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COMPARATIVE STUDY AND OPTIMIZATION OF MODIFIED BITUMEN FROM WASTE PLASTICS (LDPE AND PET)

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COMPARATIVE STUDY AND OPTIMIZATION OF MODIFIED BITUMEN FROM WASTE PLASTICS (LDPE AND PET)

MASTER THESIS

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COMPARATIVE STUDY AND OPTIMIZATION OF MODIFIED BITUMEN FROM WASTES PLASTICS (LDPE AND PET)

Presented to the School of Research and Graduate Studies, Bahir Dar Institute of Technology, Bahir Dar University

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2016

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I, the undersigned, declare that the thesis comprises my own work. In compliance with internationally accepted practices, I have dually acknowledged and refereed all materials used in this work. I understand that non-adherence to the principles of academic honesty and integrity, misrepresentation/ fabrication of any idea/data/fact/source will constitute sufficient ground for disciplinary action by the university and can also evoke penal action from the sources which have not been properly cited or acknowledged.

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External Examiner	signature	Date
Internal Examiner	Signature	Date

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LIST OF ACRONYMS

ASTM	America Standard Testing Methods
BS	British standards
G*	Complex Modulus
G'	Elastic Modulus
G"	Viscous Modulus
HDPE	High Density Polyethylene
IS	Indian standards
LDPE	Low Density Polyethylene
LLDPE	Linear Low Density Polyethylene
PET	Polyethylene teraphetalt
T	Temperature (^{0}c)
•	Non- Newtonian viscosity
, o	Stress
	Strain
f	Phase angle

ABSTRACT

The growth in various types of industries together with population growth has resulted in enormous increase in production of various types of waste plastic materials world. This creates a problem on the disposal mechanism. To deal with the problem, study on use of plastic waste as partial replacement to bitumen in flexible pavement is considered in the present work. This study examines the effect of blending waste thermoplastic polymers, namely Low density polyethylene (LDPE) and Polyethylene terephthalate (PET) in conventional 80/100 graded bitumen, at different plastic compositions. The plastics were chopped in size of 1-5mm and blended with the bitumen, with shear mixing of 1000-3000rev/min and temperature range of 150-180 ºC. Optimizations of mixing parameters were done using central composite design coupled with surface response methodology in design expert version 7.0.0 software. Optimal results of PET mixed modified bitumen size 3mm, composition 8%, temperature 160^{o}c and mixing rpm of 1099.6rev/min, whereas for LDPE mixed modified bitumen size of 2.8mm, composition of 7.39%, temperature of 160^{o}c and mixing rpm 1062.02rev/min are achieved. From the experimental result it was observed that Marshall Stability and softening value of both PET and LDPE modified bitumen increased as compare with conventional bitumen, whereas, from penetration and ductility values measurements for both PET and LDPE mixed modified Bitumen decreases as compare to conventional bitumen this is indicating that, it increased strength of modified bitumen. From this study it concluded that, by adding waste LDPE and PET plastics into bitumen it significantly improved the quality of modified bitumen. Using PET and LDPE modified bituminous mix also contribute to the recirculation of plastic wastes to another valuable product, as well as to protect the environment.

Key words Bitumen, LDPE, PET, penetration point, softening point, ductility value, Marshall stability

CHAPTER 1

INTRODUCTION

Plastic products have become an indispensable part of our daily lives as many objects of daily uses are meant from some kind of plastic. The growth in various types of industries together with population growth has resulted in enormous increase in production of various types of waste materials world over. Plastic is everywhere in today„s lifestyle. It is used for packaging, protecting, and even disposing of all kinds of consumer goods and 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, and communication or information technology have been used by the applications of plastics. Use of this non-biodegradable product is growing rapidly and creating problem of disposal of plastic waste, due to this plastic waste is particularly, Plastic bag hazard have become a serious problem especially in urban areas in terms of its misuse, its dumping in the dustbin, clogging of drains, reduce soil fertility and aesthetic problems. If ban is put on the use of plastic on emotional ground, the real cost would be much higher, the inconvenience much more, the chances of damage or contamination much greater. The risk to the family health and safety would increase and above all the environmental burden would be manifold (Nemade and Prashant v, 2013).

The threat of disposal of plastic will not solve until the practical steps are initiated at the ground level. It is possible to improve the performance of bituminous mixing using waste plastic for asphalt roads. Studies reported in the use of re-cycled plastic, mainly polyethylene, in the manufacture of modified bitumen indicated that, by adding plastic it reduced permanent deformation in the form of rutting and reduced low…temperature cracking of the pavement surfacing. The field tests withstood the stress and proved that plastic wastes used after proper processing as an additive would enhance the life of the roads and also solve environmental problems (Gawande et al., 2012a).

Advantage of modified bitumen

1) It reduced non biodegradable waste from the environment, these are carry bags, disposable cups, and bottles are essential ingredient for the preparation of modified bitumen
2) Stronger road with increased Marshall Stability Value.
3) Better resistance towards rain water and water stagnation
4) No stripping and no potholes.
5) Increase binding and better bonding of the mix

1.1 statement of Problem

Ethiopia as a developing country is experiencing genuine difficulty in the area of proper plastic waste management. This is due to plastic materials are not biodegradable and its subsequent persistence in the environment. This unfortunate situation is compounded by several factors including the poor attitude towards waste disposal and the over-reliance on ineffective waste disposal techniques. It is common place to find rivers, gutters and roadsides choked and filled with waste plastic materials.

On the other hand, increased economic activity, urbanization and higher traffic volumes are rapidly contributing to the deterioration of our roads; one of the cases is the choice of bituminous binder used.

To enhance binder, mixing plastic with bitumen it could be best solution for adverse road conditions and provide means to plastic recycling strategy through bitumen modification.

Our country is importing bitumen from abroad as result of which construction of road is highly affected by cost of bitumen. Mixing plastic waste into bitumen may substantially reduce the cost of bitumen if appropriate mix is carefully studied and tested.

The aim of this thesis was to find optimum value of mixing waste plastic in to bitumen, this helps to decreases environmental pollutions as well as one of the means to subsidize our economy by increasing quality and quantity of modified bitumen.

1.2 Objective

1.2.1 General Objective

Investigate the effect of waste plastic mix on the performance of modified bitumen and to replace bitumen by plastic waste for the improvement of roads.

1.2.2 Specific objectives

ðØ To Synthesis and characterize new prepared modified bitumen from LDPE and PET plastics

ðØ To Investigate the effect of percentage of waste plastic added on bitumen properties

ðØ To investigate the effects of operating condition on the quality of new modified bitumen.

ðØ To compare the performance of the bitumen modified with an optimum percentage of PET and LDPE using the standard 80/100 bitumen

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Today, every vital sector of the economy starting from agriculture to packaging, automobile building construction, communication or Info Tech has been virtually revolutionized by the applications of plastics. Use of this non-biodegradable product is growing rapidly and the problem is what to do with plastic waste. The concept of utilization of waste plastic in construction of flexible pavement has been done since 2000 India (Gawandea et al., 2012b). In the construction of flexible pavements, bitumen plays the role of binding the aggregate together by coating over the aggregate. It also helps to improve the strength and life of road pavement. But its resistance towards water is poor. A common method to improve the quality of bitumen is by modifying the rheological properties of bitumen by blending with synthetic polymers like rubber and plastics. Use of plastic waste in the bitumen is similar to polymer modified bitumen. Plastics industry have increased development for the uses of different purposes like building purposes, for electricity insulating purposes, packaging of food and non food grade substances and others. so for this non bio-degradable product increases and some solution has to be created(Jain et al., 2011) and Most of plastics are uses for thin plastics bag which mostly uses for packaging purposes however the disposal of this wastes causes environmental as well as ecological problem to solve problem recycling waste into useful form and most of researcher uses new innovative ideas by advancing the solution (Justo and Veeraragavan, 2002).

