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Comparative Analysis of Conventional and Baklite Modified Bituminious Mix

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Abstract: - In India, 78% of the road pavements are flexible due to increased environmental awareness and more stringent regulations on industrial waste management. The main advantage of flexible pavements is resistance to heavy loads, and there is no coincidental nature appropriate for all temperatures. However, failure in this pavement is sensitivity, fatigue, lack of cutting, and so on. Some changes are made on flexible roads to overcome this change. The performance of flexible pavements must be increased to reduce the failure compared to traditional flexible pavements. Consequently, it is obligatory to determine a remedy against these failures. For this purpose, the Bakelite high viscosity nature is added to a small amount of bitumen, which provides a higher softening point and less penetration value. In addition, the polymer plastic waste is also used in the bitumen, which results in a reduction in the sound produced by the vehicles, while improving the bleeding, as well as the quality and performance of the road at high temperature. This high-performance flexible pavement provides fewer flaws, reduces road maintenance costs, and is more durable compared to normal flexible pavements. In this research, the impact of Bakelite on sundry properties of bitumen binder is studied. This paper gives an overview on the utilization of Bakelite in roads. Previous studies show that Bakelite can improve some properties of the modified bitumen mix. Bakelite commixed in bitumen in different percentages from 1%to5% with an increment of .25%. From the environment and economic perspective, utilization of Bakelite as an additive to bitumen commix give a good result. The mixing of Bakelite with bitumen mix also increases the life of the pavement. The utilization of Bakelite material in roads construction can increment the age of pavements for a longer time.

Key Words:- Bakelite, Bitumen, Pavement, softening point testing, penetration test, coarse aggregate, Fine aggregate.

I. INTRODUCTION

India is a developing country. It has the second most astronomically immense road network spans of around 4.7 million kilometres. This road network conveys more than 60% of all goods in the country and 85 % of India's entire passenger traffic. Over the years, road transport has increased rapidly with the improvement of connectivity between cities and towns and throughout the villages of the country.

Figure 1.1 Road in India

The road network of India is the second largest road in the world, spread over 5.23 million Km.

85.9 % of the Indian population uses the road for travelling whereas 64.5 % of goods are transmitted from one state to other through the road network. For the development of road Indian government invest 9.51 billion USD.

The main objective of this research is to study the properties of bitumen on adding Bakelite. Disposal of thermoplastic material including Bakelite has become a matter of concern and waste Bakelite is prohibited to depose for direct landfilling and open burning of it leads to environmental pollution. Proper use of waste Bakelite in bituminous mixes improves the properties of the mix. The use of thermoplastic waste in road construction are based on Economic, Technical and Ecological factors. Taking an example of India the consumption of plastic is around 15 Million used for packing materials and is among the 3rd largest consumer of plastic in the world. If this waste can be used in road construction suitably, the pollution and disposal problems can be reduced to a large extent. In the construction of road, bitumen is used

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as a binder. Properties of Bitumen can be modified by adding Bakelite forming a mix which can be used as a top layer of pavement and show better stability, density, and binding property and more resistant to water. Developing of Ruts in the pavement in India is a matter of concern. This is mainly due to the incrimination in traffic volumes over the past two decenniums, authoritatively mandating engineers, more vigorous and perennial pavements. One of the best ways is to use waste thermoplastic in the construction of the bituminous road. Today, the waste thermoplastic is available commonly, as the plastic materials have become part and parcel of daily life.

A. Bakelite

Plastic is a substance with various types of 'synthetic or semi-synthetic organic' compounds that might be poured into various solid substances. Plastic is easy to use and can be easily accepted by people, but not environmental friendly and is also biodegradable. The durable chemical bonding continues to sustain the distinct natural process. In 1997, the primary fully synthetic plastic "Bakelite" has been exposed in New York by Leo Baekeland.

