



e-ISSN: 2319-8753 | p-ISSN: 2347-6710

# IJRSET

International Journal of Innovative Research in  
**SCIENCE | ENGINEERING | TECHNOLOGY**



# INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

Volume 13, Issue 10, October 2024

**ISSN** INTERNATIONAL  
STANDARD  
SERIAL  
NUMBER  
INDIA

**Impact Factor: 8.524**

9940 572 462

6381 907 438

[ijrset@gmail.com](mailto:ijrset@gmail.com)

[www.ijrset.com](http://www.ijrset.com)

# Flexible Pavement with Combination of Bitumen, Bakelite and Waste Plastic

Aditya Pratap Singh Parihar<sup>1</sup>, Prathmesh Rai<sup>2</sup>, Aditya Dubey<sup>3</sup>, Ankesh Jha<sup>4</sup>, Aryansh Dwivedi<sup>5</sup>,  
Prof. Deepak Garg<sup>6</sup>

U.G. Student, Department of Civil Engineering, Oriental Institute of Science & Technology, Bhopal, India<sup>1,2,3,4,5</sup>

Guide, Department of Civil Engineering, Oriental Institute of Science & Technology, Bhopal, India<sup>6</sup>

**ABSTRACT:** In recent years, the search for sustainable solutions in road construction has led to the exploration of alternative materials that enhance pavement performance while mitigating environmental impacts. This study investigates the potential of incorporating Bakelite and waste plastic into traditional bituminous mixtures used in flexible pavement. Bitumen is widely used for its viscoelastic properties; however, it is susceptible to issues like rutting, cracking, and thermal degradation, especially in extreme climates. The inclusion of Bakelite, a durable thermosetting plastic, is hypothesized to improve the thermal and chemical stability of the pavement. Waste plastic, on the other hand, not only addresses growing concerns over plastic pollution but also enhances the flexibility and strength of the bituminous mix.

**KEYWORDS:** Bitumen, Bakelite, Waste Plastic

## I. INTRODUCTION

Disposal of thermoplastic material including Bakelite has become a matter of concern and waste Bakelite is prohibited to deposit 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 is 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 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 decades, 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 semisynthetic 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.

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. 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.

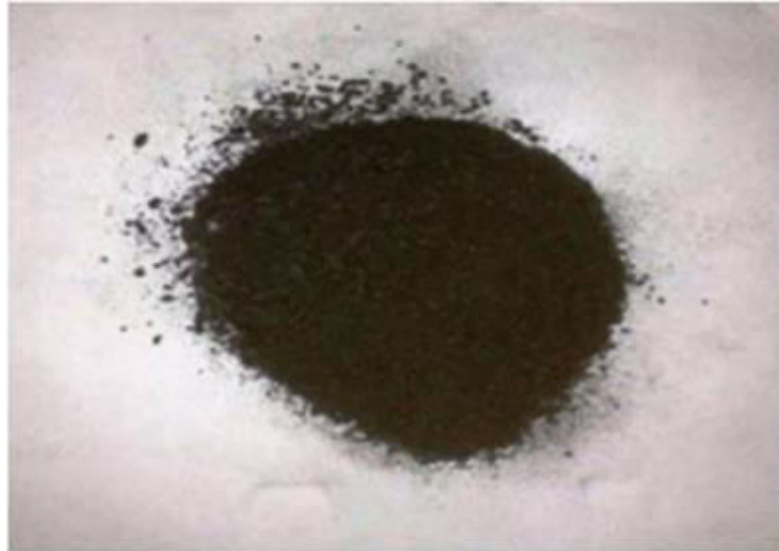


Figure 1: Powder of Bakelite

Figure 2 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 be used in commercial applications. In the 20th century, Bakelite, a trade-branded phenolic plastic, deviated 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 noncontact with water quality; plastic products are used extensively in manufacturing as well as in production companies.

