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Influence of Polymer and Industrial Waste Additives on Mechanical Behavior of Asphalt Mixes

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***Abstract* - The performance of conventional bituminous mixtures used in flexible pavements is often affected by increased traffic loading, environmental variations, and moisture susceptibility. To address these challenges, this study explores the use of reclaimed polyethylene (RPE) obtained from waste packaging materials, in combination with industrial by-products such as fly ash and granulated blast furnace slag (GBFS), for improving asphalt mix performance.**

Bituminous Concrete (BC), Dense Bituminous Macadam (DBM), and Stone Mastic Asphalt (SMA) mixes were prepared and analyzed using the Marshall mix design method. The Optimum Binder Content (OBC) and Optimum Polymer Content (OPC) were established for both conventional and modified mixtures. Mechanical performance was assessed through Marshall stability, indirect tensile strength and drain-down resistance tests.

The results demonstrate that RPE enhances the cohesion between binder and aggregates, leading to improved stability and tensile properties. The addition of fly ash and GBFS contributes to enhanced moisture resistance and overall durability. An optimum level of polyethylene content was identified, beyond which performance declines due to reduced workability.

The study concludes that the integration of polymer modifiers with industrial waste materials is an effective and sustainable approach for producing high-performance asphalt mixtures, offering both engineering and environmental benefits.

Keywords: Bituminous concrete (BC), Stone mastic asphalt (SMA), Dense bituminous macadam (DBM), OMFED polyethylene, Marshall properties, Static indirect tensile strength test, Static creep test.

I. INTRODUCTION

Flexible Pavement

Flexible pavements refer to those architectural designs which possess low flexural strength while maintaining their ability to flex under load conditions. These pavement layer types show surface deformation because they transmit lower layer changes through to their upper surface.

Rigid Pavement

Pavement surfaces built with Plain Cement Concrete materials create rigid pavements because their entire structural system remains unable to bend or show deflection under vehicle weight.

Pavement engineering includes two essential design elements which are pavement design and mix design. The current research focuses exclusively on flexible pavement mix design elements. The asphalt paving mixture design process requires multiple stages to choose binder and aggregate materials while determining their appropriate proportions which will produce desired mixture performance through defined parameters and external influences like traffic patterns and environmental conditions.

1.1 Objective of Bituminous Mix Design

Main objectives of bituminous mix design are to find;

- The optimum bitumen content creates a pavement that maintains its durability.
- The material needs to withstand shear deformation under traffic conditions that experience hot weather.
- The compacted bitumen needs to maintain proper air voids, which permit extra compaction from traffic.
- The product needs enough workability to meet its requirements.
- The material requires enough flexibility to withstand traffic load without developing cracks.

1.2 Polymer Modification

1.2.1 Present Scenario

The construction industry depends on bituminous binders which serve as road pavement materials because their viscoelastic characteristics rely on their specific chemical makeup. The current situation demands that we look for new methods to enhance pavement performance because our

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regions face increased commercial vehicle traffic and all temperature changes from daily to seasonal. The current requirement for bitumen must be fulfilled through the addition of various additives which can modify its properties at present. The polymers function as one of the additives used for this process.

1.2.2 Role of Polyethylene in Bituminous Pavements

The application of polyethylene material in the process of building roads has existed since ancient times. Certain types of aggregates show a strong tendency to attract water. Polyethylene shows the same water repelling behavior as bitumen since it functions as a hydrophobic material. The process of adding hydrophobic polymers to asphalt mix through dry or wet mixing methods results in improved strength and water repellent characteristics for asphalt mix. The road construction process starts with adding polyethylene to hot bitumen which creates a mixture that is used to build roads in the same manner as tar roads. The construction material for plastic roads uses essential ingredients which include plastic carry-bags, disposable cups, polyethylene packets and PET bottles that municipal waste collection centers retrieve from disposed garbage. Pavement performance can be enhanced through polymer modification which increases fatigue resistance while it decreases both rutting and thermal cracking. The process of creating a modified bituminous mixture through the use of recycled polymers like polyethylene produces a HMA mixture which enhances pavement durability while it also serves as an effective method to dispose of recycled plastics.

1.3 Objectives of Present Investigation

The study compared SMA and BC and DBM mixes which tested different binder contents from 3.5% to 7% and different polyethylene contents from 0.5% to 2.5%.The investigation aims to investigate the following areas:

- Study of Marshall Properties of mixes using both.
- The study investigates how polyethylene functions as an admixture to enhance the strength of bituminous mix which contains various fillers and uses slag to replace specific proportions of fine aggregate.
- The study investigates how polyethylene admixture affects the performance of bituminous mix in water through its interaction with different fillers and its use of slag to replace certain amounts of fine aggregate.
- The study examines how polyethylene content affects the resistance of mixes against permanent deformation.
- The evaluation of SMA BC and DBM mixes involved various tests which included Drain down test and Static Indirect tensile Strength test and Static Creep test.

II. LITERATURE REVIEW

2.1 Studies on Polyethylene

- IPC developed standard testing methods (ASTM D618, D882, D1005, D2370) to evaluate tensile strength, elongation, and Young's modulus of polymer films.
- Sichina et al. used Thermo Gravimetric Analysis (TGA) to identify polymers and evaluate their thermal stability and compositional properties.

2.2 Studies on Use of Waste Polyethylene in Paving Mixes

- Bindu and Beena (2010) reported that waste plastic improves the stability and durability of Stone Mastic Asphalt, with optimum performance at around 10% plastic content.
- Fernandes et al. (2008) studied SBS-modified binders and found that additives like shale oil improve compatibility and maintain rheological properties.
- Awwad and Shbeeb (2007) observed that polyethylene-modified mixes show higher stability and better rutting resistance, with HDPE performing better than LDPE.
- Gawande et al. (2012) concluded that adding 5–10% waste plastic enhances pavement performance and promotes sustainable waste utilization.
- Khan and Gundaliya (2012) found that waste polyethylene improves resistance to cracking, rutting, and moisture damage by enhancing binder–aggregate bonding.

