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TO STUDY THE PERFORMANCE OF BITUMEN WITH MODIFIED BINDERS (LDPE)

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ABSTRACT

Number of both business and private vehicle utilizing bituminous roads increments extensively day by day, which not only demands good pavement surfaces but also desirable roads which can provide safe and economical journey. To meet the demands of challenging vehicle growth bitumen needs to be modified with modified binders, which leads to construction of pavements with higher resistance to various deformations and could also boost the economy of the country. The utilization of this innovative technology (polymer modified with bitumen) upgrades the quality of roads as well as supports road life. Additionally, this innovation proves vital in hot, humid and extreme freezing temperate regions where temperature crosses 50°c and precipitation, snowfall is generally basic. While during modification the prime heed should be paid towards the cost of modification and also modifier should be related to its effect on environment.

All the polymers utilized till date enhance the properties of bitumen yet has certain impediments, keeping every one of those constraints in view modifier utilized as a part of this study polyethylene (LDPE). The morphology and designing properties of bitumen adjusted with LDPE were explored with the assistance of different tests like penetration test, ductility test and softening point test. The outcomes got are very practical. With expanding rate of LDPE, properties like penetration and ductility continues diminishing while softening point continued to be increasing. The content of modified binder LDPE was increased as 2%, 4%, 6% and 8%. On initial three perceptions come about accomplished were obviously yet on 8% expansion comes about accomplished were same as accomplished on flawless bitumen. Which demonstrated LDPE rate ought to be constrained to 6% to accomplish advantageous outcomes. To learn most sparing and long living roads.

KEYWORDS:

Bitumen Modification, LDPE (Low - Density Polyethylene), Asphalt Binder Performance, Rutting Resistance, Durability, Recycled Materials, Pavement Engineering, Rheological Aging Simulation, Microscopic Analysis, Sustainable Construction.

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INTRODUCTION

Among various transportation methods, roads stand out as the most critical and widely used for global movement of goods and business. The concept of road planning and construction can be traced back to the Romans in ancient times. Their innovation eventually led to the development of asphalt technology. This shift from basic roads to this advanced technology paved the way for comfortable and efficient roads worldwide. Broadly, there are two asphalt types: flexible and rigid. Flexible asphalt, commonly used for roadways, consists of multiple layers – sub-base, base course, and wearing course. These layers are made of bitumen (asphalt binder) and aggregates. Rigid pavements, on the other hand, are typically constructed with reinforced concrete and are less common for general road applications.

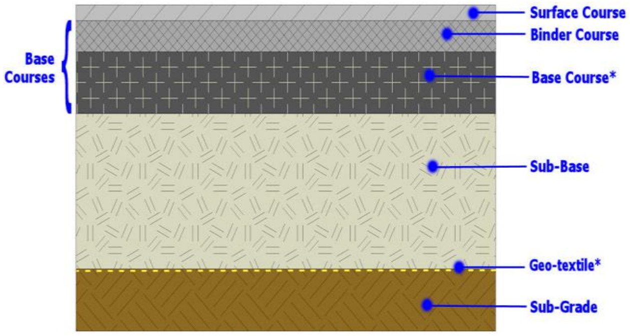

Figure 1 Layers of Roads

Bitumen, a cost-effective and readily available material, has long been the preferred choice for binding road surfaces due to its affordability, phased development possibilities, and widespread availability. However, with growing demands for extensive road networks, especially in challenging environments, and the strain of heavy traffic loads, the need for improved pavement performance has become paramount.

This has led to a surge in bitumen binder modification, a technique that addresses common problems faced by flexible pavements:

- Fatigue Cracking: Repeated traffic loads can cause fatigue cracks. Modified binders enhance elasticity, making them more resistant to this type of damage.
- Rutting: Heavy traffic, particularly in extreme temperatures and under high tire pressure, can lead to permanent deformation or rutting. Modified binders improve resistance to rutting.

Figure 2 Rutting

- Low-Temperature Cracking: Bituminous pavements in freezing conditions are susceptible to thermal cracking due to shrinkage. Modified binders with low stiffness and better stress relaxation properties at low temperatures help minimize this issue.

To address these challenges and create more durable pavements, various types of modified binders are being explored. Among these, polymers are the most common. Popular choices include Styrene Butadiene Styrene (SBS), ethylene, crumb rubber, Styrene Butadiene Rubber (SBR), Ethylene Vinyl Acetate (EVA), and polyethylene (both Low-Density and High-Density). These polymers, known for their cost-effectiveness and excellent engineering properties, are blended with bitumen to optimize performance.

