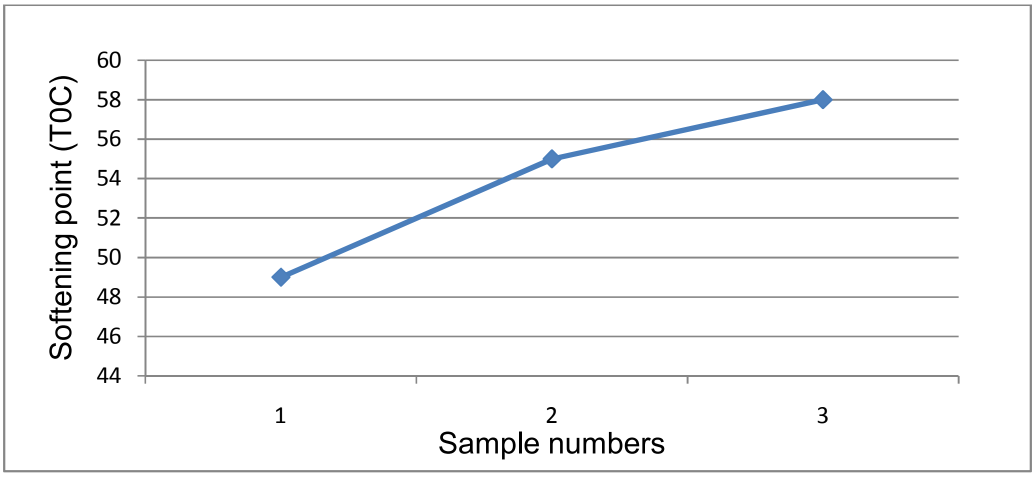
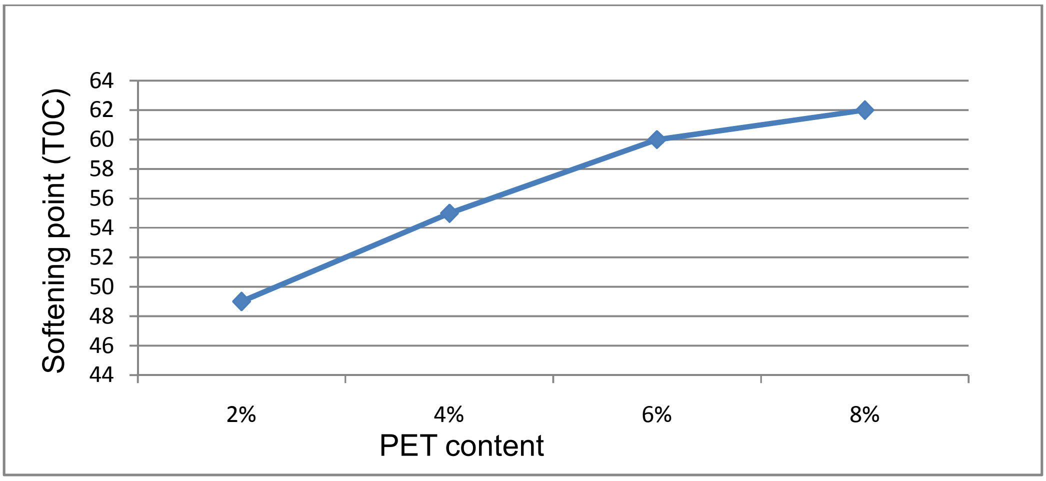


Figure 27: Chart of softening point test results on PET and bitumen mix



The softening point increased by the addition of plastic waste to the natural bitumen. Higher the percentage of plastic waste added, higher is the softening point. The influence over the softening point may be due to the chemical nature of PET added. The increase in the softening point shows that there will be lesser bleeding during summer (where temperature is high). Bleeding accounts, on one side, increased friction for the moving vehicles and on the other side, if it rains the bleedings accounts for the slippery condition. Both these adverse conditions much reduced by plastic waste-bitumen blend.

As seen in the above figures the softening point has increased compared with plain bitumen. Moreover, adding of 2%, 4%, 6% and 8% PET by weight of bitumen has increased the softening point and 8% PET by weight of bitumen has increased softening to a temperature of 62^0C, and this make the 60/70 grade bitumen to have a softening point of bitumen grade 30/40, which ranged from 50^0C to 65^0C.

Because of the increase in softening point, a road from waste plastic, appreciated to construct in areas where the temperature is high.

Table 17: plain bitumen test results for different quality

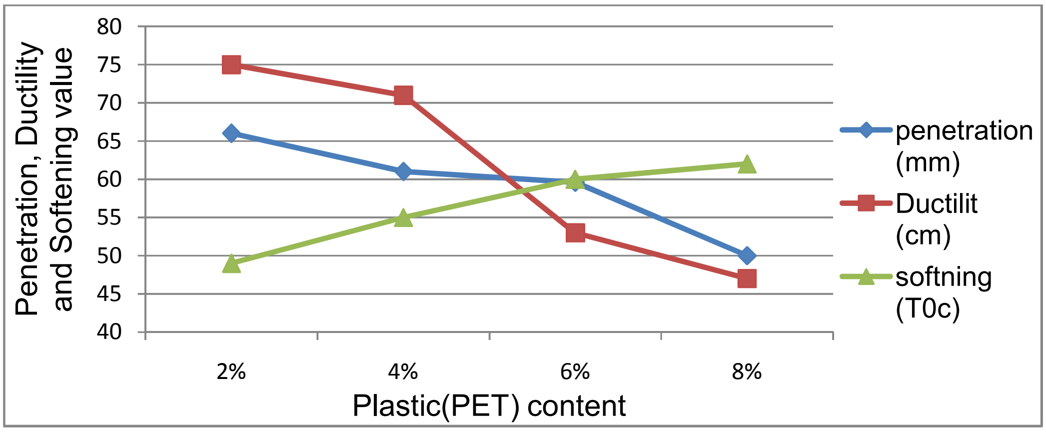
Tests	Result			Average
Penetration	66	61	59.6	62.2
Ductility (cm)	74	71	80	75
Softening point (T^0C)	49	55	58	54

The following is bitumen quality, test result for different percentage of plastic waste (PET) and bitumen mix.