III. RAW MATERIALS

3.1 Constituents of Mix

The bituminous mix contains a combination of aggregates which range from their largest size below 25 mm to their smallest size which is less than 0.075 mm. The mix needs enough bitumen to achieve full compacted state which results in an impervious material with proper dissipative and elastic characteristics. The bituminous mix design process determines the correct mix proportions of bitumen and filler materials and fine aggregates and coarse aggregates which will create a mixture that meets requirements for workability and strength and durability and cost efficiency.

The basic materials used are as follows:

- Aggregates
- Fly Ash
- Slag
- Bituminous Binder
- Polyethylene

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3.2 Materials Used In Present Study

3.2.1 Aggregates

The Bituminous mixes (SMA DBM BC) preparation needs aggregates which follow MORTH grading specifications from Table 3.1 Table 3.2 and Table 3.3. The particular type of binder and polyethylene in required quantities were mixes as per Marshall Procedure. The specific gravity and physical properties of aggregate are given in Table-3.4 and Table-3.5.

Table 3.1: Gradation of aggregates for SMA

Sieve Size (mm)	% age Passing
19	100
13.2	94
9.5	62
4.75	28
2.36	24
1.18	21
0.6	18
0.3	16
0.075	10

Table 3.2: Gradation of Aggregates for BC

Sieve Size (mm)	% age Passing
19	100
13.2	79-100
9.5	70-88
4.75	53-71
2.36	42-58
1.18	34-48
0.6	26-38
0.3	18-28
0.15	12-20
0.075	4-10

Table 3.3: Gradation of Aggregates for DBM

Sieve Size (mm)	% age Passing
37.5	100
26.5	90-100
19	71-95
13.2	56-80
9.5	-
4.75	38-54
2.36	28-42
1.18	-
0.6	-
0.3	7-21
0.15	-
0.075	2-8

Table 3.4: Specific Gravity of Aggregates

Types of Aggregates	Specific Gravity
Coarse	2.75
Fine(Stone)	2.6
Fine(Slag)	2.45
Filler (Stone Dust)	2.7
Filler (Fly Ash)	2.3

Table 3.5: Physical Properties of Coarse Aggregates

Property	Method	Result
Aggregate Impact Value (%)	IS:2386(PIV)	14.3
Aggregate Crushing Value (%)	IS:2386(PIV)	13.02
Los Angels Abrasion Value (%)	IS:2386(PIV)	18
Flakiness Index (%)	IS:2386(PI)	18.83
Elongation Index (%)	IS:2386(PI)	21.5
Water Absorption (%)	IS:2386(P III)	0.1

3.2.2 Fly Ash & Slag

Both the fly ash and slag used in present investigation are collected from Bhilai steel plant. The chemical composition and XRD results are given in Table 3.6.

Table 3.6: Chemical Composition of Fly Ash and Slag in Percentage (By Weight)

Constituents	Fly Ash	Slag
Fe_2O_3	10.3%	4.012%
CaO	4.206%	26.638%
MgO	3.023%	16.124%
Sillica	56.4%	32.14%
Al_2O_3	29%	21%
Carbon	7.18%	0%

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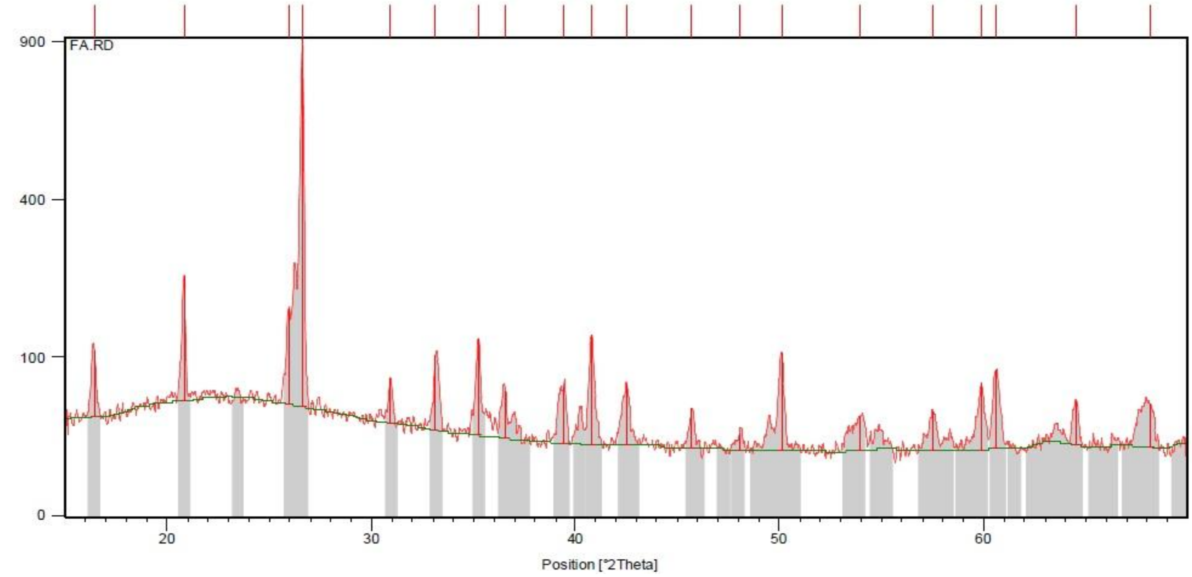

Figure 3.1: XRD Result of Fly Ash

Visible	Ref.Code	Score	Compound Name	Displacement [°2Th.]	Scale Factor	Chemical Formula
*	83-0539	77	Quartz	0.000	0.983	SiO_2
*	79-1454	67	Mullite-synthetic	0.000	0.197	Al 4.75 Si1.25 O9.63