The addition of modifiers significantly influences the engineering properties of bitumen. This advanced technique not only results in binders better suited for low service temperatures but also improves their

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viscoelastic properties at high temperatures. This translates to reduced pavement deformation and overall enhanced performance.

Polyethylene:

Polyethylene (PE) is a widely used plastic commonly encountered in our daily lives. From films and containers to pipes and toys, its versatility is unmatched. One of its key advantages is its light weight, which translates to lower transportation and installation costs. This readily available polymer has a rich history, dating back to its discovery in 1935 by British chemist Eic Fawcett and his team. They transformed ethylene gas into a solid form, forever altering the landscape of materials science.

Figure 3 LDPE Plastic Waste

Beyond its everyday applications, polyethylene plays a significant role in transportation engineering. For example, polyethylene pipes are widely used for drainage purposes. But its impact extends beyond infrastructure; it also

finds application as a bitumen modifier, enhancing the performance of road surfaces.

Types of Polyethylene

While all polyethylenes share the same basic building block (─CH2─CH2 ─), variations in their chemical structure lead to distinct properties and applications. These differences are primarily influenced by factors like molecular weight (MW), its distribution (MWD), and the degree of branching in the polymer chains. According to ASTM standards, polyethylene can be categorized into four main types based on their density, as presented in the table below.

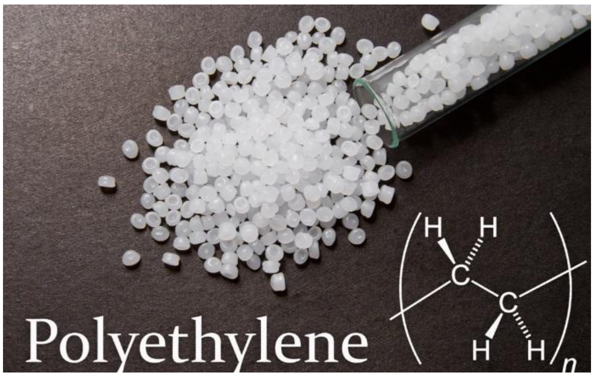

Figure 4 Polyethylene

PE Type	Density(gm/cm3)
Low	0.910-0.925
Medium	0.926-0.940
High	0.940-0.959
High Density Homopolymer	0.960 And Above

Table 1 Classification of polyethylene by density

Low-Density Polyethylene (LDPE):

LDPE is a type of thermoplastic made from ethylene gas. It holds the distinction of being the first commercially available polyethylene, introduced in 1933 by Imperial Chemical Industries (ICI) using a high-pressure free radical polymerization process. This method remains largely unchanged today. Despite competition from newer polymers, LDPE continues to be an important plastic, with a global market exceeding US$33 billion in 2013.

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Key Properties of LDPE:

- Density: LDPE falls within a density range of 0.910–0.940 g/cm³, making it one of the lighter types of polyethylene.
- Chemical Resistance: At room temperature, LDPE is relatively unreactive, with the exception of strong oxidizing agents. Certain solvents may cause swelling.
- Temperature Tolerance: LDPE can withstand continuous temperatures of 80°C and short-term exposure up to 95°C.
- Appearance and Flexibility: This plastic comes in both translucent and opaque variations and is known for its flexibility and toughness.
- Branching and Strength: Compared to High-Density Polyethylene (HDPE), LDPE has a higher degree of branching (around 2% of its carbon atoms). This branching weakens the intermolecular forces within the material, resulting in lower tensile strength but greater resilience. The branches also make LDPE less crystalline and less densely packed, contributing to its lower overall density.

Applications of LDPE:

LDPE's versatility translates into a wide range of applications. It's a familiar sight in everyday products like toys, films, bottles, and even some processing equipment. Its excellent insulating properties make it a popular choice for electrical wires and cables. In recent years, LDPE has gained traction in sustainable building practices, finding its way into green construction projects. The construction industry also benefits from LDPE drainage pipes used in highway infrastructure. Beyond these applications, LDPE plays a crucial role in road construction as a bitumen modifier, enhancing the performance of asphalt pavements.

Advantages of LDPE:

- Cost-Effective: LDPE's light weight translates to lower transportation and installation costs.
- Durable: It offers good resistance to moisture and many chemicals, making it a long-lasting material.
- Temperature Versatility: LDPE functions well in a wide temperature range, from -4°C to 90°C.
- Processing Versatility: This plastic can be readily processed using various thermoplastic methods.