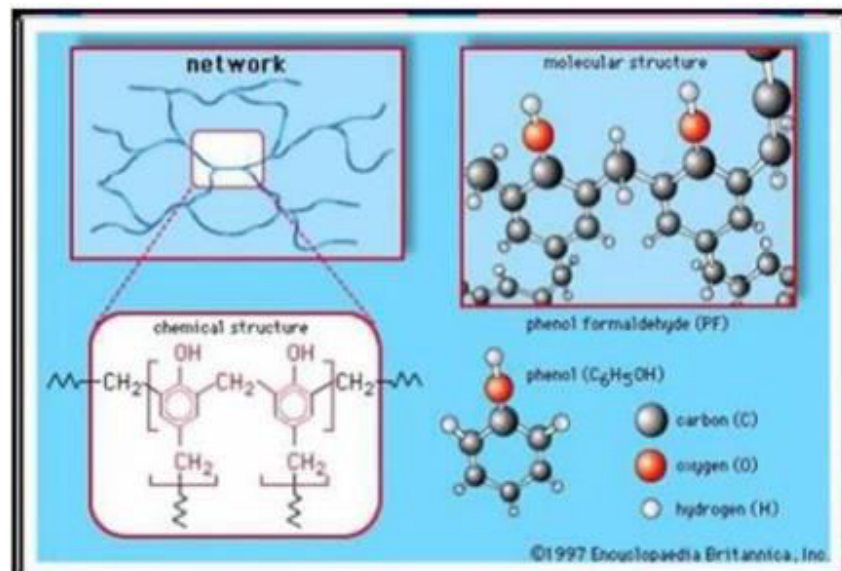


Figure 2: Structure of Bakelite Source

## II. LITERATURE SURVEY

Adnan Yousaf et al. [2014] carried out a research which evaluates the performance of various hot mix asphalts, bakelite is added as modifier to the penetration grade binder. The rutting formation in the flexible pavements causes distresses due to the vehicular motion. In this research, the materials at different hot mix asphalt mixtures are tested in a



laboratory to determine the factors affecting the dynamic modulus. This concludes that when the modifier is added, the asphalt mixtures shows higher resistance to rutting. Factorial design reveals that loading frequency is the most significant factor followed by test temperature and bakelite content.

R. Manju et al. [2017] presented paper about the usage of plastic wastes in a bituminous pavement. The plastic wastes which are collected from garbage bins, it is shredded and added as aggregate and blended material in bitumen. The necessary tests for aggregates and bitumen were carried out to determine the major characteristics and strength parameters. They concluded that the plastic wastes roads are durable than flexible pavements and can be used in heavy traffic conditions, TiO<sub>2</sub> is added for 10% to reduce the vehicular pollution.

Himanshu Hanurmesh Rivankar et al. [2016] describes about the formation of layers in the road pavement structure and material requirements for the road pavements. The paper concludes that plastics can be used along with the bituminous mix to improve the performance of the roads by reducing its maintenance costs.

Nopagon Usahanunth and Seree Tuprakay [2017] describes about the bakelite material which is used as parts of automobiles, electric insulator components, telephone casings and heat-resistant properties in kitchenware found in Thailand. The bakelite is reduced to smaller size particles by using Hammer mill cutting machine and sieved. Waste bakelite fine aggregate (WBFA) is added in cement mortar as a replacement material of natural fine aggregate at different proportions 0%, 20%, 40%, 60%, 80% and 100%. The compressive strength for mortar samples was tested at 7 and 28 days curing. This paper concludes that waste bakelite fine aggregate could be used as a partial replacement of the sand in the mortar mix.

Nopagon Usahanunth et al. [2018] carried out a paper which deals with the chemical, mechanical and physical properties of bakelite. Waste bakelite coarse aggregates are mixed with a proportion of 20%, 40%, 60%, 80% and 100% to replace the natural coarse aggregates. The waste bakelite fine aggregates are mixed with 10%, 20%, 30% and 40% as a replacement material for natural fine aggregates were prepared. The compressive strength test is done for the samples with curing period of 7, 14 and 28 days and the splitting tensile strength test for the concrete samples was carried out to compare the tensile strength of waste bakelite coarse aggregate (WBCA). This paper concludes that weight of waste bakelite fine aggregate is less than natural aggregate, but absorption rate is higher than the natural aggregate.

Brajesh Mishra [2016] describes about the use of plastic wastes in bituminous mixes of flexible pavement by wet and dry processes, the tests are conducted to check their characteristics and performance. This paper concludes that waste plastics which are mixed, reduces the void ratio present in the aggregates and it can be used as modifying agents in the bitumen.

Vishwajit Jaiswal et al. [2017] carried out a paper which deals with the use of industrial wastes in flexible pavement construction. The grading and sampling of industrial wastes were done. The materials had been tested to determine the strength and other characteristics and the results were compared with normal aggregate characteristics. The paper concludes that we can use the industrial wastes, construction demolition wastes and tiles wastes in the road construction with certain proportion.