Table 18: Bitumen quality test on modified binder

	% of plastic content			
Tests	2%	4%	6%	8%
penetration	66	61	59.6	50
Ductility(cm)	75	71	53	47
Softening point (T^0C)	49 ^0C	55 ^0C	60 ^0C	62 ^0C

Figure 28: Chart of test result on PET and bitumen mix



As we can see it from the above table, the addition of plastic to bitumen improved the quality of the asphalt road binder. In another words the natural quality of the bitumen has improved because of the addition of PET.

The penetration value of natural bitumen of grade 60/70 is from 60 mm to 70 mm, here because of the PET present in the modified bitumen it has decreased to 50 mm at 8% PET addition by weight of bitumen.

The ductility of the PET and the bitumen mix decreased along with the increment of the amount of PET. When the Amount of PET reached 8% by weight of bitumen the ductility becomes 47cm. This shows 8% is the maximum amount of PET possible to add.

4.1.4 Marshall stability result

To check the load bearing capacity of the modified asphalt Mix, different proportion of PET based on the result that have found from the bitumen quality test on the PET and bitumen mix was done. As the result of the binding property tests the grade 60/70, Bitumen had a quality closer to that of bitumen grade 30/40, When 8% PET added. Therefore, The load baring capacity of the mix at 8% PET by weight of bitumen have checked in Wet process since it is the best result found on the binder quality test.

Dry process with 10 % PET by weight of bitumen had applied for load bearing capacity test. This has gives a chance to compare from the two methods.

Stability at 12 gram of PET added was also checked which was done to further investigate the potential of this practice in consuming more PET waste.

4.1.4.1 Stability result on Natural bitumen

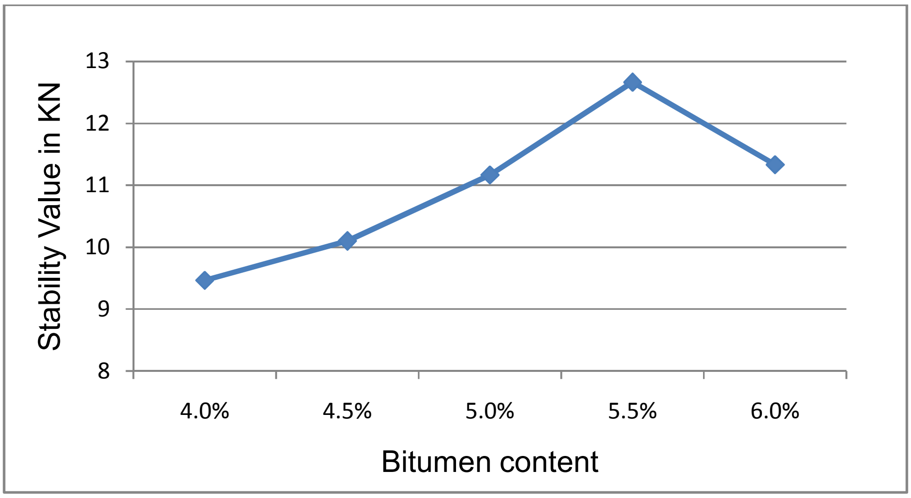
Bellow it is the test result of the load bearing capacity of the asphalt road mix was with natural bitumen mixed or plain bitumen.

Table 19: Martial stability for plain bitumen

Martial stability for plain bitumen			
Bitumen content	Sample	stability (KN)	Average (KN)
4%	1	9.5	9.5
	2	8.9	
	3	10	
4.50%	1	10	10.1
	2	11	
	3	9.3	
5%	1	11	11.2
	2	10.5	
	3	12	
5.50%	1	12.5	12.7
	2	12	
	3	13.5	
6%	1	13	11.3
	2	11	
	3	10	

The above table shows the stability result don on natural bitumen. On the natural bitumen the stability test, start with 4% bitumen content by weight of total mass of the sample (1200g) and continued with an increment of 0.5% up to 6%. The stability shows increase until the bitumen content reached 5.5%. At 5.5%, the stability reached the maximum stability point and start decrease when the bitumen content is 6%. The decrease in stability is the reason of more binder than aggregate and the load is carried by aggregate not the by the binder bitumen.

Figure 29: Chart of stability result on plain bitumen



In the above chart, the maximum load bearing capacity or stability for natural bitumen reaches maximum capacity of stability of 12.7KN at bitumen content of 5.5%, and for 6% bitumen content, it becomes 11.3KN, which have lower stability than 5.5% bitumen content.