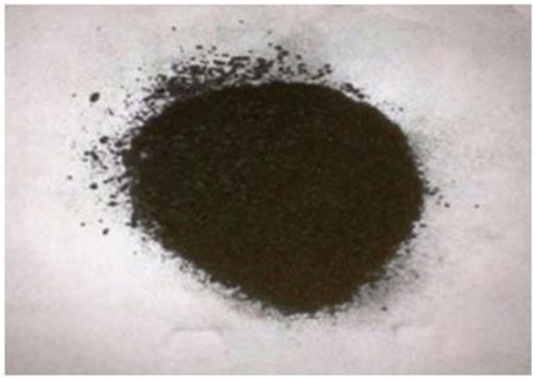

Figure 1.2 Powder of Bakelite

Bakelite is a trademark of phenol-formaldehyde. It is the first plastic which is made from synthetic components. Bakelite is a heat resistant type of thermosetting plastic composed by the condensation reaction of phenol with formaldehyde. It has high-performance engineering properties and is frugal. Bakelite in powdered form is shown in Figure 1.2. Thermoplastic polymers, thermosetting plastics, rubbers and block copolymers are typically used to alter the bitumen intended to improve the performance of the binders. Marshall Stability Test, viscosity test, and so on, have reported an increasing tendency with a certain increase in the content of Bakelite, and then diminished.

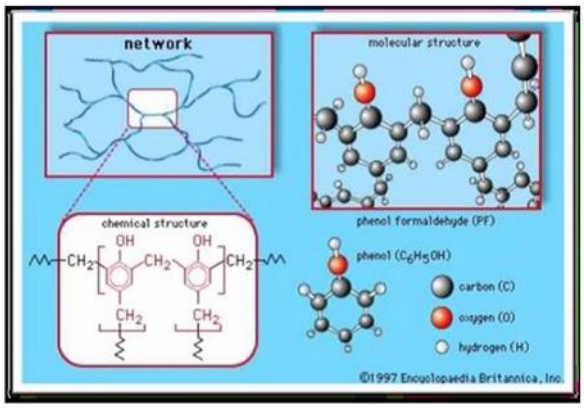

Figure 1.3 Structure of Bakelite Source

Figure 1.3 shows the structure of Bakelite, which is made up of 'phenol formaldehyde' resin and also recognized as phenolic resin. The phenol-formaldehyde resin was the first synthetic polymer to is used in commercial applications. In the 20th century, Bakelite, a trade-branded phenolic plastic, deviate the market for molded and laminated parts for electrical apparatus. Phenolic is an essential industrial polymer, although it is used today only for the plywood bonding. Due to its small costs, easy production and non-contact with water quality; plastic products are used extensively in manufacturing as well as in production companies.

India has become the world's largest plastic consumer with over 15 million consumers worldwide, often used to pack and dispose of waste into the environment. They also have a long-lasting property and, in uncontrolled conditions, the burning of these waste plastics can cause very dangerous air pollutants depending upon the polymers.

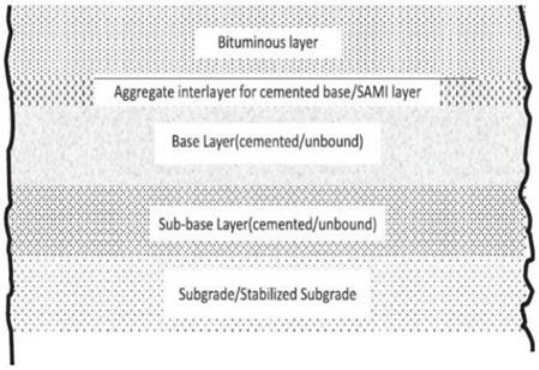

Figure 1.4 Layers in Flexible Pavement

Non-contaminated plastics are mixed with household waste and create difficulties for municipal waste disposal. The waste can be disposed of by municipal mainly in two different ways, (i) land filled or (ii) burning. Both damping processes are not appropriate for plastics, and as a result, these wastes cause soil and air pollution. With a great increase in industrialization and population growth, a variety of plastic waste goods are observed. Waste plastics, such as polyethene, plastic cups, carry bags and so on. This plastic can be softened at 130, and the temperature range lies between 130 to 180. So it can be employed as a melted plastic binder/ mixed by means of the bitumen to increase its characteristics. This can be worked well in road construction and increase the quality of bitumen. Construction of flexible pavement covers the following layers as shown in figure 1.4. 7550279461

B. Bitumen

The Indian Standards Agency defines bitumen as a black or dark brown amorphous soil with adhesive features that is originated from petroleum crude oil through the natural refining processes. In other words, bitumen is naturally tars, asphalt, mineral candles and so on. It is a binder and solid mixture of any hydrocarbons used to prepare road surface and roofing materials. It is mostly employed in following fields.