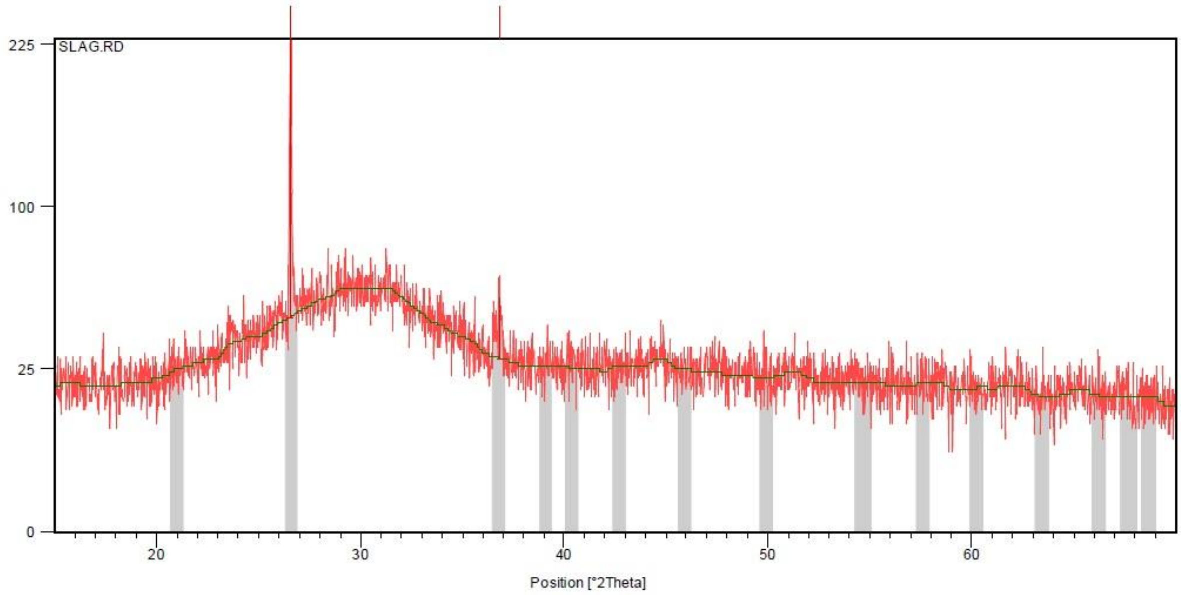

Figure 3.2: XRD Result of Granulated Blast Furnace Slag

Visible	Ref. Code	Score	Compound Name	Displacement [°2Th.]	Scale Factor	Chemical Formula
*	81-0065	42	Silicon Oxide	0.000	0.931	SiO_2

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3.2.3 Binder

Samples for this study were prepared using VG 30 bitumen which is an established standard bituminous binder. The physical characteristics of the binders were evaluated through standard testing procedures. The physical properties thus obtained are summarized in Table 3.7.

Table 3.7: Physical Properties of Binder

Property	Method	Value
Penetration at 25°C (mm)	IS:1203-1978	67.7
Softening Point (°C)	IS:1203-1978	48.5
Specific gravity	IS:1203-1978	1.03

3.2.4 Polyethylene

The present study uses polyethylene as its stabilizing additive which uses OMFED polyethylene which is locally available for milk packaging. The researchers collected OMFED polyethylene packets which they washed to disinfect the packets by submerging them in hot water for 3-4 hours. The process of drying them followed the earlier steps of the procedure.

Shredding

The dried polyethylene packets were cut into thin pieces of size 50 mm×5 mm maximum. The polyethylene needs to be cut into uniform sizes which will meet the requirements of the mixing process. The proper mixing process must be confirmed before adding polyethylene to the combination of bitumen and aggregate. Specific Gravity of polythene was found as 0.905.

Figure 3.3: OMFED Polyethylene Used

Table 3.8: Physical Properties of Polyethylene Used

Properties	Results
Specific Gravity	0.905
Softening Point	54.22°C
Young Modulus	109.75 Mpa

Strain at Break	1351%
Strain at Peak	1271.5%
Displacement at Break	135.15 mm
Displacement at Peak	127.15 mm
Load at Peak	.0146 Kn
Stress at Peak	14.59 Mpa

IV. EXPERIMENTAL WORK

4.1 General

It involves mainly 2 processes. i.e.

- Preparation of Marshall samples
- Tests on samples

Prior to the experimental work, the specific gravity, tensile strength, and softening point of polythene used in this investigation were calculated.

4.1.1 Determination of Specific Gravity of Polyethylene

The specific gravity of polyethylene was determined according to the testing procedure described in ASTM D792-08. The procedure adopted is given below;

- The weight of the polyethylene in air was measured by a balance. Let it be denoted by "a".
- An immersion vessel full of water was kept below the balance.
- The balance system included an iron wire which was suspended at 25 mm height from its container support.
- The polyethylene material was bound with the sink using iron wire which was then submerged in the vessel for weight measurement. Let it be denoted as "b".
- The polyethylene material was taken out and the wire along with the sink was weighed after being submerged in water. Let it be denoted as "w".

The specific gravity is given by **s=a/(a+w-b)**

Where:

a = Apparent mass of specimen, without wire or sinker, in air
b = Apparent mass of specimen and of sinker completely immersed and of the wire partially immersed in liquid
w = Apparent mass of totally immersed sinker and of partially immersed wire.

From the experiment, it was found that a= 19gm, b=24gm, w =26gm

=>s=19/(19+26-24)=19/21=0.90476

Take specific gravity of polyethylene=0.905.