Disadvantages of LDPE:

While LDPE boasts numerous advantages, it's not without limitations:

- Thermal Expansion: LDPE experiences high thermal expansion, which can be a design consideration.
- Weathering Resistance: It has relatively poor weathering resistance and may degrade when exposed to sunlight for extended periods.
- Stress Cracking: Bonding LDPE can be challenging under stress cracking conditions.

OBJECTIVES OF THE STUDY

- To investigate and analyse the properties and performance of bitumen when incorporated with different percentages of High-Density Polyethylene as a modifier.

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- During mixing to analyse the negative effect of aging on modified binders.
- To investigate the direct tensile strength of bituminous mixes when mixed with modified binder High Density Polyethylene.
- To compare the economic implication with the use of modified binders (HDPE) and standard mixtures.
- To investigate the stability of modified binders with bitumen while storage and also to analyse the morphology of the mixture.
- To determine the binding properties of bitumen mixed with ethylene vinyl acetate by checking the micro structure analysis of the modified bitumen homogeneity.

LITERATURE REVIEW

Bitumen modification boasts a long history, with early use of polymers documented in 1843. The lack of standardized specifications led to confusion until AASHTO established a classification system for modifiers. The need for performance-based evaluation spurred the development of the Superpave system. This innovative approach uses tests directly linked to real-world performance, including simulating long-term aging and considering the entire range of pavement temperatures. Applicable to both modified and unmodified binders, Superpave ensures optimal bitumen selection for durable pavements.

"Polymers," from Greek for "many units," are large molecules built from smaller monomers. Their arrangement dictates properties. In bitumen modification, the chosen polymer significantly influences the final mixture's performance. Polymers can be blended directly or emulsified in water (latex like SBR) for applications like chip seals. The type of monomers used (e.g., random or block copolymers like SBS) determines the final properties.

Low Density Polyethylene (LDPE)

Atul Kumar Vaidya et al., (2016) concluded from his work that Marshal Stability values and stream estimation of Dense Bituminous Mix increment because of expansion of LDPE. It has been watched that altered blend demonstrates better marshal strength esteem at 8% LDPE however VFB surpasses the constraining quality, so the ideal dosage of LDPE is chosen as 6%. His outcomes additionally reasoned that the LDPE Modified Bitumen blend indicates better Marshal Stability esteem (1445 kg) than normal (60/70 review) bituminous blend (1263 kg). The test were performed to locate the ideal cover content with 6% LDPE changed blend. The Optimum cover content in his work diminished to 5% with ideal measurements of LDPE (6%) in contrast with common bituminous blend (5.5%). The Marshall's blend configuration directed on DBM utilizing LDPE gives comes about according to MORTH proposals, show the adequacy of the LDPE in Bituminous Concrete blend, since in satisfactory range.

Noor Zainab Habib et al., (2010) investigated the influence of LLDPE, PP, and HDPE (up to 3% concentration) on bitumen's rheological properties, focusing on how these polymers affected its flow and deformation behaviour. The study observed that even small additions of these polymers stiffened the bitumen, likely due to the formation of a dispersed network of polymer particles within the bitumen. This modification not only altered the bitumen's rheological behaviour (characterized as non-Newtonian and thixotropic) but also potentially enhanced its rutting resistance, which was explored in a later part of their study. Interestingly, polypropylene (PP), due to its linear structure, appeared to blend more easily with the bitumen.

B Malpas et al., (2010) concluded that Ethylene monomers leads to the formation of thermoplastic known as low density polyethylene. It was produced in 1933 by imperial chemical industry by virtue of high-pressure process through free radical polymerization. LDPE was the first grade of polyethylene. It is having numerous applications among which the important are packing, foils, trays, and plastic bags both for food and non-food purposes. Below given are some unique characteristics of LDPE.

Flynn et al., (1993) studied that the vital utilization of LDPE is in asphaltic asphalts. From basic need sacks reused polyethylene is utilized as a part of such asphalts which prompts to utilize lasting disfigurement as low temperature warm splitting and rutting asphalt surfaces.

Kennedy et al., (1994) found that at a precise recurrence of 10 radians for each second testing a bitumen test is proportional to a movement speed of 100 km/hr. for diminishing pace of stream under 100km/hr bring down frequencies could be utilized to assess different properties and practices of altered bitumen under changing movement conditions.