- Road, platform, runway construction and many more
- Waterproof
- Frankincense floor
- Canal Lining
- Moisture proof course

Also, the benefits /advantages of bitumen are as follow:

- Bitumen production is economic
- The rhythm and physical characteristics of the bitumen are versatile
- Any melting point
- Can be turned back
- Sticky

It is estimated that 102 million tons of bitumen is used worldwide and approximately 85 percent is used as a binder in the road construction process.

The road made up of the mixed bituminous material can cause bleeding in warm weather and has low load capacity, which may develop cracks in cold weather and may cause serious damage due to high axial load due to rapid infrastructure development. In both conditions, such as in terms of length and quality, Indian transport system must raise. In general, asphalt production is a bituminous compound that acts as an essential substance and consists of a mixture of fragmented rocks.

Materials like as 'polymers' can be joined to modify the chemical and physical properties of the asphalt, based on their intended use. The road administrations around the world know that the bitumen changed in the construction of the road is profitable. Polymer-modified bitumen is one the best road construction materials that is utilized for elastic paving. This results in dropping the average and everlasting costs as the roads are uncovered to fewer flaws. This type of road decrease maintenance costs, which is not just an economic issue, but a road predicament since the road is closed during the perpetuation process. Therefore, using plastic as a bituminous mixture, it also offers plastic collectors by solving the problem of plastic collapse, altering the confusion characteristics.

C. Pavements

A highway pavement is an arrangement comprises of layers of superimposed processing material above the natural soil level, the main function of which is to deal out the applied means of transport load to the foundation. The main function of pavement is to provide a structure with high riding quality, sufficient slip resistance, good light reflection features and low noise contaminated surfaces. The definitive goal is to make sure that the transmission pressure due to wheel loading are adequately minimized so that the pavements do not go beyond the bearing capacity of the foundation. There are mainly two types of pavements that are considered for this purpose, named as flexible pavements and rigid pavements.

D. Flexible Pavements

A flexible pavement may be defined as a mixture of bitumen or bituminous materials and aggregates positioned on a bed of a suitable mass of compacted particulate material in a layer on the sub grade.

Water gravel pavements and stable roads with soil or roads without asphalt pouring are examples of flexible pavements. Principle design of flexible pavement is that the pressure/Load is transmitted downwards over a larger area and passing to the last layer through multiple granular materials. The process of transmitting the load to the lowest layer is shown in figure 1.5.

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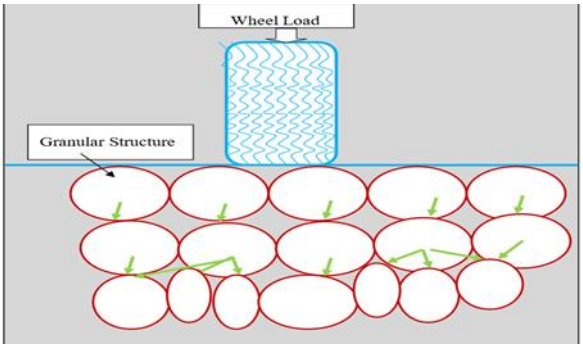

Figure 1.5 Flexible Pavement

As shown in figure 1.5, as the load by transportation means applied on the pavement, it will be spread out to a large area, and the level of stress also reduces. Due to these characteristics, the flexible pavement has utilized this concept with a number of layers. The layers are constructed in such a manner that the top layer can bear maximum stress and therefore high-quality material must be used. The lowest layer has to bear less load, therefore, it can be constructed with low-quality material. Flexible pavement is made up of Bitumen material.

E. Layers of Flexible Pavement

The layers of traditional flexible pavement comprise of a number of layers as depicted in figure 1.6.

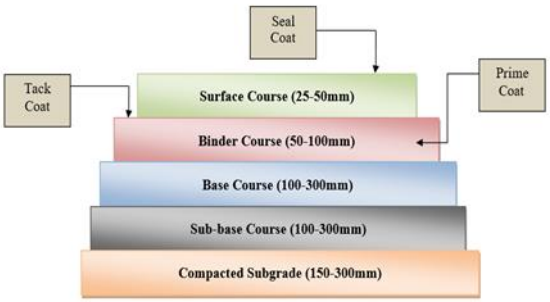

Figure 1.6 Typical cross section of a flexible pavement

Seal Coat:

It is used for road waterproofing and provides high skid resistance.