2.2 Polymer structure and classification

Polymers can be classified as

2.2.1 Thermoplastics

Thermoplastic is a class of polymer, which can be easily melted or softened by providing heat in order to recycle the material. Therefore, these polymers are generally produced in one step and then converted into the required article at a subsequent process. Furthermore, thermoplastics have covalent interactions between monomer molecules and secondary weak van der Waal interactions between polymer chains. This weak bonds can be broken by heat, and change its molecular structure. The Figure 1. and 2. illustrate the changes that occur in intermolecular interactions of thermoplastic in the presence of heat.

Figure 2:1 Thermolastic polymer

Figure 2 :2 Thermoplastic softened state

The softened thermoplastic can be placed in a mould, and then cooled to give the desired shape. When cools significantly below its glass transition temperature (Tg), weak Van der Waal bonds in between monomer chains will form reversibly to make the material rigid and usable as a formed article. Therefore, this type of polymers can be readily recycled or remoulded, because each time it is reheated it can be reshaped into a new article. Acrylic, Acrylonitrile Butadiene Styrene, Nylon, Polybenzimidazole, Polycarbonate, Polypropylene, Polystyrene, Teflon, Polyvinyl Chloride, etc. are several examples of thermoplastic materials. Among these thermoplastics, some materials such as Polybenzimidazole, Teflon, etc. have exceptional thermal stability because of their high melting points

2.2.1.1 polyethylene terphthalate (PET)

Plasticis the most recently introduced of the major packaging types. Polyethylene terephthalate (PET, in fiber form known as polyester) was developed initially as an engineering and textile polymer, began to be used for packaging films in the mid-1960s, and then became widely used for beverage containers in 1977. The use of PET for packaging has increased because of its clarity, inertness, light weight, strength (especially resistance to pressure), moisture resistance, and gas retention and barrier properties PET is still most commonly associated with carbonated beverage bottles. It is also used for other food packaging such as peanut butter jars, salad domes, biscuit and vegetable trays, and sauce and oil bottle Non-food packaging uses include toiletries, household detergents, strapping and "blister packs" combined with cardboard. PET is also used as a film for packaging food and other products

2.2.1.2 Low-density polyethylene

Low-density polyethylene is a thermoplastic made from the monomer ethylene. It was the first grade of polyethylene, produced in 1933 by Imperial Chemical Industries (ICI) using a high pressure process via free radical polymerization (Malpas, 2010) LDPE is commonly used for packaging like foils, trays and plastic bags both for food and non-food purposes.

2.2.2 Thermo set plastics

Unlike thermoplastics, thermosetting plastics have superior properties like high thermal stability, high rigidity, high dimensional stability, resistant to creep or deformation under load, high electrical and thermal insulating properties, etc. This is simply because thermosetting plastics are highly cross-linked polymers that have a three-dimensional network of covalently bonded atoms. The strong cross-linked structure shows resistance to higher temperatures which provides greater thermal stability than thermoplastics. Therefore, these materials cannot be recycled, remoulded, or reformed upon heating. The Figure 3. and 4. illustrate the changes that occur in intermolecular interactions of thermosetting polymers under high temperatures.

Figure 2:3 thermosetting plastic

Figure 2: 4 thermal degradation

Thermosetting plastic will become softer with the presence of heat, but it will not be able to shape or form to any greater extent, and will definitely not flow. Typical examples of thermosetting plastics are,

Phenolic resins that occur as a reaction between phenols with aldehydes, these plastics are generally used for electrical fittings, radio and television cabinets, buckles, handles, etc. PF are dark in color. Therefore, it is difficult to obtain a wide range of colors.

Amino resins that are formed by the reaction between formaldehyde and either urea or melamine, these polymers can be used to manufacture lightweight tableware. Unlike phenolics, the amino resins are transparent. So they can be filled and colored using light pastel shades.

Epoxy resins that are synthesized from glycol and dihalides. These resins are excessively used as surface coatings.

2.3 Plastic consumption in Bahir Dar

Table 2: 1: Total plastic wastes released in Bahir Dar City

No	year	population	total waste in ton per year	plastic consumption ton per day
1	2 0 1	2 1 8 9	9 5 .	3. 1
2	2 0 1	2 3 3 4	1 0	3.4 4
3	2 0 1	2 4 8 8	1 1	3. 6
4	2 0 1	2 6 5 2	1 1 9	3 . 9
5	2 0 1	2 8 7 7	1 2 9	4. 2
6	2 0 1	3 0 1 4	1 3 5	4 . 4

Ref: Bahir Dar city administration.

From the above table it shown that, the number of population growth are increased this plastic waste released from the city are increased this causes environmental pollution.

2.4 Bitumen

Bitumen is a sticky, black and highly viscous liquid or semi-solid, in some natural deposits. It is also the residue or by-product of fractional distillation of crude petroleum. Bitumen composed primarily of highly condensed polycyclic aromatic hydrocarbons, containing mainly carbon and hydrogen and very small amount of sulfur nitrogen, oxygen and 2000 ppm metals.

2.4.1Various grades of bitumen used for pavement purpose

I. D : These are the thicker material having higher softening point & these are used in high temperature regions.

II. D : These are semi viscous material having moderate softening point.

III. D : This type of bitumen is thinner material & is used in tropical regions. It having lower softening point.

2.4.2 Rheology of bitumen

Rheology is a branch of science dealing with the flow and deformation of materials also concerned with the time temperature dependent flow and strain characteristics of substances exposed to stress and it is used, in general, for determining the strain characteristics of solids and the flow characteristics of fluids. The behavior of bituminous binders is dependent on both loading and temperature conditions. While bitumen behaves like a viscous fluid under constant loading and hot climate conditions, they behave like an elastic solid under fast loading and cold climate conditions. Rheologically, while elastic materials show a sudden strain under the effect of external load, strain remains constant as long as the load remains constant. If the load is removed, the material quickly returns to its former shape. When a load is applied to viscous materials, creep deformation occurs by time. When the load is removed, strains cannot be recovered and remain as plastic strain. Bituminous binders generally show viscoelastic behavior demonstrating these two characteristics together. Viscoelastic materials primarily show sudden elastic strain under constant loading, and then time-dependent delayed elastic strain and viscous strain. When the load is removed, in a similar fashion, primarily elastic recovery and then time-dependent delayed elastic recovery occur. Viscous strains cannot be recovered and remain as permanent strain. In Superpave binder grading system, the delay between the applied stress and strain, which is the phase angle (δ), is used as a criterion of viscoelastic behavior of bitumen. It is accepted that the smaller the phase angle is, the more elastic it is; the bigger the phase angle is, the more viscous it is. On the other hand, the amount of deformation in material under load changes according to the stress intensity to which the substance is exposed, implementation speed and direction and the viscosity of the substance from which it was produced.