Abdel Aziz Mahrez and Mohammad Rehan Karim et al., Another exploration was made to bolster all the past studies which expresses that on expansion of LDPE the altered bitumen gets to be distinctly stiffer, harder, and predictable. Given underneath is the figure demonstrating the consistency of LDPE changed bitumen diminishes as the LDPE content increments in the blend. It was likewise one of the noteworthy changes that 10-40% diminishment in infiltration esteem was recorded with expansion of 2%, 4%, 6% and 8% of LDPE into bitumen.

Effect Of Wax on Bitumen Characteristics

Edward et al., (2006) studied rheological properties of bitumen grade 60/120 were investigated at various temperature on addition of commercial wax. The study focused with low temperature effects which can have a great influence on thermal cracking resistance of bituminous mix. The study also mentioned that the type of bitumen grade is also the governing factor regarding the rheological properties other than the type and quantity of additive used.

High Density Polyethylene as Modified Binder (HDPE)

M. S. Ranadive and A. B. Tapase et al., (2012) led by these two entitled as change of adaptable asphalts with the assistance of adjusted cover (HDPE). Bitumen utilized as a part of this review was given by Pune city organization (PMC). The review of bitumen utilized was 60/70 infiltration review. The outcomes got from both dry and wet example blend indicated half upgrade in elasticity in Comparison to ordinary blend when 8% of altered fastener was included. This review additionally demonstrated that bitumen with expanded rate of cover has higher steadiness and marshal remainder (MQ). Which gives blend a superior imperviousness to changeless twisting. One of the critical consequences of the review was that keeping every single other parameter inside point of confinement it was watched that on the expansion of 10% of HDPE there was 25.57% augmentation in steadiness.

Shirish N. Nemade and Prashant V. Thorat et al., (2013) led examine in which utilized bitumen 60/70 review which was acquired from Kothari manufacturers Akola. Test of bitumen was mixed with polyethylene (HDPE) in its powdered frame with shifting rates. It was watched that expansion of HDPE prompts to increment in softening purpose of bitumen. Which makes the asphalt more adaptable particularly amid winters which at last prompts to longer existence of the asphalt. Mixing of test with HDPE likewise demonstrated as contrasting option to defeat weakness of bitumen.

Eslam Magdy Mohammed Deef- Allah and Ahmad Mohamady et al., (2014) as indicated by their study in Egypt the bitumen was mixed with various modifiers like poly vinyl chloride

(PVC), high thickness polyethylene (HDPE), plastic packs and novolac.

Mahrez & Karim et al., (2010) In one of the reviews to reflect three unmistakable streams, three one-of-a-kind frequencies were picked. The three unmistakable streams were free stream, lessening free stream, overpowering stream. In this learn at various mid and high temperatures dynamic shear Rheometer was used to evaluate the component mechanical properties for perfect and LDPE balanced bitumen.

MATERIALS AND METHODS

Material used:

For this study neat bitumen VG30 from unknown source and aggregates with maximum size of 20 mm were used. Low density polyethylene (LDPE) in pallet form was used as a modified binder with varying percentages.

Tests Performed on Aggregates:

Various tests were conducted on aggregates which include aggregate grading test, crushing value test and loss angels' abrasion test. These tests were performed to determine and analyse the results about utility of road aggregates in terms of crushing value and abrasion value. These all the three tests were performed keeping IRC guidelines under consideration.

Tests Performed on Neat & Modified Bitumen:

Bitumen is a mixture of organic liquids, highly viscous in nature, having sticky characteristics mainly used for paving roads. Almost 90% of total produced bitumen is used in paving road surfaces. To determine the appropriate use of bitumen there are various tests performed on bitumen. Being very important component in construction of roads. Bitumen has to go through these tests to ensure its quality use.

Sample preparations

By temperance of dissolve mixing method different examples of flawless and changed bitumen were readied. Around 200gms of bitumen were warmed till it accomplishes liquid qualities. Test was warmed at around 750c to 1000c. Differing rates of LDPE were included physically. While adding ceaseless mixing was done to accomplish homogeneous blend. On arranged examples observational tests like malleability test, entrance test and softening point tests were performed. Every one of these tests were performed concurring the details gave by IRC to get attractive outcomes for utilization of changed bitumen.

RESULTS AND DISCUSSION

Aggregate crushing value test:

- Total weight of the sample (A) = 4.1kg
- Weight of sample passed through 2.36mm sieve after load application (B) = 0.48kg
- Aggregate crushing value =B/A × 100 = 0.48/4.1 × 100
- Aggregate crushing value = 11.70
- For cement concrete pavement it should not exceed 30% and for wearing coarse it should not exceed 40%.