Tack Coat:

Tack Coat It is a very light asphalt application, which typically consists of an asphalt emulsion diluted with dihydrogen monoxide. It is thin and used to make connectivity between binder and surface course.

Prime Coat:

It is the application of a cutting bitumen which leaks down to an absorbent surface in the binder layer.

Surface Course. This layer is directly in contact with the vehicles (first layer) and must comprise of high- quality materials with dense graded asphalt concrete. It must have the following properties:

- Opposition to the entrance of surface water
- Tough
- Waterproof

Binder Course:

This layer provides the basic part of the asphalt concrete structure. The main goal is to lay the foundation of the load. The Binder course layer mainly includes aggregates with lesser asphalt and will not require high-quality surfaces, so it is more economical to replace a part of the fastening course.

Base course:

This layer is immediately below the surface of the binder course and provides additional load sharing, helps the drainage of the lower surface. It can consist of small stones, compressed slag and other natural or stabilized materials.

Sub-Base course:

This layer consists of the substance that underlying the base course and is designed to provide structural support, get better drainage, and lessen the intrusion level of fines from the lower pillar structure. The lower-base course with more penalties can accommodate as a filler between the lower grade and the main course. The sub-base course is not always needed or is not used. For example, high-quality pavement may require additional features that offer a sub-grade sub-base course. In such cases, a sub-base course cannot be used

Sub-grade:

Subgrade is a natural soil layer designed to accept stress from the above layers. No part of the soil should never be eroded. It is necessary to intensify any density near the amount of optimum moisture.

F. Rigid Pavement

The rigid pavement has enough flexibility to deliver tire pressure loads to a broad area below. The general structure of rigid pavements is illustrated in figure 1.6. Rigid pavements are located on a rectangular bottom surface or a single layer of rich or stable material compared to a flexible pavement. This layer can be referred to as base or sub-base since there is only one layer between concrete and lower grade. The load distribution process in rigid pavement is similar to the slab action, in which, the load is distributed along the groove motions and acts as a paved plate. The structure is prepared by Portland cement concrete (PCC) and examined on the basis of plate theory rather than the layer theory as examined in the flexible pavement. In plate theory, the concrete slab is considered as a medium thick plate that must remain plane before and after loading. The plate might be bending due to the excess load and high temperature.

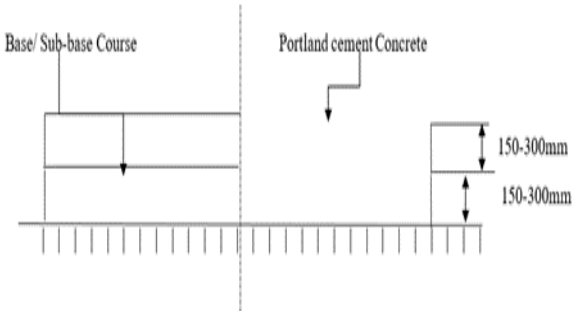

Figure 1.7 Typical Cross section of Rigid pavement

Table 2.1 Comparative analysis of existing work

References	Proposed work	Material used	Outcomes
Lalith et al. (34, 2018)	The researchers have used fly ash bricks in addition to plastic powders. The mixture has been prepared in different percentage such as 5, 10, 15 and 20.	Class F Flyash, Quarry dust, lime, waste plastic powder and water.	The experiment has shown that as the plastic powder percentage increased the strength also increases. The water absorption decreases with the increases in the plastic material. It has also been analyzed that the partial replacement of plastic in the quarry reduces the weight of the brick and can be effectively used in the construction sector.
Kumar et al. (35, 2018)	Studies the failures occur in the flexible pavement and presented a remedy to overcome these failures	Sulphur is mixed with bitumen, polymer plastic waste	The Sulphur with bitumen has provided high viscosity, increased softening point with minimum penetration value. The addition of polymer plastic waste with bitumen helps to decrease bleeding during summer, increase quality as well as performance. This researcher also contributed to reducing sound pollution as these materials absorb noise produced by vehicles.
Nouali et al. (37, 2018)	This research explores the accuracy of the use of plastic bag waste as bitumen to enhance the asphalt mixtures behaviours. The authors have also examined the impact of the addition of plastic bag wastes; low-density polyethene (LDPE),	Plastic Bags (LDPE a& HDPE) and Bitumen	The performance parameters such as penetration, softening point, ageing and storage stability have been measured. The penetration of modified bitumen has been reduced whereas the softening point has been increased.