2.4.2.1 Rutting Resistance

(Bahia and Anderson, 1995) is defined an accumulation of pavement deformations caused by the repeated loading of traffic. As a failure mechanism, it occurs in the wheel path and is most prevalent in warm climates and with soft binders. It is a stress-controlled cyclic phenomenon, when observed in the surface layers of the pavement. Each cycle does work to deform the layer, however some is recovered by elastic rebound and the remainder is lost in permanent deformation and heat. The work associated can be defined as follows.

$$W = \pi \times \sigma_0 \times \varepsilon_0 \times \sin\delta$$

Where

$$\varepsilon_0 = \frac{\sigma_0}{G^*}$$

And it can be further manipulated to show that work dissipated per loading cycle is inversely proportional to $\frac{G^*}{\sin\delta}$

$$W = \pi \times \sigma_0 \times \left[\frac{G^*}{\sin\delta}\right]$$

In this equation, G* represents the total resistance to deformation and sin δ is the relative non-elasticity, as well as the ratio of the loss modulus, G", to the complex modulus, G*, the permanent component of deformation. Based on this relationship, rutting resistance can be improved by increasing the value of G* or decreasing the overall non-elasticity.

2.4.2.2 Fatigue cracking resistance

Failure due to fatigue cracking is not as prevalent or visible as that of rutting, but the SHRP committee felt that it was worth testing and better understanding. Depending on whether the pavement is thick or thin, fatigue cracking is controlled by stress or strain. In the case of thin pavement layers, it is strain controlled and becomes a prominent failure mechanism. As a result, deformations occur from a lack of support from subsurface layers. This can occur due to poor design or construction as well as saturation of base layers in rainy seasons. The work dissipated per loading cycle is represented by the following equation.

W = À × Ão × × s i ƒ n

Where

Ão = × "

W = À × × [" s i ƒ n]

The work is this situation is dissipated via cracking, crack propagation, heat or plastic flow. Dissipation is limited by limiting the value of G*×sinƒ. A lower G* value indicates a softer material more apt to deform without developing large stresses and cracks. When ƒ is smaller, the binder tends to be more elastic and recover without dissipating energy (Roberts et al., 1996).

2.5 Review of Plastic Wastes application for asphaltic roads

(Swami et al., 2012) Have doing experiment on modified bitumen first Collected Plastic was cut into fine pieces, then sieved through 4.75mm sieve and retaining at 2.36mm sieve was collected, then. Bitumen was heated up to the temperature about 160^{0}C-170^{0}C which is its melting temperature .Optimum percentage of plastic added in between 5% to 10% added slowly to the hot bitumen of temperature around 160-170^{0}C. The mixture was stirred manually for about 20-30 minutes the result show that penetration, ductility and stripping value decreases this indicating that load resistance and water resistance capacity increases. Flash point and fire point increases prevent the inclusion of highly inflammable volatile fractions in kerosene distillates. (Gawande, 2013) has done first he has collected plastic bag mainly LDPE and HDPE raw material made clean and dry plastic waste. Shredded plastic waste in the required size of 2-4mm then blend with standard grade of 60/70 hot bitumen, at temperature of 180^{0}c stirrer properly and cool up to 130-150^{0}c, from this it analyzed penetration and ductility value decreases, softening point and flash and fire point increases.

(Sadeque and Patil, 2013) studied, the effect of waste Low Density Polyethylene (LDPE) and Polypropylene (PP) obtained from waste carry bag, on various properties of bitumen based on penetration, ductility softening point have been evaluated the process are Waste LDPE and PP modified bitumen is prepared in laboratory by heating bitumen at 200^{0}C and waste plastic mixed in 2%, 4%, 6%, 8% and 10% with 60/70 standard grade of bitumen and stir for one hour the result are, The reduction in penetration is 4 to 60%, for LDPE concentration increases from 2 to 10 %, ductility value decreases by 5 to 60%, softening value increases from 40^0 to 70^{0}C, increases LDPE concentration from 2 to 10% of respectively.

(Kalantar et al., 2010) changed the quality of asphalt pavements by adding different types of polymeric substances together with asphalt mix gives different advantages this are increases fatigue resistance , improved thermal cracking property of asphalt and reduced temperature susceptibility. By changing crashed waste plastic mixing ratio into bitumen from 6% up to 12% varying 1% and conventional bitumen(without plastic) for stone mastic asphalt using quality criteria of Marshall Stability, tensile strength and compressive strength test it is achieved that 10% optimum percentage of adding plastic waste in to modified bitumen. The result shown that increase in the stability by 64%,tensile strength by 18% and compressive strength by 75%, respectively compared to the conventional bitumen for stone mastic asphalt. (Bindu and Beena, 2010) Polymer bitumen has better quality as compare to plain of bitumen by using performance criteria of softening point, penetration and ductility, from laboratory result it analyzed that softening point of blend bitumen has increased ,penetration value and ductility decreases this resisted high temperature and load by changing coating plastic porosity ,absorption of and moisture improve of soundless therefore from this Hence the use of waste plastics for flexible pavement is one of the best methods for easy disposal of waste plastics. Use of plastic bags in road help in many ways like Easy disposal of waste, better road and prevention of pollution (Vasudevan, 2006) (Khan et al., 2009) using plastic waste 8% and polymer waste 15% compare conventional bitumen result shown that it increases Marshall Stability, retained stability, indirect tensile strength and rutting was observed in Plastic modified bituminous concrete mixes therefore from this the quality of Asphaltic road enhance substantially life of pavement surfacing using the waste plastic. (Zoorob and Suparma, 2000) describes using recycled plastic made of LDPE raw material substitute mineral aggregate of size between 2.36 - 5.0mm final result it indicate that 30% of aggregate substituted by LDPE plastics and reduced bulk density by 16% and comparing Marshall stability much higher as compare to convectional bitumen. (Dixit and Rastogi, 2013) using waste plastic fiber at temperature of 170^{0}c, Mechanical Stirrer of 1550rpm by varying percentage of modifier from 0.1% up to 0.9% the result shows that penetration value decrease up to adding 0.6% plastic fiber using 80/100 bitumen reach quality 60/70 and softening point increase more than 55^{0}c by addition plastic fiber 0.7,0.8, 0.9% ductility value decreases as increases plastic waste modifier and optimum point he can achieved 0.6% plastic added to bitumen. (Afroz Sultana and Prasad, 2012) uses 80/100 grade bitumen mix with waste plastic (LDPE ,HDPE ,PP) size between 4.75 pass and 2.36mm retain plastic, temperature range 160 ^{0}C and 170 ^{0}C by varying composition plastic taken 0.5,2.0,2.5,3,5% by weight maintain constant stirring 120 rpm. The result indicate that softening point and Marshall stability increases as composition plastic increase and ductility value decreases as composition of plastic waste increases and optimum value he can achieved that for PP 6% and 8% for LDPE (Ghuzlan A et al). Are study by mixing polyethylene with ratio of 3, 4, 5, 6, and 7% with Bitumen. First heated bitumen to a temperature of 160-170 ^{0}C, and the required mass (ratio) of PE was added in the form of small segments of plastic and mixing takes places using a mechanical mixer rotational speed of 1,300 rpm for 30 minutes then analyze