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4.1.2 Determination of Tensile Properties of Polyethylene

The most essential material property which scientists measure in their research focuses on a material's ability to withstand tensile forces without breaking. The tensile strength of polyethylene was determined through testing with the INSTORN – 1195 CORPORATION equipment which operated at a sample rate of 9.103 points per second and a crosshead speed of 50 millimeters per minute. The preparation of rectangular polyethylene samples followed the ASTM D882 standard testing procedure. Digital Vernier calipers were used to measure the dimensions of polyethylene which included a width of 10 millimeters and a thickness of 0.1 millimeters and a gauge length of 10 millimeters and a grip distance of 40 millimeters. The test results discovered the following outcomes.

Young's modulus (also called as tensile modulus) = $\frac{Stress}{Elastic\ Starin}$ = 109.75 Mpa

Strain at break=1351%
Strain at peak=1271.5%
Displacement at break=135.15mm
Displacement at peak = 127.15 mm Load at peak =.0146 kn

Stress at peak =14.59 Mpa (Stress at peak or ultimate tensile strength or tensile strength at break is the percentage increase in length that occurs under tension before break. If polyethylene possesses high elongation and high ultimate tensile strength it is called as tough).

4.1.3 Determination of Softening Point of Polyethylene

The softening point of polyethylene was measured through differential scanning calorimetry using a DSC 822 low temperature differential scanning calorimeter which operates at a heating rate of 10°C per minute. The temperature was maintained in between 25 ℃- 80℃ according to melting point of polyethylene. The glass transition temperature is found as 54.22℃ (It the temperature at which phase change occurs and it is the service temperature).

4.2 Preparation of Marshall Samples

The mixes were prepared according to the Marshall procedure specified in ASTM D1559. For SMA, BC, and DBM mixes the coarse aggregates, fine aggregates and filler were mixed with bitumen and polyethylene according to the adopted gradation as given in Table 3.1, Table 3.2, and Table 3.3 respectively. The researchers conducted a comparative study on SMA, BC, and DBM mixes which used stone dust as filler in between samples with and without polyethylene in their mixes. The researchers conducted a comparative study on SMA, BC, and DBM mixes which used slag and fly ash as filler in between samples with and without polyethylene in their mixes. The Marshall Test determined both Optimum Binder Content (OBC) and optimum polyethylene content (OPC) results. The ingredients were mixed together according to these specific steps:

- The required quantities of coarse aggregate fine aggregate mineral fillers were taken in an iron pan and kept in an oven at temperature 160℃ for 2 hours. Preheating is required because the aggregates and bitumen are to be mixed in heated state.
- The required amount of shredded polythene was weighed and kept in a separate container.
- The aggregates in the pan were heated on a controlled gas stove for a few minutes maintaining the above temperature. The mixing process began by adding polyethylene to aggregates which were then mixed for 2 minutes.
- The mixing process began by adding bitumen to the sample which was then mixed throughout the sample until it reached a uniform and complete mixture. The mixing process continued for 15-20 minutes until the mixture achieved a uniform color throughout all its components. The mix was then moved to a moulding casting area. The sample received 75 blows on each side which resulted in a total of 150 blows being delivered to each sample. The samples received identification marks and were stored in individual containers.

4.3 Tests on Marshall Samples

4.3.1 Marshall Test

The method measures plastic deformation resistance through loading tests which use a bituminous mixture compacted cylindrical specimen at a deformation speed of 50 mm per minute. The Marshall method of mix design contains two primary components which serve as its fundamental elements.

a) Stability, flow tests and
b) Voids analysis

The Marshall stability of the mix is defined as the maximum load carried by the specimen at a standard test temperature of 60°C. The flow value represents the total deformation that the test specimen experiences during loading until it reaches its maximum load capacity. The method serves as a common technique in India for characterizing bituminous mixes because it offers both simple execution and affordable cost. The study examined Marshall properties which included stability testing and flow value measurement and unit weight assessment and air void determination to discover the optimal

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binder levels (OBC) and the optimal polyethylene levels (OPC).

Figure 4.1: Marshall Test in Progress

4.3.1.1 Retained Stability Test

The moisture-induced striping of the mix results in loss of stability through weakened bond between aggregates and binder materials. The test was conducted following STP 204-22 on the Marshall machine with the normal Marshall samples. The stability of the samples was established through water bath testing at 60 °C for both 30 minutes and 24 hours.

$$\text{Retained Stability} = \frac{S_{2*100}}{S_1}$$

S_2 = Soaked Stability (after soaking of 24 hours at 600 C

S_1 = Standard Stability

4.3.2 Drain Down Test

The test method determines the quantity of drain down occurring in un-compacted asphalt mixture sample through its assessment when the sample undergoes testing at elevated temperatures which match the thermal conditions used during production and storage and transportation and placement of the mixture. The test method applies directly to open-graded friction course and Stone Matrix Asphalt (SMA) mixtures. The study adopted the drain down method which MORTH (2001) proposed. The local production of drainage baskets shows their design in Fig-4.2. The loose un-compacted mixes moved to the drainage baskets which were then stored in a pre-heated oven set at 150°C for three hours. The pre-weighed plates remained positioned under the drainage baskets during their oven placement to collect all binder drippings which drained out. The drain down test results enabled calculation of binder drainage through the equation:

$$\text{Drain down equation is} = \frac{W_2 - W_1}{X} \times 100$$

Where,

W_1=Initial mass of the plate

W_2= Final mass of the plate and drained binder

X=Initial mass of the mix

For a particular binder three mixes were prepared at its optimum binder content and the drain down was reported as an average of the three.

Figure 4.2: Drain Down Test of SMA Without Polyethylene

4.3.3 Static Indirect Tensile Strength Test

The test applied a compressive load at 51 mm per minute on a Marshall cylindrical specimen through its vertical diametrical plane using two stainless steel curved strips which had matching radius of curvature to the specimen. The sample was kept in the Perspex water bath maintained at the required temperature for minimum 1/2 hours before test, and the same temperature was maintained during test. The testing procedure created even tensile stress distribution which extended perpendicular to the applied load direction and followed the vertical diametric plane, resulting in specimen failure through vertical diameter splitting.