4.1.4.2 Wet process Stability result for modified bitumen binder

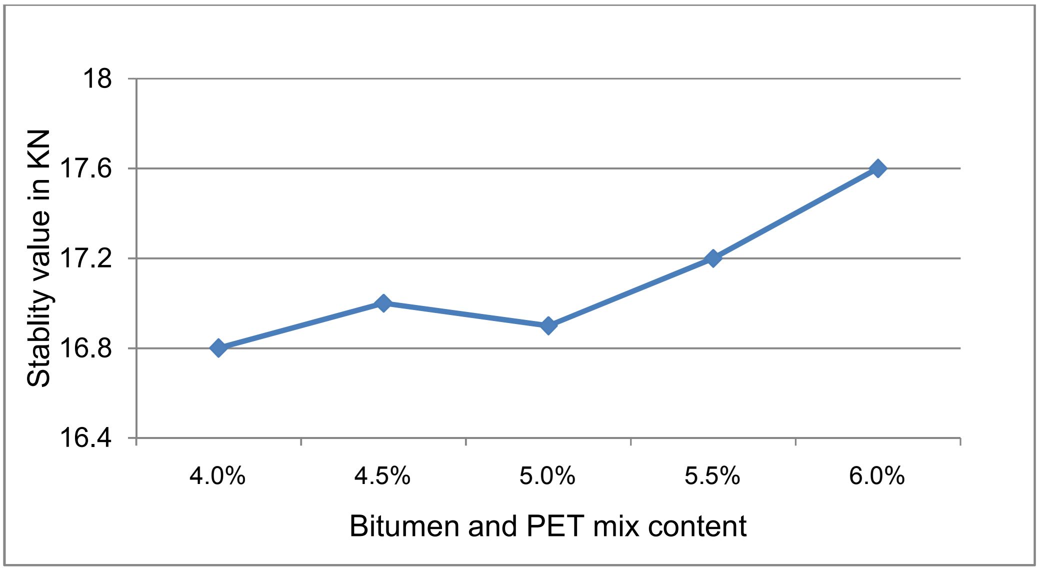
The following is the test result of the load baring capacity of the asphalt road mix, which mixed, in wet process. The 8% plastic content has chosen because of the promising result that has seen in the bitumen quality test.

Table 20: Stability result for modified bitumen with 8% PET by weight of bitumen (Wet process)

Martial stability for 8% plastic(Wet process)			
Bitumen and PET mix content	Sample	stability (KN)	Average (KN)
4%	1	16.4	16.8
	2	17.1	
	3	17	
4.50%	1	16.9	17
	2	17	
	3	17.1	
5%	1	17	16.9
	2	16.4	
	3	17.3	
5.50%	1	17.2	17.2
	2	16.8	
	3	17.5	
6%	1	18	17.6
	2	17.5	
	3	17.2	

In the wet process, 8% of bitumen substituted with PET. 4% of bitumen content is 48g from the total 1200g aggregate. From the total of 48g, 8% of it substituted with PET, Which is 4g of PET. In the same way bitumen has been substituted with PET for all bitumen content.

Figure 30: Chart showing stability result for Modified bitumen by 8% of PET. Wet process



The stability increased from 4% to 4.5% and decreased on 5%, and again shows increment until it reaches 6% bitumen and PET mix content. This inconsistency of stability caused by mixing problems of aggregates and binder or it could be because of cooling of the mixing cylinder. When the mixing jar not heated enough, bitumen sticks to the mixing cylinder surface, which would minimize the amount of binder in the mix and let the mix have weaker bond. In this wet process the 6% bitumen and plastic mix shows highest stability value of 17.6KN.

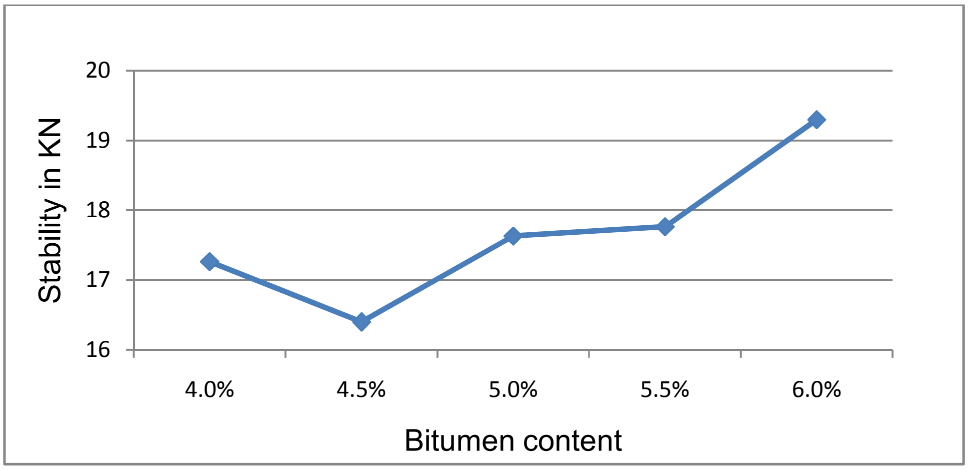
4.1.4.3 Dry process Stability result for 10 % of PET added

The dry process have similar amount of bitumen content with that of done in natural bitumen. But the amount of fillers are substituted by PET.

Table 21: Stability result for 10 % of PET added. Dry process

Martial stability for 10 % of waste Dry process			
Bitumen content	Sample	Stability (KN)	Average (KN)
4%	1	17.8	
	2	18	
	3	16	17.3
4.5%	1	16	
	2	15	
	3	18.2	16.4
5%	1	17	
	2	17.9	
	3	18	17.6
5.5%	1	18	
	2	16.8	
	3	18.5	17.8
6%	1	20	
	2	18.9	
	3	19	19.3

Figure 31: Chart of Stability result for 10 % of PET In dry process



The stability shows decrease from 17.3KN at bitumen content of 4% to 16.4KN at bitumen content of 4.5% and it shows increase from 17.6KN at bitumen content of 5% to 17.8KN at bitumen content of 5.5% and stability reaches maximum at bitumen content of 6% which is 19.3KN.