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	to a traditional 40/50 grade bitumen.		
Köfteci et al. (38, 2018)	The test has been conducted on three samples prepared by adding ground plastic pipes content in different proportion such as 2 %, 4 % and 6 % respectively.	ground plastic pipe	The efficiency in terms of bending beam rheometer (BBR) has been tested and observed that the pure bitumen resistance has been increased by 4%.
Surya et al. (39, 2018)	The aim of this paper is to lessen the effect of rutting, cracking and an additional failure in the flexible pavement.	bio-medical waste plastic	From the test conducted on waste mixture in 15 %, 20 %, 25 % and 30 % in place of Bitumen have higher strength.
Yousaf et al. (32, 2014)	The performance of different hot mix asphalt mixtures has been evaluated	Asphalt content	The rutting resistance test and Asphalt mixture performance test has been conducted. The rut depth has been decreased by 29 5 and 38 % for class-A and Class-B mixtures.
Moghaddam et al. (36, 2012).	The authors have studied the influence of adding waste plastic fibres to Hot Mix Asphalt (HMA).	Two waste plastic fibre and two asphalt binder have been considered.	From the tests, it has been examined that the rutting resistance and fracture resistance has been increased by 54.4°C and -10- 21.1°C respectively.
Hınıslıoğlu, S., & Ağar, E. (33, 2004)	The objective of this study is to explore the possibility of using various plastic wastes, such as high density polyethylene, as a polymer addition to asphalt concrete.	The binder that has been utilized in hot mix asphalt was prepared by adding HDPE in 4-6 % and 8%. The AC20 bitumen has been used.	The efficiency has been measured in terms of stability, flow, and Marshal quotient. It has been observed that the sample prepared with the mixing temperature 165 °C and 30°C and mixing time of a respectively for 4 % HDPE determine the maximum stability and the lowest flow, which specified that the HDPE mixtures have higher strength compared the control mix.

II. Research Gap

I considered base paper, the paper published by Suman Kumari Saha on Characterization of bakelite-modified bitumen published in Springer International Publishing Switzerland 2017. The authors have utilized bitumen by waste Bakelite in proportion 1%,2%,3%,4%,5 and came to conclusion that compressive strength of Bakelite waste decreased with increment of replacement percentage and compressive strength of Bakelite waste with curing time. I decided to replace bitumen by waste Bakelite with an increment of 25% i.e., 1%,1.25%,1.5%,1.75,2%,2.25,2.5%,2.75,3%,3.25,3.5%,3.75 %,4%,4.25%,4.5,4.7%,5%, because replacement in small proportion provides better result as compare to increase in amount of waste Bakelite in mixes.

III. Mathematical Model

Newly constructed bituminous pavements are failing faster than expected. The use of higher binder grades is commonly recommended to solve some of the encountered structural problems and distresses. However, with today's budget cuts and economic constraints, it may be deemed infeasible. In this study, adding Bakelite plastic waste as a bitumen binder modifier was evaluated and its effects on bitumen binders and mixes performance was investigated.

Plastic waste accounts for a large portion of the total amount of Municipal Solid Waste (MSW) produced in India. It is estimated that approximately 10,000 tons of plastic waste are produced per day (that is 9 percentages of the MSW's Rs. 1,200,000 TPD). Their visibility is considered a serious problem and makes plastic a target for solid waste management. Plastic is not biodegradable. They also have a long service life, and burning plastic waste under uncontrolled conditions can also result in the production of many HAP (Harmful Air Pollutants), depending on the type of polymer and additive used. However, the scrap plastic can be recycled to the second life application, but after each heat treatment, the degradation of the plastic occurs to some extent.

In order to solve the problem of plastic waste disposal, attempts have been made to describe the possibility of reusing plastic waste (post-consumer plastic waste) in road construction. The CPCB (Central Pollution Control Board) Delhi published the "Guidelines for the Recycling of Waste Plastics – Guidelines for the Construction of Asphalt Road Construction" (PROBES / 101 / 2005-06). This document explains the methods of collecting, cleaning, chopping, sieving, and then mixing with asphalt for paving the road.