The tensile strength of the specimen was calculated according to ASTMD 6931 (2007) from the failure load noted from the dial gauge of the proving ring.

$$S_T = \frac{2 \times P}{\pi \times D \times T}$$

Where

S_T=Indirect Tensile Strength, KPa

P=Maximum Load, KN

T=Specimen height before testing, mm

D=Specimen Diameter, mm

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The test temperature was varied from 5°C to 40°C at an increment of 5°C. The tensile strength was reported as the average of the three test results.

Figure 4.3: Close View of Indirect Tensile Strength Test on Progress

V. RESULT ANALYSIS AND DISCUSSION

5.1 Effect of Polyethylene Concentration on Marshall Properties of SMA, BC and DBM Mixes With Stone Dust as Filler

Here result in variation of Marshall properties with different binder content where polyethylene content is taken as 0%, 0.5%, 1%, 1.5%, 2% and 2.5% for SMA and DBM and 0%, 0.5%, 1%, 1.5%, 2% for B Care explained below.

5.1.1 Marshall Stability

The graph analysis shows that Marshall stability value rises with increasing bitumen content until it reaches its peak at certain bitumen levels before starting to decline. The specific bitumen level which achieves this maximum effect serves as the optimal binder content (OBC). The study determined OBC values for conventional SMA, BC and DBM mixes at 6% and 4.5% for DBM. The study determined OBC values for modified SMA, BC and DBM mixes at 4% which used polyethylene at various concentrations. The graphs demonstrate that polyethylene addition increases stability until a certain threshold after which stability begins to decline. This may be due to excess amount of polyethylene which is not able to mix in asphalt properly. That polyethylene concentration in mix is called optimum polyethylene content (OPC) which is found as 2% for SMA and DBM and 1.5% for BC mixes.

Table 5.1: Optimum Binder Contents

Types of Mix	Optimum Polyethylene Content (%)	Optimum Binder Content (%)
SMA Without Polyethylene	0%	6%
SMA With Polyethylene	2%	4%
DBM Without Polyethylene	0%	4.5%
DBM With Polyethylene	2%	4%
BC Without Polyethylene	0%	4.5%
BC With Polyethylene	1.5%	4%

Table 5.2: Comparisons of Stabilities at OBC

Types of Mix With Stone Dust	Stability (Kn)
SMA Without Polyethylene	12.765
SMA With Polyethylene	14.965
DBM Without Polyethylene	12.76
DBM With Polyethylene	17.444
BC Without Polyethylene	10.875
BC With Polyethylene	17.587

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Table 5.3: Comparisons of Flow Values at OBC

Types of Mix With Stone Dust	Flow (mm)
SMA Without Polyethylene	3.9
SMA With Polyethylene	3
DBM Without Polyethylene	4.02
DBM With Polyethylene	2.6
BC Without Polyethylene	3.9
BC With Polyethylene	2.45

Table 5.4: Retained Stability of SMA, BC and DBM with and without Polyethylene

Types of Mix	Avg. Stability After Half an Hour in Water at 60°C	Avg. Stability after 24 Hours in Water at 60°C	Avg. Retained Stability, in%	Design Requiremen
SMA Without Polyethylene	10.932	8.497	73.22	Minimum 75% (as per MORTH Table 500-17)
SMA With Polyethylene	10.875	8.497	78.13	
DBM Without Polyethylene	12.765	9.962	74.04	
DBM With Polyethylene	14.965	12.013	80.27	
BC Without Polyethylene	17.587	14.13725	76.38	
BC With Polyethylene	17.444	14.2105	81.46	

5.2 Effect of Polyethylene Concentration on Marshall Properties of SMA, BC and DBM Mixes with Slag as a Part of Fine Aggregates and Fly Ash as Filler

The test results show how Marshall properties change with various binder amounts which were tested using 0% 0.5% 1% 1.5% and 2% polyethylene content for SMA BC and DBM mixtures through an experimental setup that replaced two fine aggregate gradation ranges of 0.3mm-0.15mm and 0.15mm -0.075mm with granulated blast furnace slag while fly ash served as the filler material.

Table 5.5: Optimum Binder Contents

Types of Mixes with Fly Ash and Slag	Optimum Polyethylene Content (%)	Optimum Binder Content (%)
SMA Without Polyethylene	0%	6%
SMA With Polyethylene	1.5%	5%
DBM Without Polyethylene	0%	4.5%
DBM With Polyethylene	1.5%	4%
BC Without Polyethylene	0%	4.5%
BC With Polyethylene	1.5%	4%

Table 5.6: Comparisons of Stabilities at OBC

Types of Mix With Fly Ash and Slag	Stability (Kn)
SMA Without Polyethylene	13.94
SMA With Polyethylene	16.24
DBM Without Polyethylene	12.98

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DBM With Polyethylene	18
BC Without Polyethylene	14.23
BC with polyethylene	18

Table 5.7: Comparisons of Flow Values at OBC

Types of Mix with Fly Ash and Slag	Flow (mm)
SMA Without Polyethylene	3.6
SMA With Polyethylene	2.5
DBM Without Polyethylene	3
DBM With Polyethylene	2.35
BC Without Polyethylene	3.7
BC With Polyethylene	3

Table 5.8: Retained Stability of SMA, BC, and DBM With and Without Polyethylene with Fly Ash and Slag

Types of Mix with Fly Ash and Slag	Avg. Stability after Half an Hour in Water at 60°C	Avg. Stability After 24 Hours in Water at 60°C	Avg. Retained Stability, in%	Design Requiremen
SMAWithout Polyethylene	13.94	10.87	74.98	Minimum 75% (as per MORTH Table 500-17)
SMA With Polyethylene	16.24	13.28	80.8	
DBM Without Polyethylene	12.98	10.31	77.48	
DBM With Polyethylene	18	14.72	81.78	
BC Without Polyethylene	14.23	11.51	75.9	
BC With Polyethylene	18	14.48	84.45	

5.3 Drain Down Test

Drain down test is carried out for both SMA and BC for both of following cases;

a) Stone dust with and without polyethylene and
b) Fly ash and slag with and without polyethylene.