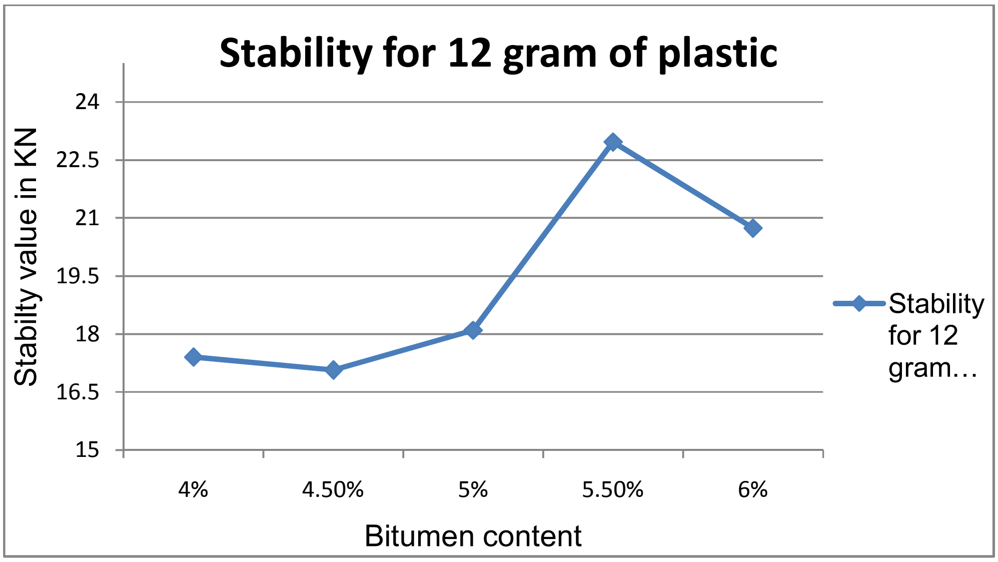
Decrement in stability shown at bitumen content of 4.5%. This decrease in stability could be because of cooling of the mixing jar that could minimize some amount of bitumen by sticking on its surface.

4.1.4.4 Dry process Stability result for 12g of PET added

Table 22: Stability result for 12 gram of PET added. Dry process

Martial stability for 12 g of waste Dry process			
Bitumen content	Sample	Stability (KN)	Average (KN)
4%	1	18	17.4
	2	17.2	
	3	17	
4.50%	1	17.8	17.1
	2	17.4	
	3	16	
5%	1	18	18.1
	2	18.3	
	3	18	
5.50%	1	23.4	23
	2	22.5	
	3	23	
6%	1	20	20.7
	2	21	
	3	21.2	

Figure 32: Chart of Stability result for 12 gram of PET added. Dry process



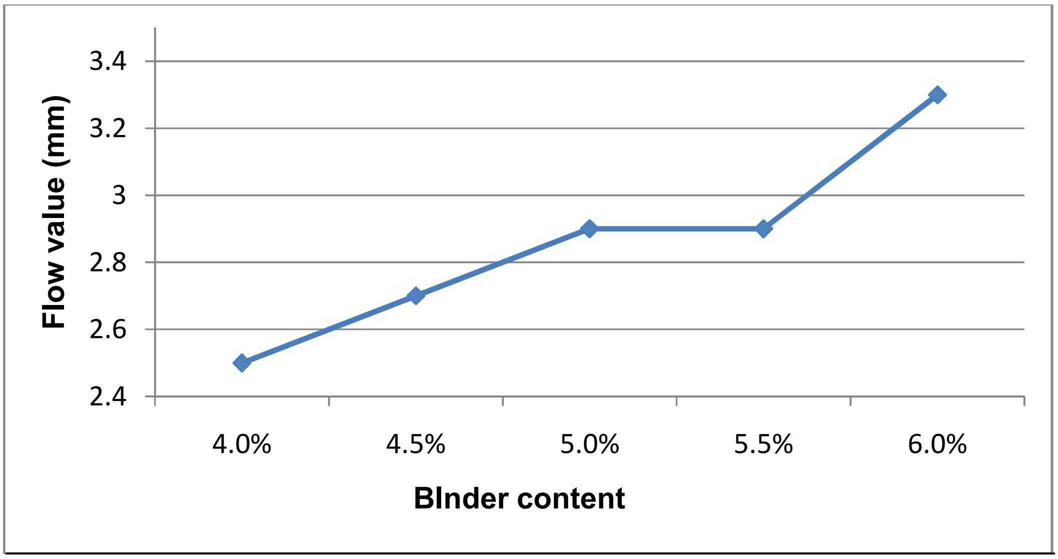
When 12g of PET add in the dry process, as seen in the above table and chart the stability shows significant increment in stability, when the bitumen content reaches 5.5% the stability is 23KN, which is the highest stability that have found in this study.
When the bitumen content is 6% the stability became 20.7KN. This decrease in stability is the result of increasing of bitumen in the mix. When the binder or bitumen increased in a mix, the space that needed to be filled with filler and aggregate would be filled with bitumen, and that makes the sample weaker in stability.