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IV. OBJECTIVES AND METHODOLOGY

Objectives:

The objectives proposed for this study are briefed as follows:

- To identify the optimum percentage of Bakelite to be added in the bitumen mix for getting the required strength.

Methodology:

Bitumen VG-40 viscosity grade bitumen has been used in this research. The step by step description of the proposed work is given below.

Step 1. Fine aggregate, Coarse aggregate, hard, angular is used in varying proportions to satisfy MORTH specifications. The collected aggregate is shown in the figure below.

Figure 4.1 Aggregate Collection

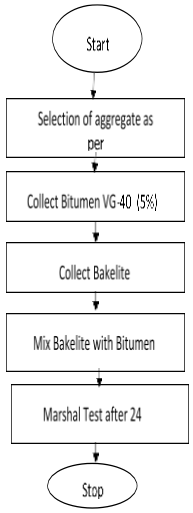

Figure 4.2 Flow of work

Step 2. Waste thermoplastic (Bakelite) was grounded and powdered waste Bakelite mixed with the bitumen. Shredded plastic acts as a binding agent for tar making bitumen to increase the lifetime.

Figure 4.3 Collection of Bitumen

Step 3. Mixing waste Bakelite with asphalt increases the capability of bitumen to bear up high temperature and also enhance the strength and life of the road.

Waste Bakelite is dissolved and mixed with asphalt in an exact ratio. Usually mixing take place at a temperature of 45 but when Bakelite is added, it stays stable at 54. The final sample is shown in the figure below.

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Figure 4.4 Final sample before Marshal Testing

The laboratory test conducted on the prepared specimen has proved that the asphalt concrete mixes prepared using waste plastic Bakelite fulfilled the criteria of Marshall mix specimen for the surface course of road pavement.

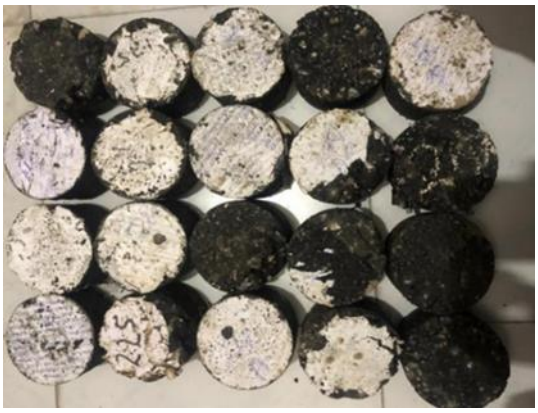

Figure 4.5 Sample after Marshal testing

There is a considerable rise in Marshal Stability value of the asphalt mix; it is two to three times more compared to the unmodified bitumen. The entire process of work is shown in figure 4.1.

V. RESULT AND ANALYSIS

1. *Marshal stability test.*

Table.1. Aggregate weight with size

Weighting of aggregate	Size	Filler
72g	12.5mm	480g
312g	10mm	
84g	4.7mm	
204g	2.6mm	

Table.2. Calculation of flow

Mold No.	Optimum Bitumen content (%)	Percentage of Bitumen replaced by Bakelite (%)	Flow (mm)
1.	5	1	2.21
2.	5	1.25	2.26
3.	5	1.5	2.32
4.	**5**	**1.75**	**2.45**
5.	5	2	2.56
Range as per MORTH specifications			2-4

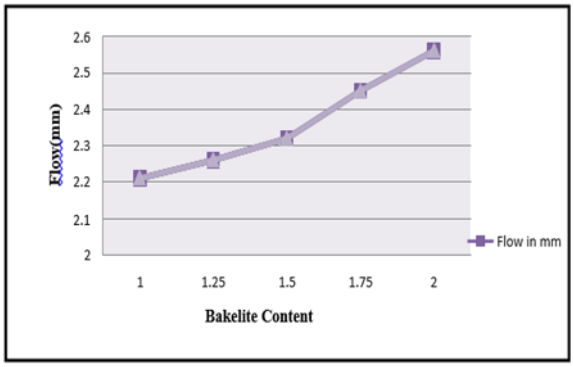

Fig.5.1. Effect of Bakellite on flow

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Table.3. Values of Stability