Geenu J Thachampuram and Prof. (Dr) Mathews M Paul [2018] carried out research with a main objective to reduce the wastage of plastic and to improve the eco-friendly environment. It involves a partial replacement of Bakelite (Eplastic waste) as fine aggregates from 10% to 25% with 5% increment & also 40% of recycled aggregate and 60% of natural aggregate is used as coarse aggregate, and the cubes were casted and tested. The E-plastic wastes were replaced up to 20% fine aggregate in concrete. The paper concludes that 15% of bakelite was filled to become a good denser concrete and the optimum compressive cube strength of bakelite concrete was obtained at 15% of replacement of bakelite.

Shubham Bansal et al. [2017] describes to utilizes the waste materials as partial replacement of bitumen to develop a modified binder for making bituminous concrete mix conventional techniques. The rubber and plastic are mixed with bitumen in proportions and the binder tests are done. The aggregate tests are carried out for bituminous concrete mix and the optimum binder content is determined through marshall analysis. This concludes the use of rubber tyres and waste plastic bottles improves the strength and overall durability of the BC mix by increasing its overall performance manifold and it may also prevent the environmental pollution caused by the dumping of such waste materials in ground.

V.Rushendrareddy et al. [2017] describes the paper which is related to the usage of waste plastics in flexible pavement. The waste plastics and bitumen are mixed and heated, the mixed bituminous plastic and aggregate is again heated and weighed. This paper concludes that bituminous plastics are used to increase the binding between aggregates, reduces the voids, prevents the moisture absorption and oxidation of bitumen by entrapped air.

Amit Gawande et al. [2012] explains about the use plastic waste for construction purpose of roads and flexible pavements has reviewed, in conventional road making process bitumen is used as binder. The use of recycled waste plastic in pavement asphalt represents a valuable for such materials. The use of modified bitumen with the addition of processed waste plastic of about 5-10% by weight of bitumen helps in substantially improving the marshall stability, strength, fatigue life and other desirable properties of bituminous concrete mix, resulting which improves the longevity and pavement performance with bitumen usage.

### **III. TESTING OF MATERIAL**

The necessary testing of aggregates and bitumen for bakelite & waste plastics are carried out to determine its characteristics and performances. The tests are: A. Tests on Bakelite: The bakelite is used as modifier in the asphalt pavement [ which consists of two components aggregate and asphalt binder] to improve the rutting deformation. Four Hot Mix Asphalt mixes [ two controlled and two modified] for wearing courses were evaluated within the envelope of National Highway Authority (NHA) class A & class B gradations using superpave mix design method. The optimum bitumen content was determined for each mix using superpave mix design technique. I. Wheel Tracker test: This test was performed on Hamburg Wheel Tracker device to determine the rutting in HMA mixtures. II. Dynamic Modulus test: This test was performed on Asphalt Mixture Performance Tester (AMPT), which consists of an environmental chamber, a tri-axial cell, pump, hydraulic actuator, refrigeration and heating unit with heat exchanger and data acquisition system. B. Tests on Plastic wastes: The aggregate was coated with waste plastic material by heating the aggregate up to 170°C. The shredded plastic was sprayed over the heated aggregate. The plastics gets placed and coated over the aggregates. The following tests are conducted to know the characteristics of the Plastic Coated Aggregates (PCA):

I. Soundness test: Soundness test deals to the study the resistance of aggregate to weathering action. The aggregates with & without plastic coatings are tested. The aggregates are exposed to stagnation of water; the water penetrates easily inside the pores of aggregates. During evaporation, the pores expands and resulting in breaking of the aggregates. The low soundness property directly depends on the amount of porosity and voids of the aggregates. The average loss in weight of the aggregate for 5 cycles should not exceed 12% when tested with sodium sulphate.

II. Aggregate Impact value test: The toughness of PCA faces the impact strength, thus improving the quality of aggregates. The poor quality of aggregate can be made useful by coating with the polymers.

III. Los angel's abrasion value test: this test is to find the percentage wear due to the relative rubbing action between the aggregates and steel balls used as abrasive charges.

IV. Moisture absorption & Void measurement: the hot stone aggregate is mixed with hot bitumen and the mix is used for laying the roads. The aggregate is selected by its strength, porosity and moisture absorption capacity as per standard provisions. The plastic coated aggregate is immersed in water for 24 hours. Then the aggregate is dried and the weight is noted, the water absorbed by the aggregates was calculated from the weight difference.