Table 5.9: Drain Down of Mixes Without Polyethylene

Mixes With Stone Dust	Drain Down Value (%)
SMA	1.8
BC	1.2
Mixes With Fly Ash and Slag	**Drain Down Value (%)**
SMA	1
BC	0.8

Table 5.10: Drain Down of Mixes with Polyethylene

Mixes With Stone Dust	Drain Down Value (%)
SMA	0
BC	0

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Mixes With Fly Ash and Slag	Drain Down Value (%)
SMA	0
BC	0

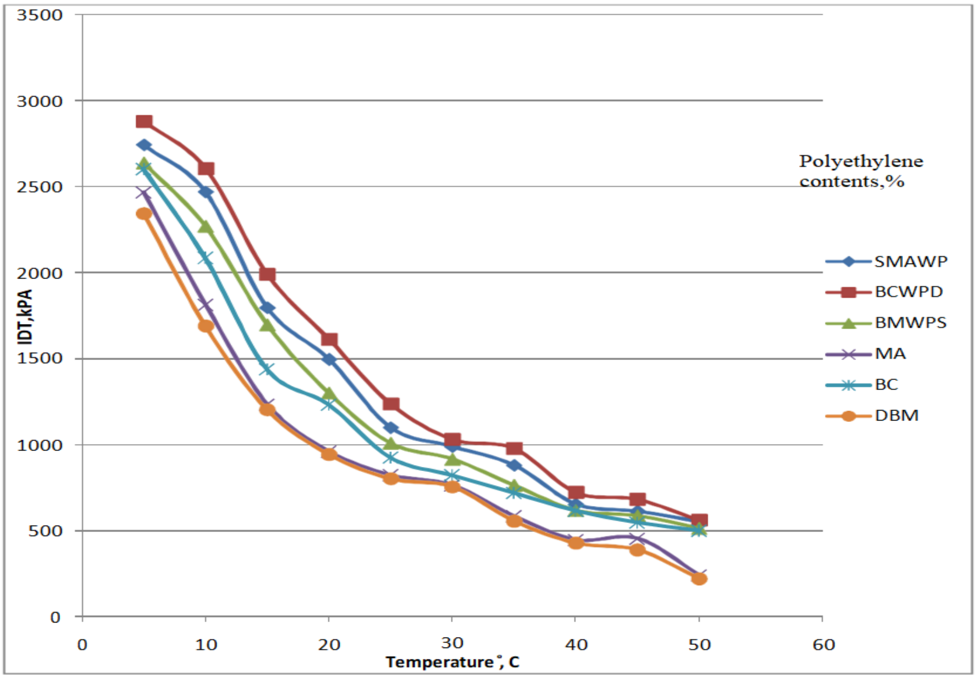

Figure 5.1: Variations of ITS Values of SMA, DBM and BC with Stone Dust as Filler in Different Temperatures

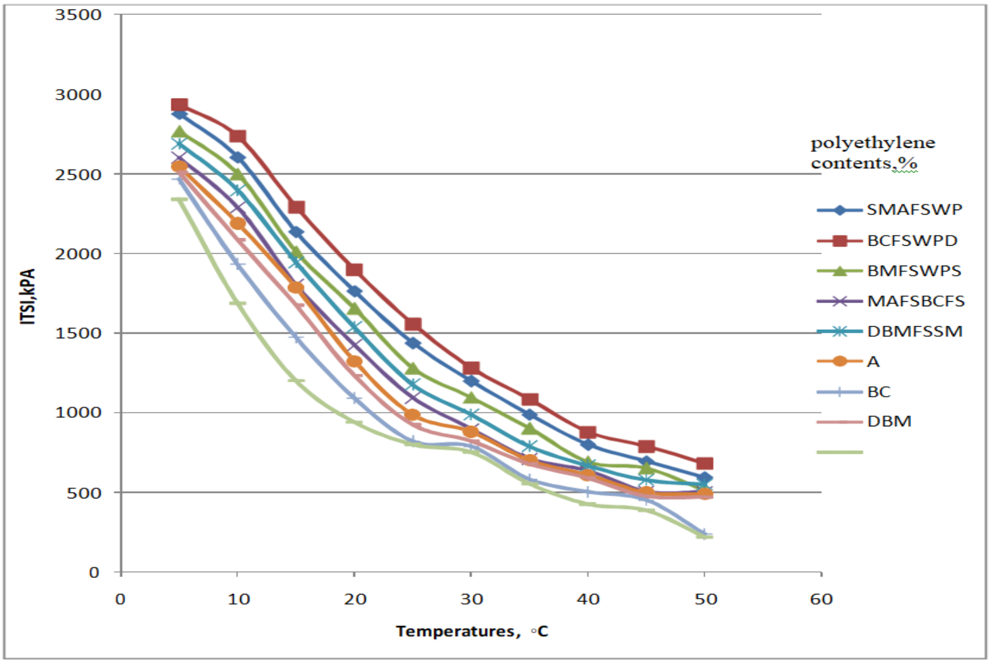

Figure 5.2: Variations of ITS Values of SMA, DBM and BC with Fly Ash and Slag in Different Temperatures

5.3.1 Indirect Tensile Strength Ratio

The tensile strength ratio testing for SMA and BC and DBM was conducted at their respective optimal binder and polyethylene levels. The TSR value of the mixture increases when polyethylene is added to the mixture. The addition of polyethylene to the mix results in improved resistance against moisture damage. The mixes which contain fly ash and slag exhibit higher tensile strength ratio values when compared to standard mixes.