Mould No.	Optimum Bitumen content (%)	Percentage of Bitumen replaced by Bakelite (%)	Stability (Kn)
1.	5	1	12.8
2.	5	1.25	14.2
3.	5	1.5	18.1
4.	**5**	**1.75**	**24.2**
5.	5	2	22.5
Range as per MORTH specifications			>9

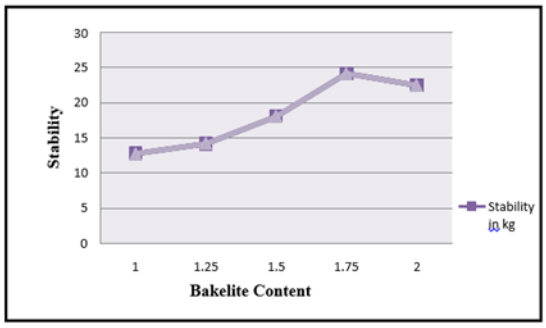

Fig.5.2. Effect of Bakelite on Stability

Table.4. Values of Air Voids

Mould No.	Optimum Bitumen content (%)	Percentage of Bitumen replaced by Bakelite (%)	VA (%)
1.	5	1	8.59
2.	5	1.25	6.76
3.	5	1.5	6.28
4.	**5**	**1.75**	**5.3**
5.	5	2	6.78
Range as per MORTH specifications			3-6

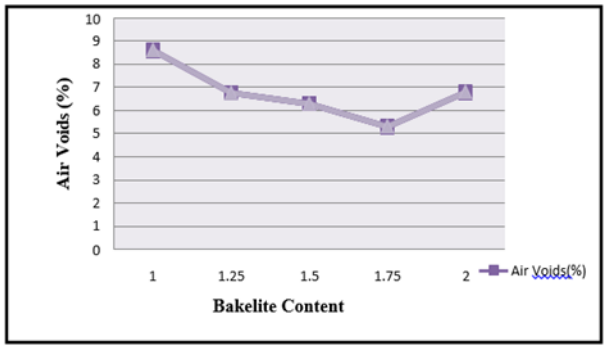

Fig.5.3. Effect of Bakelite on VA

Table.5. Values of Void in Mineral aggregate

Mould No.	Optimum Bitumen content (%)	Percentage of Bitumen replaced by Bakelite (%)	VMA (%)
1.	5	1	19.8
2.	5	1.25	18.13
3.	5	1.5	17.73
4.	**5**	**1.75**	**16.81**
5.	5	2	18.12
Range as per MORTH specifications			Minimum 11

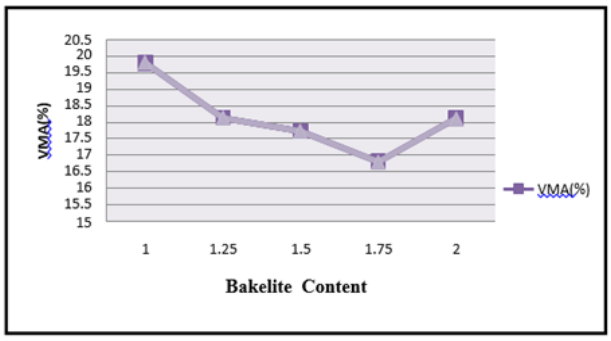

Fig.5.4. Effect of Bakelite on VMA

Table.6. Values of VFB

Mould No.	Optimum Bitumen content (%)	Percentage of Bitumen replaced by Bakelite (%)	VFB (%)
1.	5	1	56.61
2.	5	1.25	62.68
3.	5	1.5	64.56
4.	**5**	**1.75**	**68.47**
5.	5	2	62.58
Range as per MORTH specifications			65-75

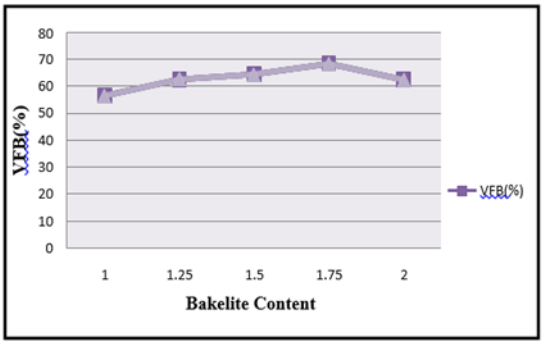

Fig.5.5. Effect of Bakelite on VFB

2. Softening Point Test

Table.7. Observations for tests on bitumen mix.