Rheological Properties of Polyethylene Modified bitumen using DSR (Dynamic Shear Rheometer) instruments using Four testing temperatures used (58, 64, 70, and 76°C) while the loading frequency was set at 10 rad/s (1.59 Hz) the result show that The original asphalt binder failed to meet the specifications for the Superpave rutting parameter (G*/sin ƒ) at temperatures of 70 ^{0}C and more. On the other hand, all the PE-modified asphalt binders satisfied the Superpave specifications for this parameter at all temperatures: 58, 64, 70, and 76 ^{0}C. By increasing the temperature, the G* /sin ƒ value decreased. However, none of the tested PE-modified asphalt binders provided a G* /sin ƒ value below the minimum Superpave specification of 1.0 kPa. As a result of the PE modification, the rutting resistance of the asphalt binder was significantly improved. (Kumar et al., 2009) uses bitumen grade (80/100) tests as per guide lines AASTHO TP5-1994 using sinusoidal shear stress (frequency 10rad/s) and temperature between 46-82 ^{0}C were taken with increment of 6 ^{0}c from lab it analyzed that at temperature for neat Bitumen using 10 rad/s and temperatures at 58 ^{0}C phase angle(ƒ) 89.8 ^{0} almost completely viscous and at 70 ^{0}C phase angle(ƒ) become 98.2 ^{0} unmodified bitumen lose its nature completely but by adding crumb rubber into modified bitumen shows considerable elasticity at 70 ^{0}C (Gawande et al, 2012)

2.6. Wet process

Basically there are two process technologies, wet process and dry process to modify bitumen with plastic wastes. However, for this project wet process selected since this process technology more coincides to principles of chemical engineering and the Process can be utilized for recycling of any type, size, shape of waste material like Plastics, Rubber etc. Wet process involves continuous mixing of blending bitumen and waste plastic by modifying rheological properties through blending with synthetic polymers (Gawande et al, 2012) and Waste plastic is ground and made into powder; 6 to 8% plastic is mixed with the bitumen. Plastic increases the melting point of the bitumen and makes the road retain its flexibility during winters resulting in its long life, use of shredded plastic waste acts as a strong †binding agent‡ for tar making the asphalt last long by mixing plastic with bitumen the ability of the bitumen to

CHAPTER 3

MATERIALS AND METHODS

3.1 Chemicals and Instruments

3.1.1 Chemicals

All chemicals used in this study were analytical grades; which is found in civil engineering at Bahir Dar institute of technology, Bahir Dar University. The materials used are Dextrin and Glycerin (purity>99), Benzene, Crushed LDPE, PET and Bitumen. the Dex and Glycerin are used to remove modified bitumen from the equipment after checking the qualities. Benzene is used to clean up all the equipments. Crushed LDPE, PET and Bitumen are used as a raw material.

3.1.2 Instruments

Prepared Modified bitumen the qualities were analyzed by, Ductility, penetration, softening and Marshall Stability apparatus. The instrument are used to characterized the result are, Sieves range from 37.5mm up to 0.00mm, Digital Balance and Magnetic stirrer to measure quantity of an aggregate and modified bitumen.

3.2 Experimental Descriptions

3.2.1 Modified bitumen preparations process

Waste plastic was collected from Ashraf Agricultural Industrial PLC Bahir Dar Ethiopia. First of all the bitumen is heated until it became liquid and the crushed PET and LDPE waste became sieved with sieve size of 2-5 mm. The molten bitumen using temperature range of 150-180 ^{0}C poured into pans with a volume of 800 ml. Added PET and LDPE 6, 8, 10 ,12% by weight of bitumen and plastic sizes of 1,2,3,5mm were mixed into bitumen according to laboratory analysis ratio. The mixing was performed in the laboratory used mechanical stirrer at frequencies of 400, 1600, 1000 and 200 RPM. The typical time used for preparation of the blend bitumen was 1 hour.

.

Fig 3:1 General Process of modified bitumen preparation equipment

3.2.2 Characterization of plastic

3.2.2.1 Thermal analysis

Thermal behavior study of polymers shows that polymers get softened easily without any evolution of gas around 130-140 ^{0}C (Gawande et al, 2012) At around 350 ^{0}C they get decomposed releasing gases like methane, ethane etc. and at 700 ^{0}C they undergo combustion, producing gases like CO and CO2. Thermal property of plastic raw material was determined by differential scanning calorimetric (DSC) using glass transition and melting point analysis.

Fig 3: 2 DSC measuring instrument

3.3 Experiments for Optimization of modified bitumen

Design Expert software, Version 7.0.0 (Stat-Ease) was used to design the experiment and to optimize the modified bitumen production using waste plastic as a raw material. Response surface method coupled with central composite design was used to analyze the data obtained from the experiments. The four independent variables considered in this study are temperature, sizes, mixing rpm and composition. Table 3.1 presents the target and levels of the four independent variables considered in this particular study. Table 3.2 total run for each experiment 30 points are selected based on central composition methods design experts. The responses of the modified bitumen preparation process are Softening point (^{0}C), penetration value (mm), Ductility value (cm) and Marshall Stability (KN). Selection of each level for each factors are based on the literature reports.

Table 3:1 : Target and levels of manipulated variables

No	Factors	Unit	Target	Level and Coded numbers				
				-2	-1	0	1	2
1	Size	mm	Maximize	1	2	3	4	5
2	Composition	%	Maximize	4	6	8	10	12
3	Temperature	^0C	Minimize	153	160	167	174	181
4	stirring rpm	rev/min	Minimize	400	1000	1600	2200	2800

Table 3: 2: Central Composite Design matrix of four independent variables

Run	Manipulated variables							
	A		B		C		D	
	Size (mm)	Level	Composition (%)	Level	Temp (^0C)	Level	RPM (rev/min)	Level
1	3	0	4	--2	167	0	1000	-1
2	2	-1	6	-1	174	1	2200	1
3	2	-1	6	-1	160	-1	1000	-1
4	4	1	6	-1	160	-1	1000	-1
5	4	1	6	-1	160	-1	2200	1
6	2	-1	6	-1	160	-1	2200	1
7	4	1	6	-1	160	-1	2200	1
8	4	1	6	-1	174	1	2200	1
9	4	1	6	-1	174	1	1000	-1
10	3	0	8	0	181	2	1600	0
11	3	0	8	0	167	0	1600	0
12	3	0	8	0	153	-2	1600	0
13	3	0	8	0	167	0	1600	0
14	5	2	8	0	167	0	1600	0
15	3	0	8	0	167	0	1600	0
16	1	-2	8	0	167	0	1600	0
17	3	0	8	0	167	0	1600	0
18	3	0	8	0	167	0	1600	0
19	3	0	8	0	167	0	2800	2
20	3	0	8	0	167	0	1600	0
21	3	0	8	0	167	0	400	-2
22	3	0	12	2	167	0	1600	0
23	2	-1	10	1	160	-1	1000	-1
24	2	-1	10	1	160	-1	2200	1
25	4	1	10	1	160	-1	1000	-1
26	4	1	10	1	160	-1	2200	1
27	2	-1	10	1	174	1	2200	1
28	4	1	10	1	174	1	2200	1
29	4	1	10	1	174	1	1000	-1
30	2	0	10	1	174	1	1000	-1

3.4 Modified bitumen characterization processes

The quality of modified bitumen is strongly determine by application of several factors such as specific gravity, softening point, penetration value, ductility, Marshall stability, solubility and stripping value measurements (Nemade and Thorat, 2013)

3.4.1 Specific gravity of modified bitumen

Specific gravity is telling one of the means to identify the property bitumen. Heating modified bitumen sample and Pour into Pycnometer instrument up to 3/4th of its capacity, allow the pycnometer to cool ambient temperature for period of more than 40min and weight filled modified bitumen. Insert filled modified bitumen into water bath for period for 30min.