Los Angeles abrasion value test:

- Weight of aggregate sample (W1) = 2.5kg
- Weight of aggregate sample retained (W2) = 1.575
- Weight passing 1.70mm Is sieve =W1-W2 = 0.925kg
- Los Angeles abrasion value = (W1-W2)/W1 × 100 = (2.5-1.575)/2.5 × 100
- Los Angeles abrasion value =37%

Ductility test:

Reading	Neat Bitumen	2% LD PE	4% LD PE	6% LD PE	8% LDP E
Ist reading	38	36	32	29	39

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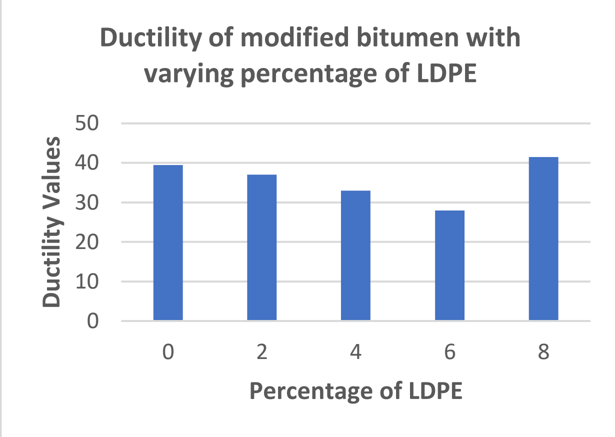
Neat bitumen	Initial reading	Final reading	Penetration	Mean (P)
Test 1	200	265	65	65.333
Test 2	265	328	63	
Test 3	328	396	68	
2% LDPE				
Test 1	200	259	59	56.00
Test 2	259	312	53	
Test 3	312	368	56	
4% LDPE				
Test 1	200	249	49	54.33
Test 2	249	302	53	
Test 3	302	359	61	
6% LDPE				
Test 1	200	247	47	48.66
Test 2	247	296	51	
Test 3	296	344	48	
8% LDPE				
Test 1	200	270	70	58.66
Test 2	270	321	51	
Test 3	321	376	55	

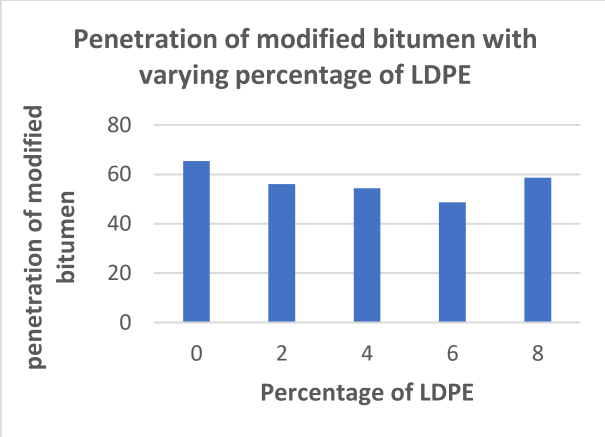
Second Reading	41	38	35	27	42
Ductility value (cm)	39.5	37	33	28	41.5

Table 2 Ductility values (cm).

Table 3 penetration of modified bitumen with varying percentages of LDPE



Penetration test:



Softening point test:

Temperature when ball touches bottom	2%LDPE	4%LDPE	6%LDPE	8%LDPE
1st reading	54	56	56	51
2nd reading	51	54.4	57	49.5
Softening point ^{0}C	52.5	55.2	56.5	50.25

Table 4 Softening point values for modified bitumen with varying percentages of LDPE

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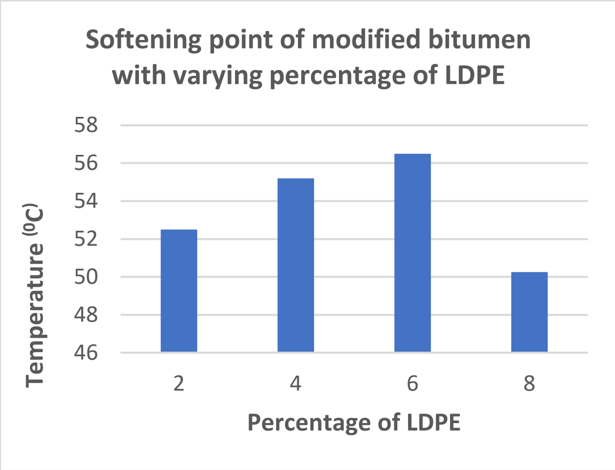