Percentage of Bitumen	Percentage of Bitumen Replaced by Bakelite	Softening Point(degree celsius)
5	0	52
5	1	54
5	1.25	56
5	1.5	59
5	**1.75**	**61**
5	2	58

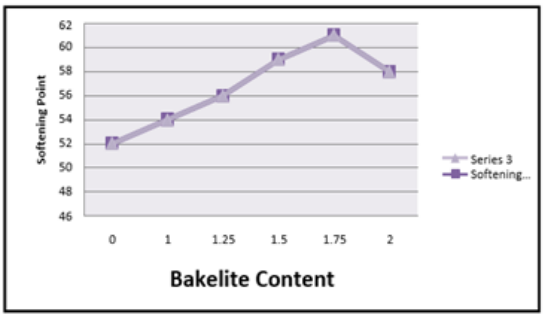

Fig.5.6. Effect of Bakelite on Softening.

3. Penetration Test

Table.8. Observations for tests on bitumen mix.

Percentage Of Bitumen	Percentage Of Bitumen Replaced by Bakelite	Penetration value in mm
5	0	49
5	1	45
5	1.25	43.5
5	1.5	42.25
5	**1.75**	**39**
5	2	40.5

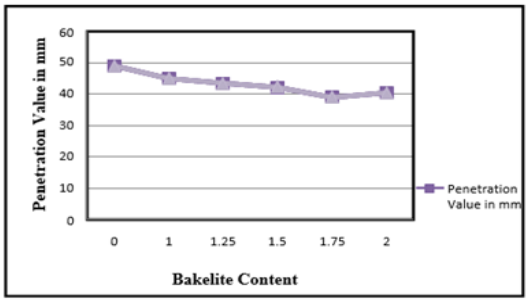

Fig.5.7. Effect of Bakelite on Penetration

4. Cost Comparison

Table.9. Cost Comparison

Conventional bitumen seal coat cost	Modifies Bitumen Coat Cost
Rs.2,25,922	Rs.2,25,274

5. Test on Material

Table.10. Values of water absorption, Loss Angle and Aggregate Crushing test

S. No.	Test Type	Values	Acceptable Limits As per MORTH Table-500-7
1	Water Absorption	1.32%	2% Maximum
2	Loss angle	20.22%	30% to 35% Maximum
3	Aggregate Crushing Value %	22%	45% Maximum
4	Aggregate Impact Value %	20%	

6. Comparison

Mould No.	Optimum Bitumen Content (%)	Percentage of Bitumen replaced by Bakelite	Stability (Kn)	Flow (mm)	VA(%)	VMA(%)	VFB(%)
1.	5	0	20	3	4.03	15.57	74.08
2.	5	1.75	24.2	2.45	5.3	16.81	68.48

VI. Conclusion And Future Scope

The concept of mixing plastic waste with bitumen, can help to the re-utilization and reduction of plastic material dumping. It's a non-biodegradable product and encourages the engineers to increase the infrastructure and the national economy by using these materials in the construction field. Some waste is released fuel and land charging may cause environmental damage. This research estimates that waste can be used as a bactericide agent, that waste may be plastic used in the construction of a flexible pavement for better performance, and both will continue to have a certain degree of conditional change and aggression against heavier traffic. To determine the efficiency of the proposed work, a number of experiments have been performed on the mixed bitumen with Bakelite. Bakelite content has been added gradually in different percentage (1%, 1.25%, 1.5%, 1.75% and 2%). Also, the effect with and without Bakelite content has been examined. The following points are observed during the analysis process.

Utilization of waste Bakelite help in minimizing the disposal problem. The Life and strength of flexible pavements are more as compared to the ordinaries and increment in properties of bitumen mix is seen and penetration values 1.75% lowest indicates great enhancement in shear resistance at high temperature and value of softening point value which is highest with 1.75% of Bakelite indicates better improvement in resistance to deformation. Hence it can be used at hot climatic areas. The percentage of Bakelite to be added in the bitumen in 1.75%.

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