3.4.2 Softening point test

The softening point is an empirical test and denotes the temperature at which bitumen would behave more like a liquid and less like a solid under standard conditions of heating and loading. This test is conducted using ring and ball apparatus. The principle behind this test is that softening point is the temperature at which the substance attains a particular degree of softening under specified condition of the test. Modified bitumen to be tested were gently heated and stirred to prevent agglomeration. The sample was poured into a brass ring then allows cooling at a temperature between 15^0C and 30^0C for 30-40minute. A steel ball is placed upon the bitumen sample and the liquid medium is heated at a rate of 5^0C per minute. When the softened bitumen touches the metal plate which is at specified distance temperature was recorded and take average.

Fig 3:3 Softening point measuring apparatus

3.4.3 Penetration index test

Penetration measures the hardness or softness of bitumen by measuring the depth in tenths of a millimeter to which a standard loaded needle will penetrate vertically in 5 seconds. BIS had standardized the equipment and test procedure. The penetrometer consists of a needle assembly with a total weight of 100g and a device for releasing and locking in any position, the bitumen is softened to a pouring consistency, Stirred thoroughly and poured into containers at a depth of at least 15mm in excess of the expected penetration. The test should be conducted at a specified temperature of 25^0C

Fig 3:4 Penetration measuring apparatus

3.4.4 Ductility index tests

The Ductility test is an empirical test which measures the cohesive strength of bitumen. It is the property of bitumen that permits it to undergo great deformation or elongation. The ductility of a bituminous material is measured by the distance in cm to which it will elongate before breaking when a standard briquette specimen of the material is pulled apart at a specified speed and a specified temperature Bitumen sample was melt and then pour in the mould assembly and place on a brass plate, after a solution of glycerin and dextrin is applied at all surfaces of the mould exposed to bitumen. Samples with moulds are cooled in the air for about 30-40 minute. And remove the sample and mould assembly from water bath and cut off the excess bitumen material by leveling the surface using hot knife. After trimming the specimen, the mould assembly containing sample was replaced in water bath maintained at 27^0c for 85 to 95 minutes. Then the sides of the mould were removed and the clips were hooked carefully on the machine without causing any initial strain. Three specimens in the moulds were prepared and clip to the machine, so as to conduct these tests simultaneously. Finally set the pointer to read zero. Finally start the machine and the two clips are thus pulled apart horizontally. The distance up to the point of breaking of thread is the ductility value which is reported in cm.

Fig 3:5 Ductility value measuring instrument

3.4.5 Marshall stability measurements

Marshall Stability measures the maximum load sustained by the bituminous material at a loading rate of 5 mm/min. Marshall Stability is related to the resistance of bituminous materials to distortion, displacement, rutting and shearing stresses. The coarse aggregate, fine aggregate, and the filler material should be proportioned so as to fulfill the requirements of the relevant standards. The required quantity of the mix is taken based on (ASTM D5315) so as to produce compacted bituminous mix specimens of thickness 63.5 mm approximately and total of 1200 gm of aggregates with different size of filler. To produce the desired thickness mould gradation of aggregate presented in table 3.3 were considered.

Table 3:3: Gradation of Asphalt Binder aggregate size

No	Aggregate size in(mm)		Blending proportion	
	pass	retained	Percentage	Mass(gm)
1	25	19	5	60
2	12.5	9.5	27	324
3	6.3	4.75	18	216
4	4.75	2.36	14	168
5	0.6	0.3	25	300
6	0.15	0.075	6	72
7	0.075	0.0	5	60
Total mass				1200

Then aggregates were heated to a temperature of 175 to 190 ^{0}C the compaction mould assembly and rammer are cleaned and kept pre-heated to a temperature of 100 ^{0}C to 145 ^{0}C. The bitumen is heated to a temperature of 121 ^{0}C to 138 ^{0}C and the required amount of first trial of bitumen is added to the heated aggregate and thoroughly mixed. The mix is placed in a mould and compacted with number of blows 50 on both side. The sample is taken out of the mould after few minutes using sample extractor.

In conducting the stability test, the specimen is immersed in a bath of water at a temperature of 60^0 C+/- 1^0C for a period of 30 minutes. It is then placed in the Marshall Stability testing machine and loaded at a constant rate of deformation of 5 mm per minute until failure. The total maximum in kN (that causes failure of the specimen) is taken as Marshall Stability and the total amount of deformation is units of 0.25 mm that occurs at maximum load is recorded as flow value. The total time between removing the specimen from the bath and completion of the test should not exceed 30 seconds.

3.4.6 Visco- elastic property of bitumen

The dynamic shear rheometer is a common tool used to study the rheology of asphalt binders. Asphalt binder is viscoelastic material and it behaves as elastic and viscous material at the same time. DSR is used to capture this elastic and viscous behavior of the asphalt binder and is used to measure asphalt binder properties at intermediate to high service temperatures. Testing temperature is obtained based o the geographical location of the place where this binder will be used. The output of the DSR testing is the complex shear modulus (G*) and phase angle (ƒ). The complex shear modulus (G*) is defined as the ratio of maximum applied shear stress to the maximum applied resulted shear strain which under test conditions is caused by the oscillating plates of the DSR. Elastic portion of the asphalt binder is measured through the phase lag or phase angle (ƒ). No time difference between shear stress and she strain indicates a completely elastic material (zero phase angle). A completely viscous material would have a phase difference or angle of 90^0. Therefore, a phase angle between 0° and 90° indicates a viscoelastic condition of the material. The elastic portion of the complex shear modulus is defined as the storage shear modulus (G*cosƒ), whereas the viscous portion is defined as the loss shear modulus (G*sin ƒ).

Fig 3:6 Dynamic Shear Rheometer instrument

To this end first a hot bitumen sample/specimen (0.15-0.20 g) was transferred onto design silicon mold after that it cool in the air then inserted in to DSR instrument. The top test plates was moved until the gap between the plates equaled the testing gap (1.5 mm) plus the closure required to create a suitable bulge in the test specimen. The excess bitumen was trimmed by moving a heated trimming tool around the edges of the plates so that the bitumen sample was flush with the outer diameter of the plates. After the trimming was complete, the gap between the test plates was decreased in to 1mm. The test specimen is maintained at the test temperature of 70.0 ^{0}C ± 0.1 by enclosing the upper and lower plates in a thermally controlled environment or test chamber the angular frequency was put 10 rad per second (equivalent to 1.59 Hz). Then the Complex Shear Modulus (G*), phase angle (δ), elastic modulus (G') and viscous modulus (G'') are calculated automatically using DSR instrument.

3.4.7 Solubility test

Bitumen consists of high-molecular-weight hydrocarbons soluble in carbon disulfide. The bitumen content of a bituminous material is measured by means of its solubility in trichloroethylene. In the standard test for bitumen content (AASHTO D T-44 (2006)) a small sample of about 2 g of the asphalt is dissolved in 100 ml of trichloroethylene for 30 minutes and the solution is filtered through a filtering mat in a filtering crucible. The material retained on the filter is then dried and weighed, and used to calculate the bitumen content as a percentage of the weight of the original asphalt

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Characterization of raw materials

4.1.1 Thermal analysis

Thermal property of plastic raw material was determined by differential scanning calorimetric (DSC). The result obtained for the thermal property of LDPE and PET plastics is presented in figure 4.1 and 4.2. As it can be seen in the figure, for LDPE glass transition temperature is found to be around 52°C and melting point 120°C. Whereas for PET glass transition temperature is 54°C and melting point is 264°C. The results are in agreement with literature reported by (DEMˆREL et al., 2011). This suggest that the raw material used for modified bitumen are pure LDPE and PET plastic.