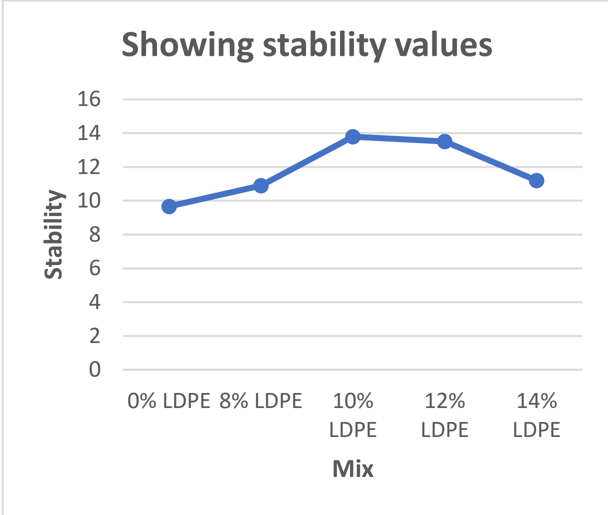
Marshal stability test

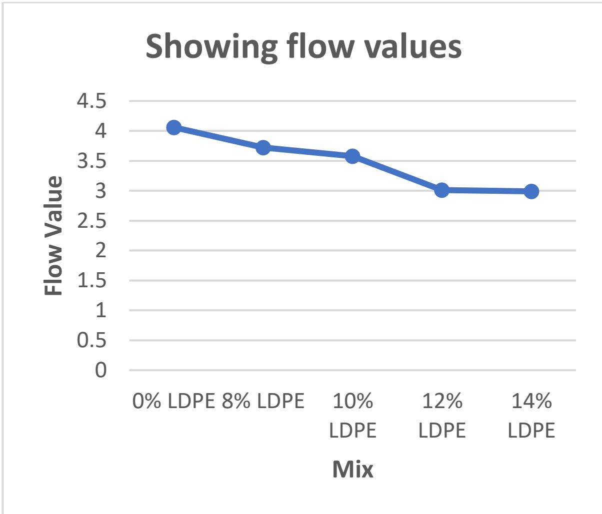
S. No.	Bitumen content	Marshal stability values	Flow Value	Bulk Density Of the mix	Air Void	VMA	VFB
		S	F	G_m	V_v		
	%	KN	mm	Gm/cc	%	%	%
1	4.5	9.53	4.05	2.15	6.63	12.7	66.9
2	5.0	9.67	4.06	2.17	5.26	14.4	68.8
3	5.5	9.53	4.19	2.16	4.94	13.8	67.2
4	6.0	9.25	4.30	2.15	4.73	13.0	65.1
5	6.5	8.93	4.31	2.14	4.31	12.3	61.1

Table 5 Results of BM Mix using VG-30 Grade Unmodified bitumen

S. No.	Mix	Stability	Flow Value	Bulk Density	Air Voids	VMA	VFB
		(kN)	(mm)	(g/cc)	(%)	(%)	(%)
1	Unmodified bitumen	9.67	4.06	2.17	5.26	14.4	68.8
2	B + 8 % LDPE	10.89	3.72	2.21	4.67	16.1	73.5
3	B + 10 % LDPE	13.79	3.58	2.52	3.12	18.7	76.2
4	B + 12 % LDPE	13.51	3.01	2.45	3.24	18.6	70.1
5	B + 14% LDPE	11.20	2.99	2.34	3.31	17.2	67.2

Table 6 variation of stability, flow, bulk density, air voids, VMA and VFB values with





CONCLUSIONS

- The results of this study concluded that addition of LDPE waste has improved the properties of penetration, ductility and softening temperature of the modified bitumen. As the stiffness of the material is improved,
- It is capable of taking high load and increase the resistance to pavement ruts. Therefore, the durability of the pavement is improved by the use of waste material that also helps to use the waste in an efficient manner.

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- On the basis of the analysis of results obtained in the present investigations, the following conclusions were drawn:
- The optimum bitumen content (OBC) for conventional BM Grade VG30 mixes was found to be 5%. For BM mixture with Grade VG30 the most significant percentage of LDPE was obtained 6 to 7 %.
- The addition of plastic waste reduces the air voids which prevents the moisture absorption and oxidation of bitumen by entrapped air. This has resulted in enhancement of Marshall Stability value.
- The flow value of mix was decreasing with increase in the waste content in the mix from 8 to 14%. The bulk density of the mix was also increasing with increase in the LDPE content.

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