4.1.5 Flow result

Table 23: flow value for 8% PET in Wet process

Flow value for 8% of waste wet process				
Bitumen content	Sample	stability (KN)	Flow value	Average
4%	1	16.4	2.8	2.5
	2	17.1	2.5	
	3	17	2.3	
4.50%	1	16.9	2.6	2.7
	2	17	2.7	
	3	17.1	2.7	
5%	1	17	2.8	2.9
	2	16.4	3	
	3	17.3	2.9	
5.50%	1	17.2	2.8	2.9
	2	16.8	2.9	
	3	17.5	3.1	
6%	1	18	3.1	3.3
	2	17.5	3.9	
	3	17.2	3	

Figure 34: Flow value of 8% PET in Wet process



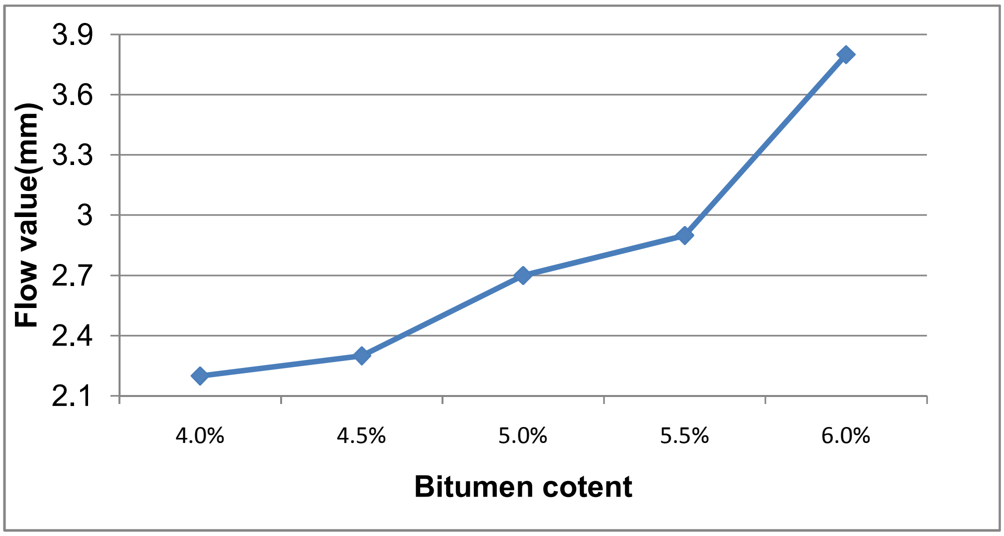
This is an index of plasticity or the resistance to distortion. The amount of bitumen that fills the aggregate voids affects the flow. The flow value increases as the bitumen content of the mixture increases. Mixtures contain high air voids usually develop excessive flow values before reaching the bitumen content, which will produce a satisfactory density. Flow value increases rapidly with small increases in asphalt in mixtures contain a large amount of filler.

This shows the effects of flow with different percentage of plastic in asphalt mixture. Flow has relation to stability and shows the flexibility of the mix. Flow for the conventional asphalt mixture is **2.85 mm**, which is the lowest. Flow of the modified asphalt mixture is higher than the flow of the conventional asphalt mixture. The highest flow is 3.8 mm, which is when 12 gram of plastic waste added.

Table 24: Flow value for 12 g PET in Dry process

Flow value for 12 g of waste Dry process				
Bitumen content	Sample	Stability (KN)	Flow value	Average
4%	1	18	2.5	2.2
	2	17.2	2.2	
	3	17	2	
4.50%	1	17.8	2	2.3
	2	17.4	2.7	
	3	16	2.3	
5%	1	18	3	2.7
	2	18.3	2.5	
	3	18	2.7	
5.50%	1	23.4	2.6	2.9
	2	22.5	3.1	
	3	23	3	
6%	1	20	3.7	3.8
	2	21	3.4	
	3	21.2	4.2	

Figure 35: Flow value of 12g PET added in dry process



Waste Plastic have used in asphalt concrete mix to improve the natural bitumen, as well as to be used as a replacement in place of fine aggregates. After we follow proper stapes and procedures for testing the quality of the modified bitumen and the Marshall Stability has tested.

The use of waste plastic in the construction of road is not only one good choice of plastic waste management but also it strengthened the road; Plastic will increase the melting point of the bitumen and increased the road life as well as creating a source of income. Roads from waste plastic would be a better waste management for our country.

From the experiment conducted, the amount of plastic waste should add for the improvement of bitumen properties like that of softening point ductility and penetration, **Is 8% by weight** of the binder adding in the asphalt mix. This amount of waste plastic is possible to add in wet process of asphalt mixing.

4.2 Discussion

The negative impact of Climate Change is already here. Toxic substances released by burning of plastics, open combustion, incineration, posing a danger to the surrounding areas including vegetation and health of individuals. Proper development of policy with respect to plastic waste management must be set.

There is no agreement on the time that plastic takes to degrade but it could be hundreds or thousands of years. Because of the nature of plastic's non-degradability nature, it elongates the degradation period of organic substances. Disposal of plastics in landfills is unsustainable and reduce land resources fit for other uses of higher community value. As it understood from this work, it is possible to minimize the amount of plastic waste in our case the amount of PET that goes to land fill sites, In doing so biodegradable wastes degradation period will not be elongated as well as it is possible to save large plot of land used for landfills.

The amount of PET waste left in the street, or that goes to the land filling or solid waste Incineration plant, minimized by using PET as this thesis suggested.

In our work the temperature at which the PET is exposed is 170^0c, which is below the deception point of the plastic, therefore, there is no toxic gases released to the environment and there will not be any remain ashes of plastic like that of incineration or open burning have. Polyethylene Terehathalate (PET) release Light hydrocarbons (C5-C10) when burned above a temperature of 200^0C. Especially in Incineration plant, the plastic waste burned above the deception temperature of the plastic waste, and that leads to the generation of toxic gases, Due to the generation of unacceptable emissions of gases such as nitrous and sulfur oxides, dusts, and dioxins, incineration are not the best mode of waste disposal.