Fig 4:1 Endothermic heat flow versus temperature graph for LDPE

Fig 4:2 Endothermic heat flow versus temperature graph for PET

4.2 Characterization of Aggregates

Aggregates uses for concrete should satisfy the requirements of standard grading in order to achieve non-porous, high strength, workability and good finishes, this are crushing value, water adsorption, specific gravity and aggregate shapes.

Crushing value:

Crushing value test was standardized by BS 812: Part 3, used to determine the crushing strength of aggregates. It specifies that minimum acceptable limit value for heavy-duty concrete finishes 25 %, pavement-wearing surfaces of 30% and 45%, this provides a relative measure of resistance to crushing under gradually applied crushing load. For this particular study the crushing value is found to be 16.58%. This is within the range of BS 812 of an aggregate so, it possible to used any road construction purposes.

Water absorption:

Water absorption tells the strength of aggregate, if an aggregate absorb more water, it became more porous in nature, this causes weak strength and unsuitable to uses for road construction purposes. The water absorption test of the prepared aggregate 0.29% which is the standard range of coarse aggregate specified as per BS 812: Part 2:1975

Specific gravity:

Specific gravity it indicated the strength of aggregate, standard criteria for coarse aggregate specified on BS 812: Part 2:1975 range from 1.95- 2.87, from laboratory result 2.477.so our laboratory result met the standard.

Flakiness index:

Flakiness index very important to analyze bitumen quality based on Marshall Stability measurement. from table 4.1 below it indicated that total percentage of an aggregate passed using thickness gauge from total sample taken, standard criteria for flaky aggregate used BS 882:1992 (Ref.3) range from 11-35%, our laboratory result 32.05%, therefore an aggregate qualified the standard to used for road construction purposes

Table 4:1 : Thickness gauge aggregate sieving measurement result

No	Type of sieve (mm)	First trial		Second trial		Average(pass)	
		Total weight(retain)	pass	Total weight(retain)	pass	Average(total weight)	Average pass
1	37.5	0	0	0	0	0	0
2	28	292.47	43.75	293.65	56.32	50.035	293.06
3	20	363.25	28.64	322.54	51.61	40.125	342.89
4	14	695.91	298.7	547.23	356.78	327.74	621.57
5	10	415.85	131.31	425.36	110.25	120.78	420.60
6	6.3	7.84	1.78	12.6	3.2	2.49	10.22
Total weight		1775.32	504.18	1601.38	578.16	541.17	1688.3

Determination of Elongation Index:

The elongation index it shown that to analyze bitumen quality based on Marshall Stability measurement From table 4.2 below it determined that total percentage of an aggregate retain on length gauge over total sample taken, standard criteria for elongated aggregate use British standard 812:1989:Section 105.2 range from 10-37% , our laboratory result 19.99, therefore an aggregate qualified the standard

Table 4:2 : Length gauge aggregate measurement result

No	Type of sieve (mm)	First trial		Second trial		Average	
		Total weight(retain)	Retain	Total weight(retain)	Retain	Total weight	retain
1	37.5	0	0	0	0	0	0
2	28	292.47	0	216.56	4.6	2.3	254.51
3	20	363.25	69.58	322.54	55.89	62.73	342.89
4	14	695.91	93.53	588.23	125.36	109.4	642.07
5	10	415.85	165.47	200.31	98.63	132.0	308.08
6	6.3	7.84	6.65	8.89	2.36	4.505	8.365
Total weight		1775.32	335.23	1336.53	286.8	311.0	1555.9

4.3 PET mixed modified bitumen

Experimental result listed on table 4.3 and table 4.5 for each 30 points are selected based on central composition methods design expert. The laboratory result has done for Softening point (^{0}C), penetration value (mm), Ductility value (cm) and Marshall Stability (KN).

Table 4:3: Experimental results for PET mixed modified bitumen

Run No	Ductility (cm)	Penetration (mm)	Softening pt(^{o}c)	Marshall (KN)	Run No	Ductility (cm)	Penetration (mm)	Softening pt(^{o}c)	Marshall (KN)
1	81.4	75	63	7.8	16	98.4	96	54.8	4.563
2	82.6	78	63.5	7.85	17	84.8	84	58.6	5.481
3	86.8	89	59	6.322	18	83	85	57	5.481
4	76.4	74	62.2	6.541	19	100.2	98	55.4	4.821
5	83.6	84	57	5.841	20	80.4	84	48.2	4.432
6	82.8	83	56.4	5.641	21	84.2	86.6	42.6	4.322
7	83.4	84	57.2	5.481	22	78.6	82.6	51.6	4.862
8	77.8	78	62.8	6.586	23	99.6	98	52.6	4.921
9	82.4	79.6	64.6	7.821	24	77.4	74.6	61.8	6.59
10	83.4	84	57	5.481	25	80.6	74.8	62.4	7.632
11	75.6	80.4	48.2	4.671	26	81.2	85.8	44.8	4.632

12	78.6	79.6	63.2	6.32	27	66.5	68.6	67.6	7.923
13	96.4	92.6	58.8	5.781	28	83.8	88.8	46.8	4.654
14	83.2	84	57	5.481	29	98.6	98.8	52.6	4.841
15	83.1	84	57	5.481	30	79.8	86.2	49.6	4.741

4.3.1 Regression analysis of pet mixed modified bitumen

The empirical response model was fitted by regression analysis of the collected response variable data. By using regression analysis the response obtained in table 4.3 were correlated with four independent factors using the polynomial equation as shown in equation below. The model is expressed by equation 4.4.1, which takes their coded value.

Pet mixed modifed bitumen $= +56.63 - 1.50 * A + 3.62 * B + 1.25 * C + 1.50 * D + 0.3A*B - 0.79 * A^2 + 0.27 * B^2 + 0.21 * A^2 * B$

The assumption of normality was checked with the residual plots generated in design expert. Normality requires that the data has zero mean and constant variance. This is necessary in order to apply the hypothesis. As it can be seen from Figure 4.6 the data meet this assumption.

Fig 4:6 Normal probability distribution of PET mixed modified bitumen

Using Design Expert software, analysis of variance (ANOVA) was performed to investigate fitness and significance of the model. It can also present the effects of individual parameters and interaction of variables on the responses. Summaries of the analysis of variance (ANOVA) are reported in table 4.4 Values of "prob. > F" less than 0.0500 indicates the model terms are significant. The ANOVA table shows that the four parameters size (A), composition(B), temperature (C), stirring rpm (D), also interaction of size to composition (BD) and quadratic terms of size (A^2), composition (B^2) significantly affect the measured response of PET mixed modified bitumen. The coefficient of determination, R^2 for the model was 96.45%. This indicates only 3.55% of the total variability was not explained by the regressors in the model. The high value of R^2 specifies that the model able to give a good estimate of response of the system in the range studied.