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Table 5.11: TSR of Mixes with Stone Dust and With Fly Ash and Slag With and Without Polyethylene

Types of Mixes	Tensile Strength Ratio of Mixes with Stone Dust (%)	Tensile Strength Ratio of Mixes with Fly Ash and Slag (%)	Design Requirement
SMA Without Polyethylene	76.81	80.4	Minimum 80% (as per MORTH Table 500-17
SMA With Polyethylene	82.14	85.4	
DBM Without Polyethylene	79.26	81.6	
DBM With Polyethylene	84.78	87.2	
BC Without Polyethylene	79.68	82.7	
BC With Polyethylene	87.26	89.1	

5.4 Static Creep Test

The static creep test measures how bituminous mix with and without polyethylene permanent deformation under applied static load. The test results show that mix deformation decreases with polyethylene addition at every temperature tested. The fly ash and slag mixes produce lower deformation values when compared to standard mixes. The BC mixes which contain polyethylene show the least deformation at both OPC and OBC levels for all mix types which include stone dust and fly ash and slag. The graphs show the plotted relationships between;

a) Time and deformation and,
b) Time and strain.

It is observed from the time Vs stain graphs that BC mixes with polyethylene give the minimum strain as compared to other mixes.

5.4.1 Deformations of Mixes with Stone Dust Used as Filler

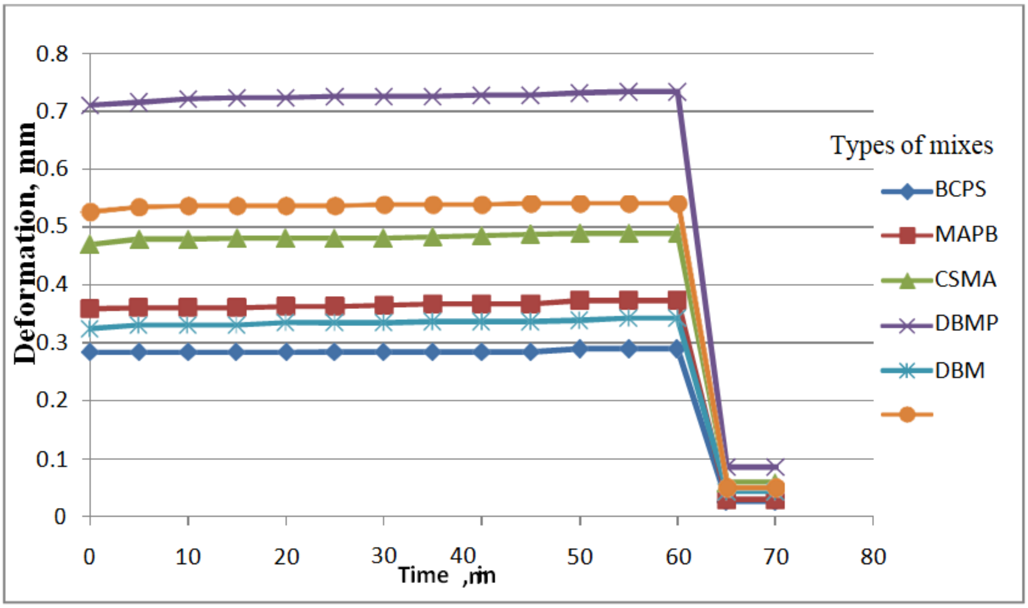

Figure 5.3: Deformation Values at 60°C for SMA, BC and DBM

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5.4.2 Strain Vs Time Relationships for Mixes with Stone Dust at All Temperatures