Incineration plants use more plastic as an input to get high temperature to make the water boil in electric energy production. More PET means more gases that are toxic and more ashes of plastic that still destined to land filling sites.

The leakage of plastic into the environment is a big issue of current human being. There is no one particular solution to deal with the pollution of plastic waste into the environment. Based on the outcome of different tests conducted in this work, and the disadvantages of current solid waste management options found in various research works, it is possible to conclude that using plastic PET in road is a better option to minimize the health issues to human and animal as well as to minimize environmental pollutions.

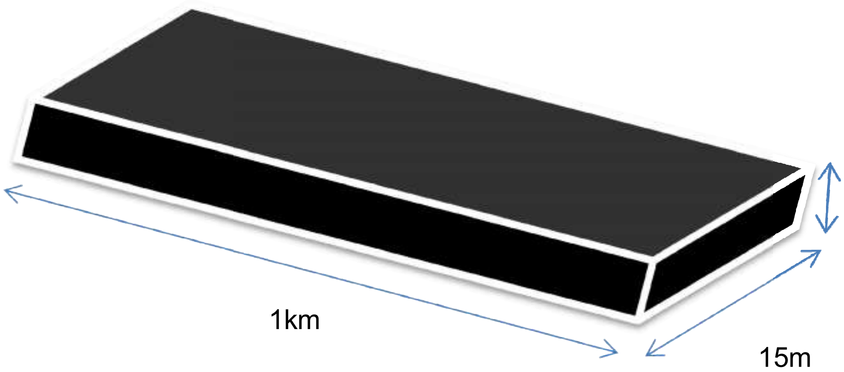
There is no proper solid waste management system in our cities. Wastes thrown to the streets, these wastes either picked up by waste collectors or dumped there for years. In relatively developed areas of the city, scavengers collect the waste and dump it in an open area usually at a distance from densely populated area. Existing landfills of Addis Ababa city has not well designed. Open burning of waste on the dumpsites observed. From the wastes generated in the town, large amount of its portion is plastic waste. Mineral water packing bottles are some of the waste plastic generated. Water bottles as a waste create conducive environment for disease causing vectors like that of malaria.

All of the issues associated with poor plastic waste management could be minimized using plastic waste in road construction. This process is eco friendly and in the low class people applicable since it serve as a source of income generation, and hence one of the best methods for easy disposal of Waste plastics.

4.2.1Amount of plastic waste (PET) recycled

The amount of plastic waste and the amount of bitumen that consumed in wet process calculated below. This research, has tried to replace the Bitumen with plastic waste as much as the bitumen and plastic waste mix have the quality that satisfies the standards of tests like Penetration test, softening point and ductility testes.

Let us say we want to construct asphalt road with a dimension of 1000m (1 km) by 15m width and 0.15m depth.



The total weight of the asphalt concrete mix calculated as

Volume = Length * width * Depth

Volume = 1000m*15m*0.15m

=2250m^3

The samples tested have a dimension of 64mm height and a diameter of 10.4cm, and a weight of 1265.5gram (1.2655kg) including all aggregate bitumen and PET.

The standard asphalt concrete has a density of 2330 kg/m^3. However, because of the plastic PET added in the mix the density has become lower than the usual. Considering these size of these samples the density were 2327.7kg/m^3

Therefore, the weight of the asphalt calculated as

Density = Mass/ Volume

Volume = 1000m*15m*0.15m

=2250m^3

Density = Mass/ Volume

Mass = Density * volume

Mass = 2327.7 kg/m^3 * 2250 m^3

= 5237325 kg

= 5237.325 tones

From the marshal stability test the amount of the binder or modified bitumen that shows good stability value is at six percent by weight of the total mass of the samples.

In this wet process from the total mass of asphalt mix six percent (6 %) of the total weight is waste plastic and bitumen mix (Modified Bitumen).

6% of 5237325kg

0.06 * 5237325kg= 314239.5kg

=314.3 tons

The amount of binder used is 314.3 tons or 314239.5 kg of plastic waste and bitumen mix.

From this 314239.5 kg of binder, some portion of it is plastic waste (PET) and it was 8 % by weight of the binder.

8 % * 314239.5 kg =

0.08 * 314239.5 kg = 25139.16 kg

Therefore, in wet process the amount of plastic waste possible to be recycled is **25139.16 kg** or **25.1 Tons** of plastic waste per 1km long, 15m width, and 0.15m thick road.

As we have seen plastic waste in road construction, has been implemented in to two different ways, one is using plastic as bitumen quality improvement and the second is to substitute the plastic waste in place of filler. When we use the waste plastic as filler, which is in dry mixing the quantity of the plastic waste possible to add is much higher than wet process. In this study, the amount of plastic possible to add to get good quality of stability was by adding one % (1%) of the total asphalt concrete mix . or it is 12gram of PET plastic for each 1200 gram of asphalt mix.

Taking of similar dimension of road, construction of asphalt road with a 1000m (1 km) long, by 15m width and 0.15m depth

The total weight of the asphalt concrete mix calculated as

Volume = Length * width * Depth

Volume = 1000m*15m*0.15m

$=2250m^3$

Density of asphalt mix taken as 2327.7 kg/m^3

Therefore, the weight of the asphalt calculated as

Density = Mass/ Volume

Mass = Density * volume

Mass = 2327.7 kg/m^3 * 2250 m^3

= 5237325 kg

= 5237.325 tones

From this total mass of asphalt mix one percent (1 %) of the total weight is waste plastic that used in place of fillers in dry process.

One percent of (1 %) of 5233500 kg of asphalt mix is

0.01*5237325 kg = 52373.25 kg.