Table 4: 4: ANOVA table of PET mixed modified bitumen

No	Source	Sum Squares	df	Mean Square	F- Value	Prob > F	
	Model	735.717	22	33.44168	25.96211897	< 0.0001	significant
1	A-size	18	1	18	13.974122	0.0073	significant
2	B-compostion	105.125	1	105.125	81.61275416	< 0.0001	significant
3	C-temperature	12.5	1	12.5	9.704251386	0.0170	significant
4	D-strring rpm	18	1	18	13.974122	0.0073	significant
5	AB	0.25	1	0.25	0.194085028	0.008	significant
6	AC	0.16	1	0.16	0.124214418	0.7349	
7	AD	0.1225	1	0.1225	0.095101664	0.004	
8	BC	2.89	1	2.89	2.243622921	0.1778	
9	BD	1.8225	1	1.8225	1.414879852	0.2730	
10	CD	1.1025	1	1.1025	0.855914972	0.3857	
11	A^2	17.28107	1	17.28107	13.41598891	0.0080	significant
12	B^2	1.981071	1	1.981071	1.537985213	0.0009	significant
13	C^2	0.181071	1	0.181071	0.140573013	0.7188	
14	D^2	25.08107	1	25.08107	19.47144177	0.3831	
15	ABC	0.2025	1	0.2025	0.157208872	0.7035	
16	ABD	0.64	1	0.64	0.496857671	0.5037	
17	ACD	0	1	0	0	1.0000	
18	BCD	3.61	1	3.61	2.8025878	0.1380	
19	A^2B	19.5075	1	19.5075	15.14445471	0.0060	significant

4.4: LDPE mixed modifed bitumen

Table 4: 5: Experimental result for LDPE mixed modified bitumen

Run No	Ductility (cm)	Penetration (mm)	Softening pt(^{o}c)	Marshall (KN)	Run No	Ductility (cm)	Penetration (mm)	Softening pt(^{o}c)	Marshall (KN)
1	80.4	74.6	58	8	16	101.4	93.8	47.8	4.563
2	81.4	73	66.5	8.05	17	79.8	79	51.6	5.681
3	82.8	84	52	6.522	18	78	80	50	5.681
4	72.4	74.6	55.2	6.751	19	103.2	90	48.4	4.821
5	78.6	79	50	6.041	20	74.8	83.8	41.2	4.432
6	76.8	78	49.4	5.841	21	79.2	81.6	35.6	4.322
7	78.6	79	50.2	5.681	22	73.6	77.6	44.6	5.062
8	72.8	73	55.8	6.786	23	102.6	91	45.6	4.921
9	85.4	69.8	57.6	8.021	24	72.4	69	54.9	6.79
10	78.4	79	50	5.681	25	83.6	70	55.4	7.832
11	70.6	75.4	41.2	4.871	26	78.8	81.2	37.8	4.632
12	73.6	68	56.2	6.52	27	58.6	63.6	60.6	8.123
13	99.6	87.6	51.8	5.981	28	79.4	78	39.8	4.654
14	78.2	79	50	5.681	29	101.6	92	45.6	4.841
15	78.1	79	50	5.681	30	76.2	80.8	42.6	4.741

4.4.1 Regression analysis of LDPE mixed modified bitumen

The empirical response model was fitted by regression analysis of the collected response variable data. By using regression analysis the response obtained in table 4.5 were correlated with four independent factors using the polynomial equation as shown in equation below. The model is expressed by equation list below, which takes their coded value.

LDPE mixed modifed bitumen = +49.85 - 2.61* A+6.70 * B +0.87 * D - 0.26 A*B+1.14* B * D

The assumption of normality was checked with the residual plots generated in design expert. Normality requires that the data has zero mean and constant variance. This is necessary in order to apply the hypothesis. As it can be seen from Figure 4.7 the data meet this assumption.

Fig 4:7 Normal probability distribution of LDPE mixed modified bitumen

Using Design Expert software, analysis of variance (ANOVA) was performed to investigate Fitness and significance of the model. It can also present the effects of individual parameters and interaction of variables on the responses. Summaries of the analysis of variance (ANOVA) are reported in table 4.6. Values of "prob. > F" less than 0.0500 indicates the model terms are significant. The ANOVA table shows that the four parameters of size (A), composition(B), temperature(C), stirring rpm (D), also interaction of size to composition (AB), size to temperature and temperature to stirring rpm (BD significantly affect the measured response of LDPE mixed modified bitumen. The coefficient of determination, R^2 for the model was 99.45%. This indicates only 0.05% of the total variability was not explained by the regressors in the model. The high value of R^2 specifies that the model able to give a good estimate of response of the system in the range studied.

Table 4: 6: ANOVA table of LDPE mixed modified bitumen softening point.

No	Source	Sum of Squares	df	Mean Square	F - Value	p-value Prob > F	
	Model	1329.936	10	132.993583	30.30599	< 0.0001	significant
1	A-size	163.2817	1	163.281667	37.2079	< 0.0001	significant
2	B-compostion	1077.36	1	1077.36	245.504	< 0.0001	significant
3	C-temperature	0.201667	1	0.20166667	0.045955	0.0285	
4	D-strring rpm	18.375	1	18.375	4.187214	0.0148	significant
5	AB	7.0225	1	7.0225	1.600256	0.2212	significant
6	AC	12.96	1	12.96	2.953268	0.1020	significant
7	AD	15.21	1	15.21	3.465988	0.0782	

8	BC	14.8225	1	14.8225	3.377686	0.0818	
9	BD	20.7025	1	20.7025	4.717594	0.0427	significant
10	CD	0	1	0	0	1.0000	

4.5: Effects of operating conditions on modified bitumen preparation process

Central composite design coupled with response surface methodology was used to optimize the experimental parameters for the desired response of the system on the basis of the model and input criteria. Four parameters were optimized using response surface methodology by fitting the experimental data obtained from the design expert 7.0.0 software

Fig 4: 8 Interaction effects of mixing parameters for wastes LDPE and PET plastics into bitumen

Optimization of the mixing parameters was carried out using a numerical optimization method; the results are PET mixed modified bitumen size 3.00mm, composition 8% , temperature 160 ^{o}C and mixing rpm 1099.56rev/min and responses are Ductility 80.3cm, penetration 81.3mm, Softening point 55.6 ^{0}C Marshall Stability 5.338KN based on 88.8% of desirability.

Fig 4: 9 3-D response surface plot of modified bitumen

For LDPE mixed modified bitumen Optimal mixing values are size 2.80mm, composition7.39% , temperature 160^{o}c and mixing rpm1062.07rev/min and response are Ductility 80.3cm, penetration 81.9074mm, Softening point 47.69^{o}c Marshall Stability 5.338KN based on 76.7% of desirability.

4.6 Validation of the optimum values of the results

In order to confirm the validity of the model, ten experiments were done using optimum value of factors (size, composition, mixing rpm and temperature) and check all quality criteria based on standards values The average result are shown table 4.7 it seen that, experimental result almost similar value with software analysis.

Table 4:7 : Optimum values of validation results

	optimum values	Size (mm	Comp (%)	Temp (^{o}c)	Rpm (rev/min)	Softening (^{0}C)	Penetration (mm)	ductility (cm)	Marshall (KN)
LDPE	Software	2.80	7.39	160	1062.07	47.69	81.91	80.3	5.338
	Actual	2.80	7.39	160	1062.07	47.20	82.41	84.6	5.321
PET	Software	3.00	8.00	160	1099.56	55.60	81.3	80.3	5.338
	Actual	3	8.00	160	1099.56	56.3	80.26	79.54	5.438

4.7 physico-chemical property and Comparison of Bitumen based on standards values

From the table 4.8 listed below it indicated that by adding waste LDPE and PET plastic in to bitumen, using a parameter of size, composition, temperature and mixing rpm and comparing the result with unmodified bitumen, the value of penetration, ductility , softening point and Marshall stability have improved.