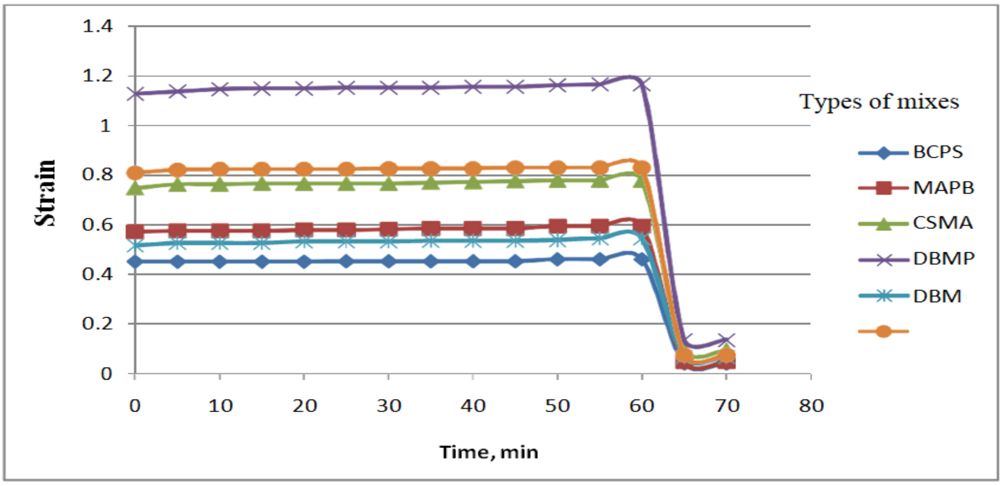

Figure 5.4: Time Vs Strain at 60°C for SMA, BC and DBM

5.4.3 Deformations of Mixes with Slag As a Part of Fine Aggregates and Fly Ash as Filler

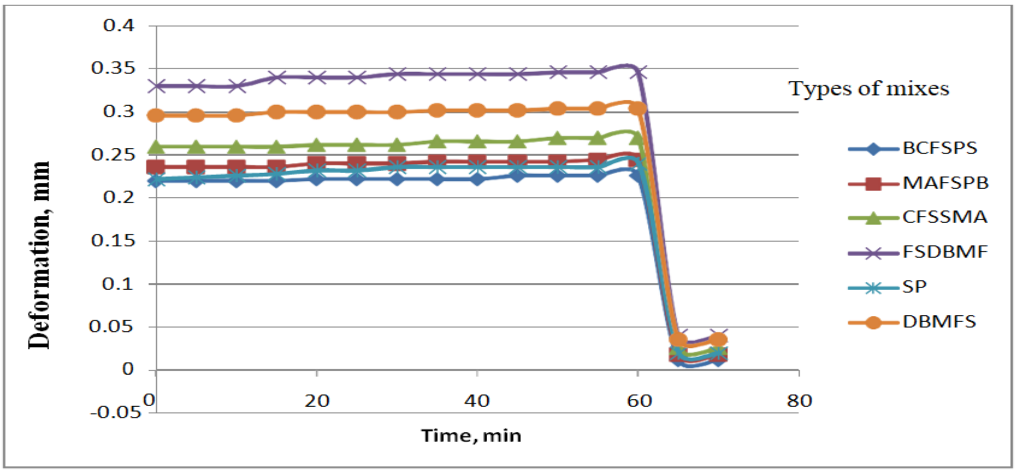

Figure 5.5: Deformation Values at 60°C for SMA, BC and DBM

5.4.4 Strain Vs Time Relationships for the Mixes with Fly Ash and Slag at Different Temperatures

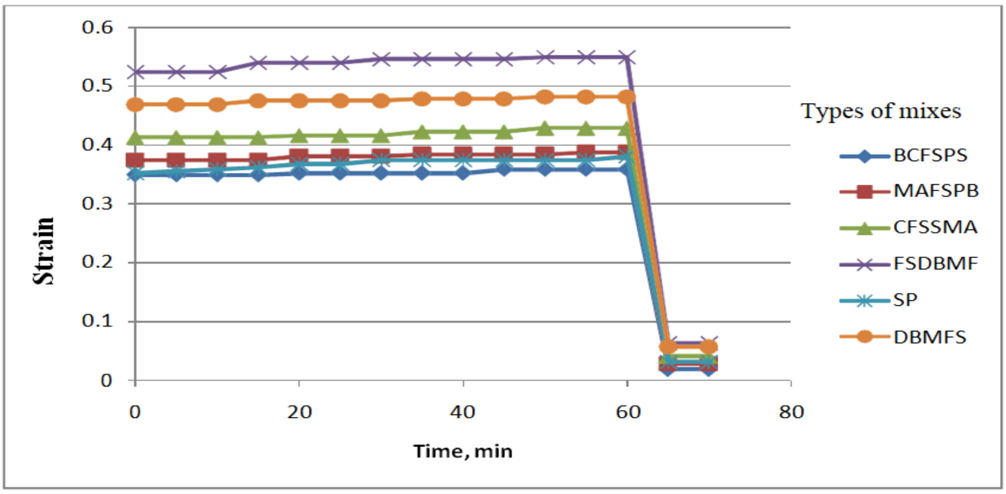

Figure 5.6: Time Vs Strain at 60°C for SMA, BC and DBM

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VI. CONCLUSION

- The Marshall Method of mix design was used to determine optimum bitumen content (OBC) and optimum polyethylene content (OPC) for different types of mixes. The researchers discovered that 2% polyethylene addition produced optimal Marshall Properties for SMA and DBM mixes while BC mixes achieved the same result with 1.5% polyethylene content when using stone dust as a filler material. The optimal Marshall Properties for all mix types resulted from 1.5% polyethylene addition when using granulated blast furnace slag as fine aggregate replacement and fly ash as filler replacement. The OBCs for modified SMA and DBM mixes which used stone dust as a filler material showed a 4% OBC value while modified (i) SMA and (ii) BC and DBM using fly ash and slag material showed 5% and 4% OBC values respectively.

- The researchers conducted their test under normal and wet conditions using Marshall specimens prepared at their optimal polyethylene content (OPC) and optimal bitumen content (OBC) through two different filler methods which included (i) stone dust as filler and (ii) replacing stone dust with fly ash and fine aggregate with slag. The findings revealed that polyethylene addition to the mixes resulted in increased retained stability for all specimens that used both (i) stone dust as filler and (ii) fly ash and fine aggregate replacement with slag.

- The addition of polyethylene creates a reduction in drain down effect which produces minor impact. The SMA material shows a slightly higher drain down value than BC which lacks polyethylene. The mixes which were created at their optimal polyethylene content (OPC) do not exhibit any drain down behavior.

- The research indicates that Indirect Tensile Strength (ITS) values experience a downward trend as temperature rises because polyethylene addition to mixes from a particular binder leads to increased ITS values. The BC mixes with polyethylene impose the highest indirect tensile strength values which are followed by SMA and DBM.

- The addition of polyethylene to the mixture improves its resistance against moisture susceptibility. The highest tensile strength ratio occurs in BC with polyethylene while DBM with polyethylene and SMA with polyethylene create lower ratios for both situations.

- The static creep test results show that polyethylene addition decreases the mix deformation at every test temperature which was applied. The BC mixes which contained polyethylene resulted in the least deformation among all tested mixtures.

6.1 Future Scope

- The study examined multiple characteristics of SMA and BC and DBM blends through Marshall testing and drain down assessment and static tensile strength testing and static creep testing which used VG 30 penetration grade bitumen and polyethylene as the only materials. The study required investigation of fatigue properties and rutting resistance and dynamic indirect tensile strength and dynamic creep behavior.

- The study added polyethylene to them mix through the dry mixing method. The study evaluated how polyethylene modifies bitumen through wet mixing and compared the results with other modification methods.

- The study required selection of proper methods to examine the microstructure between different modified bituminous mixtures in order to assess their homogeneity levels.

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