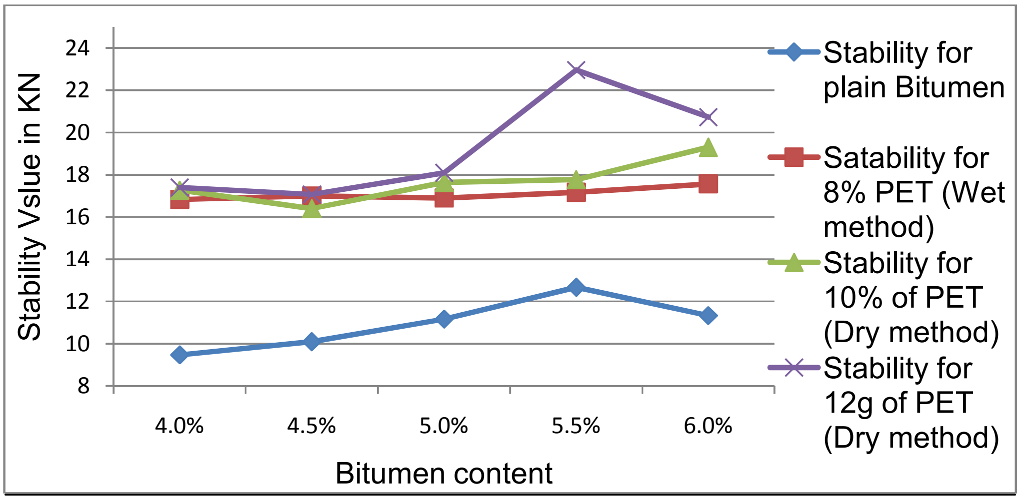
= 52.4Tons

Therefore to construct an asphalt road of a dimension of 1000m (1 km) by 15m width and 0.15m depth. The amount of waste plastic used would be **52.4 Tons** per 1km length, 15m width and 0.15m thick.

In this Dry process, we are able to replace 1% by the total weight of the asphalt mix. That give a better stability quality than asphalt mix with natural bitumen binder and even stronger than asphalt concrete mix with modified binder. As the result showed, it was able to use **52.4 Tons of plastic waste (PET)** in the dry process of asphalt mixing for only constructing a road with a cross section of 1km long, 15m width by 0.15m depth. Recycling of this much amount of waste plastic means it is possible to save the environment from the toxic gases and toxic plastic ashes that generated from landfills or incinerations.

4.2.2 Stability (Strength) comparison between natural bitumen asphalt and PET modified asphalt.

Figure 33: Chart of Stability result for all PET composition and In the two Methods



The chart above shows the stability value of sample that is with the addition of PET and without PET. The samples were prepared in wet and dry process. These two methods show different result of stability with the addition of PET. As the result the stability value of samples with PET in the dry process, in general have better stability value compared to the PET added in wet process, and better than the natural bitumen asphalt mix. At the same optimum bitumen content (5.5%) the stability of natural bitumen is 12.7KN, while in PET modified bitumen asphalt in wet process is 17.2KN. In wet as well as in dry method of mixing the addition of PET in the mix improves the load bearing capacity of the asphalt.

4.2.3 Cost comparison between natural bitumen road and PET modified bitumen road (wet method)

The amount of PET modified bitumen used per 1km length, 15m width and 0.15m thick, road construction is 314239.5kg of plastic waste and bitumen mix. Eight % (8%) of the plastic modified binder is PET; it means same amount of bitumen substituted with PET.

Cost of plastics waste PET = 7birr/kg

Cost of Bitumen grade of 60/70 per barrel (180±2.5 Kg) = 5000 birr/barrel

One-barrel weights from 177.5kg to 182.5kg, taking the average 180kg weight for a barrel the cost per kilogram is 27.80 birr.

It the binder was entirely natural bitumen grade 60/70 for the total amount of binder (314239.5kg) it would have cost us 8,735,858.1 birr

Because of modifying the bitumen with PET, it was possible to save 8% of bitumen in wet process. With 8%, bitumen reduction the remaining 92% (289100.34 kg) bitumen cost 8,036,989.452 birr. And the 8% PET (25139.16 kg) costs 175974.12birr

The cost of the PET modified binder (8% PET and 92% bitumen) becomes 8,212,963.572birr per 1km long, 15m width and 0.15m thick road.

The economic impact of adding PET to modify bitumen **is 6% reduction** on the binder (bitumen) cost.

4.2.4 Cost comparison between natural bitumen road and PET modifier asphalt road (dry process)

In dry process, the bitumen content not changed. Because in this process the PET added used as filler. In natural bitumen asphalt rod construction, cement is used as a filler. In road construction without adding of PET, for each 1265.5 g weight sample 20 g of cement used.

When PET added in dry process of asphalt road making, 12 g of PET added in place of cement. Which means 60% of cement was substitute with PET.

Cost of cement per quintal (100kg) = 240 birr, which is 2.4birr/kg.

Cost of plastic PET collection and segregation = 7birr/kg.

Cost of cement (20 g) in each sample is 0.048 birr

Cost of PET added (12 g) in each sample is 0.084 birr.

The cost of filler in a single sample of 1265.5 g weight asphalt mix in dry process is the cost of 20g filler (60% PET and cost of 40% cement). Which is 0.084 birr + 0.0192 birr = 0.1032 birr.

Cost of filler material (Cement) in regular way of asphalt road making is the cost of 20g cement, which is 0.048 birr per each sample (1265.5g).

Using plastic waste in road construction in dry process would bring in an increment of 53.5% by cost of filler (cement). Cement has a smaller share in the construction of asphalt road.