Table 4: 8: Comparative study of modified bitumen and detail quality criteria measurements

No	Type	Unit	Bitumen	Optimum value detail criteria Measurements		Standards ranges	Standards measurement
				Modified bitumen (PET)	Modified Bitumen (LDPE)		
1	Specific gravity	g/cm^{3}	0.978	0.982	0.98	0.97-1.02	IS 1202:1978
3	Size	mm		3.00	2.8	1-5	(Gawande, 2013)
4	Composition	%		8	7.39	0-8	(Gawande et al, 2012)
5	String RPM	Rev/min		1099.56	1062.07	1000-3000	(Dixit and Rastogi, 2013)
6	Temperature	^{o}C		160	160	160-180	(PATIL, 2015)
7	Softening point @25^{0}c	^{o}C	41.6	56.3	47.20	40-60	IS 1205:1978
8	Penetration point (100 g/5 sec)	mm	95.8	80.26	82.41	80-100	IS 1203:1978
9	Ductility @25^{0}c	cm	102.6	79.54	84.26	≤75	IS 1208:1978
10	Marshall stability	N	4569	5438	5321	≤5338	ASTM: D 1559 - 1979
11	Marshall flow(0.25mm)	mm	10.6	9.2	9.0	8-16	ASTM: D 1559 - 1979
12	Solubility test	%	99.8	99.4	99.6	99% min	AASHTO D T44-03 (2006)
13	Rutting resistance G*/sinƒ @10 rad/s	Kpa	2.4321	3.2457	3.1986	2.2 (min)	AASHTO TP58
14	Fatigue cracking resistance G*×sinƒ @10rad/s	Kpa	1.4256	3.0662	3.0648	5000Kpa (max)	AASHTO TP58
15	Stripping value	kg	1.58	0	0	<5%	IS : 6241-1971

CHAPTER 6

CONCLUSIONS AND OUTLOOKS

6.1 Conclusions

The quality of Modified bitumen improved by adding crushed waste plastics was investigated. In this work optimum value of mixing waste PET and LDPE plastics in to modified bitumen were analyzed by taking size, composition, temperature and mixing RPM as factors and Softening point, penetration value, Ductility and Marshall Stability as responses using central composite method of design expert together with laboratory analysis.

From softening point value measurement concluded that, by adding wastes plastic in to modified bitumen, it increased melting point and become very viscous, this help to increased temperature susceptibility resistant characteristics of Modified bitumen and uses for higher temperature zones. Penetration value measurements it indicated that, mix wastes plastics in to Bitumen it helped to increased the strength of Modified bitumen by decreased penetration values. Ductility value measured elastic nature of bitumen, therefore by added waste plastics in to modified bitumen up to 50cm elastic limit; it decreased deformation of asphaltic binder. Marshall Stability and flow measured the strength of asphaltic road by added wastes plastic in to bitumen it decreased deformation by increased strength asphaltic road, this possible to uses for high load resistance road construction.

From laboratory analysis, optimum value of waste PET and LDPE plastic added in to modified bitumen 8 percent and 7.43 percent respectively. PET mixed modified bitumen optimum operating parameters size 3mm, composition 8%, temperature 160 ^{o}c and mixing rpm 1099.6 rev/min and for LDPE mixed modified bitumen size 2.8mm, composition 7.39%, temperature 160 ^{o}c and mixing rpm 1062.02 rev/min.

Plastics are not easily decompose in to soil as a result of that it decreases soil fertility this causes environmental pollutions. So, by changing plastic waste in to useful form it decreases environmental impact. Therefore, from above it concluded that mixing wastes plastic in to modified bitumen best solution to increases the quality of bitumen as well as it controls plastic wastages that released from cities.

6.2 Outlooks

The current research thesis investigates the possibility of mixed plastic wastes in to modified bitumen using different parameters. According to all the results and observations, it indicated that the key findings in this thesis led to the following ideas for further considerations:

- ðØ For this project only analyzed optimum mixed ratio of plastic waste mixing into modified bitumen, but further study has needed, for detail investigation on Economic analysis of this project.
- ðØ For this project only studied, the effects of LDPE and PET waste plastic independently on modified bitumen, but further study have needed on optimum mixing ratio of LDPE and PET mixed in to modified bitumen.
- ðØ Under this work used grades 80/100 standards bitumen for road construction making purposes, but further study have needed to mix plastic waste in to bitumen using 30/40 and 60/70 grade of bitumen by considering a factor of temperature, size, stirring RPM, and composition of plastic wastes
- ðØ Further study has also needed using different plastic waste studies independently compare the result and finding optimum value.

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APPENDICES

APPENDIX A

Laboratory work pictures

Crushe
plastic

Crushed
PET bot

Fig: A.1 Crushed PET bottle and crushed LDPE plastic bag

Water

Modified bi

Fig: A.2 pycnometer apparatus

Weight sample blow sample crushing apparatus

Fig: A.3 Crushing aggregate procedure

Water

Aggrega

Fig: A.4 Socking aggregate with water

Water absorbi
cotton

Fig: A.5 Drying of aggregate

Fig: A.6 Flakiness index measuring apparatus (6.3-4.75mm)

Fig:A.7 Elongation measuring apparatus (37.5-6.3mm)

Fig: A.8 Different size of sieves

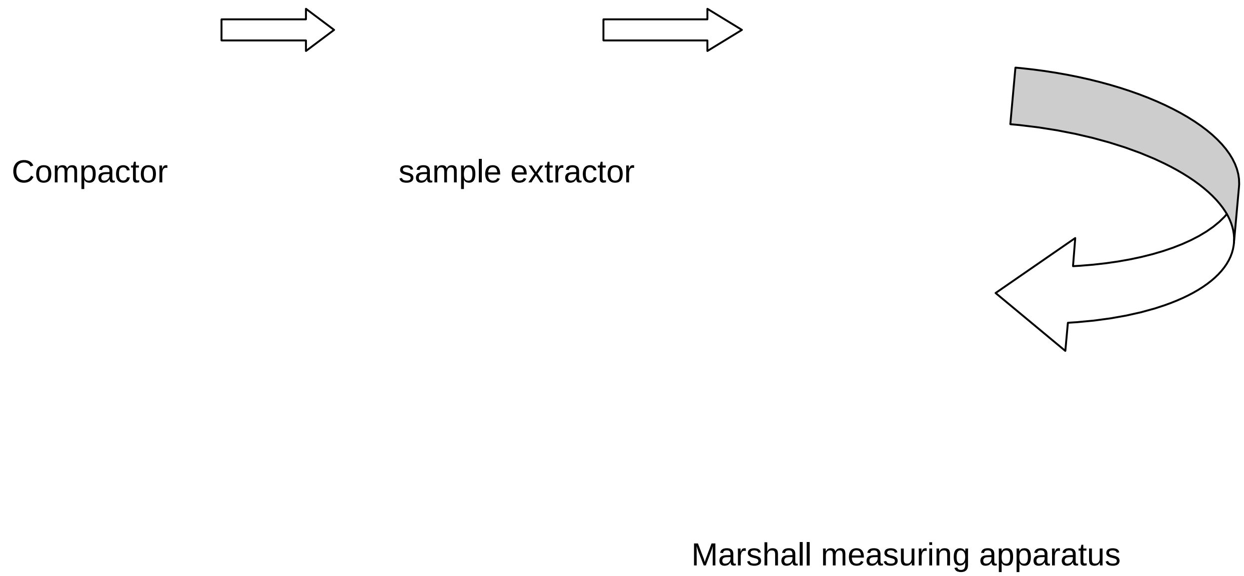

Fig: A.9 Marshall measuring procedure