4.2.5 Comparison of PET modified mix asphalt with different modifiers and reclaimed asphalt

A study uses 3-mm granule of PET bottle wastes, to improve road quality and dispose PET waste properly. The result they found was smaller in plastic waste consumption than result found in this research. Which was optimum plastic content 5% total weight of bitumen mixture and optimum bitumen content 5% by weight of total asphalt mix (Rahman and Wahab , 2013). It improved permanent deformation resistance, which leads to increased service life of road. In this research, the optimum bitumen content we have found was 8% by weight of the total optimum bitumen content. With similar property improvement, it was possible to use more PET waste.

Using reclaimed asphalt (RA), used motor oil (UMO), and HDPE to improve asphalt quality, to minimize cost of road construction and to protect the environment. Using of recycled asphalt pavement with used motor oil and HDPE shows a potential cut in costs of material around 40-60% and 50% (Abreu et al, 2015). In addition, the quality of the road improved in stability. It also minimizes the optimum bitumen content. In improving the road quality and protecting the environment this research paper shows promising result. When it comes to cost of road construction it may need further studies. Because the cost able to minimize was only 6% in wet method and in dry method it shows increment in cost of filler.

Different study used LDPE carry bag wastes. In this study, the LDPE improved the stability, flow, and air voids. It also reduced pavement deformation, increased fatigue resistance, and provided better adhesion between asphalt and aggregates. It also reduced the amount of bitumen used in construction. The optimum bitumen content found is 4.94% by weight of total mix, and for that of optimum plastic content, it is 10% by weight of bitumen (Musa and Haron, 2014)

Chapter 5

Conclusion and Recommendation

Penetration, softening point, ductility and Marshall Stability value of the plain bitumen and plastic modified bitumen had been examine in this study. the finding result shows that addition of plastic PET reduces penetration value from that of plain bitumen, Increases the softening point, decreases the ductility and Utilizing of PET Improve properties of flexible pavement such as increasing of stability, stiffness, hence it can improve stripping, thermal cracking, temperature susceptibility, fatigue damage. Using plastic waste PET as a modifier to the bituminous mixture would solve the problem of safe disposal of waste plastic materials in an eco-friendly way.

This study examined the possibility of using PET in road construction with the two processes wet and dry process. Results from the analysis of data revealed that, both Dry and Wet process of PET addition improves the binding property of the natural bitumen asphalt mix and increases the asphalt stability and durability. Therefore, it was possible to get a good quality of asphalt mix by adding **8% PET by weight of bitumen** content in wet process and **12gram of PET** in dry process.

In wet process, 25.1 tons of PET is possible to use in 1km, 15m wide, and 0.15m thick road. For each kilometer of road construction, the same amount of bitumen substituted with PET. The substitution in return will help to minimize carbon footprint of bitumen production and its transportation. In addition to that, 6% of binder material cost minimized as the result of using PET modified bitumen.

The finding shows that, using plastic waste in road construction can minimize tons of plastic waste that chocked the swear system, covers the sea beads, scattered in domestic areas. as well as the plastic wastes that goes to land fill sits or to other waste disposal sites in which the negative impact to our environment and health is greater. The use of plastic PET in road construction will reduce Pollution of the environment with used plastic wastes and as a result, improve the sanitation problem and reduce the incidence of malaria.

Researches of similar title have done by researchers but in Ethiopia, it is not as much as it should be considering the problems we are facing from plastic waste. Most of the researches focused on how much of waste plastic produced or how the plastic waste affects our health.

The contribution of this thesis is that, it is done with the two methods Dry and Wet process and comparison between the two processes have been tried, which is not done in Ethiopia or outside (I did not came across) and that helps to choose from the two methods.

The following are the general conclusions drawn from the study

- Strength of the PET road is better than natural bitumen road
- Use of 12g of PET was possible for each 1200g sample (Dry process)
- Reduction in the use of bitumen
- This way of plastic waste handling is eco-friendly

- Saves land that would have used for land filling
- Avoid the need of anti-stripping agents
- Using of plastics waste in road construction can be better than land filling and incineration, because of no toxic gas released to the environment.
- Generate jobs for plastic bottle pickers
- Bleeding of the road reduced in hot temperature areas

Recommendation

The recommendation of this paper would be for further investigation on the Dry process of asphalt road making. In the study, the best stability of road found was in dry process and it was possible to use more plastic waste than the wet process. This study believed that dry process could give better result, with different aggregate size selection.

In dry process the material cost for filler increased. But considering the amount of waste disposed without harming the environment and the cost minimized that would have been spent for collection transportation and disposal of plastic waste. Using PET in asphalt road in dry process is affordable. If Wet method used probably, bigger mixing unit (cylinder) for the bitumen and plastic mixing is needed which is additional cost in the regular way of asphalt road making.

It is recommend to do research on different kinds of plastic waste; PET is thicker than the other plastic wastes because of that it will last longer in the soil. In addition, the waste production of PET and its influence on the environment is becoming real, and it is increasing from time to time, therefore much emphasis shall be give to PET waste.

It is not only PET that have been creating the environmental and health problem on human and animal. Like that of plastic bag (Low-density polyethylene LDPE) on high density, polyethelen (HDPE) should also give much attention.

The limitation for this idea not to put on the ground could be cost. The cost of waste collection cleaning and making the plastic into the desired size could cost more than the cost needed for bitumen in dry process.

It's been tried to do as many samples as possible but because of the broadness of the concept the study was forced to limited its focus on some of the main points we think affects more. Because of financial and time limitation, it was limited for further investigation on the concept. Further investigation will be necessary on the effect of PET waste on the time of service of the road.

Chapter 6
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