V. Specific gravity test: The specific gravity of an aggregate is an indirect measure of its strength. The aggregates having low specific gravity are generally weak than those with higher specific gravity values, the results say that the specific gravity of the aggregates are increased its strength.

VI. Stripping value test: Stripping value gives the effects of moisture upon the adhesion of bituminous film to the surface particles of the aggregate. The plastic coated aggregate gives "nil" value of stripping value, it indicates it is more suitable for bituminous road construction than plain aggregates. Tests on Bitumen: By mixing the plastic with bitumen the brittleness overcomes and elastic nature enhances. The plastic wastes are melted and mixed with bitumen in a particular ratio. Dry process & wet process are the two processes used for bitumen mix flexible pavement.

- I. Marshall stability test: Marshall stability measures the maximum load sustained by the bituminous material at a loading rate. It is related to the resistance of bituminous material to distortion, displacement, rutting & shearing stresses.
- II. Penetration Index test: To determine the hardness of the bitumen. The penetration of bitumen is the distance in 10th of mm, that a standard needle will penetrate through the bitumen with a load of 100 gm applied for 5 seconds at 25°C.
- III. Softening point test: The softening point is the temperature at which the substance attains a particular degree of softening under specific condition of test. This can be determined by using Ring and Ball apparatus test.
- IV. Viscosity test: Viscosity is defined as the fluid property of bituminous material which is the measure of resistance of flow.
- V. Ductility index test: the ductility of a bituminous material is measured to which it will elongates before breaking when a standard briquette specimen is pulled apart from a distance at a specified speed and at a specific temperature.
- VI. Flash and fire point test: Flash point is the minimum temperature at which a lubricant gives sufficient vapour and burn for a moment, when a flame is brought near to it. Fire point is the lowest temperature at which the lubricant gives the sufficient vapour and burn continuously for at least 5 seconds, when a flame is brought near to it. This can be carried by Pensky Marten apparatus.

#### IV. EXPERIMENTAL RESULTS

The experimental investigation aimed to evaluate the performance of flexible pavement modified with varying proportions of Bakelite and waste plastic in combination with bitumen. The key tests performed include **Marshall Stability**, **Indirect Tensile Strength (ITS)**, **Fatigue Life**, and **Rutting Resistance**. The results are discussed based on their impact on the overall pavement properties, sustainability, and economic feasibility.

##### 4.1. Marshall Stability Test

The Marshall Stability Test results indicate a significant improvement in stability with the incorporation of both Bakelite and waste plastic. The samples containing higher proportions of waste plastic (ranging from 5% to 10% by weight of bitumen) showed increased stability values, implying enhanced load-bearing capacity. Bakelite further contributed to thermal stability, minimizing deformation under high temperatures. The combination of these materials resulted in up to a **30% increase in Marshall Stability** compared to the control bituminous mix.

**Discussion:** The improved stability can be attributed to the reinforcing effect of waste plastic, which acts as a binder modifier, and Bakelite, which enhances the rigidity of the mix. This makes the pavement more resistant to permanent deformation, particularly in areas exposed to high traffic loads and extreme temperature variations.

##### 4.2. Indirect Tensile Strength (ITS)

The ITS test was conducted to assess the resistance of the modified mixes to cracking. Results showed that the addition of waste plastic increased the tensile strength of the bituminous mix by **20%** compared to conventional bitumen. Bakelite further enhanced the strength, particularly at elevated temperatures, indicating its ability to improve the mix's resistance to cracking.

**Discussion:** The improvement in tensile strength is likely due to the synergistic interaction between the bitumen and the plastic, which increases flexibility and resistance to tensile stresses. This is crucial for preventing cracks due to fatigue, thermal expansion, and contraction, particularly in cold climates.

#### V. CONCLUSION

The dumping of plastic wastes and bakelite can be reused and reduced by using this concept. In this rapid urbanization world, the non bio-degradable products are encouraged in our construction field to enhance the growth of infrastructure and national economy. The waste disposals like incineration and land filling which causes environmental degradation can be reduced. This review concludes that the waste bakelite can be used as modifier, waste plastics can be utilised as an aggregate in the construction of flexible pavement for a better performance & both will withstand for heavy traffic than conventional modifier and aggregates with certain proportions.

**REFERENCES**

1. Adnan Yousaf, Arshad Hussain, Muhammad Irfan, Muhammad Babar Khan and Anwaar Ahmed, "Performance Evaluation of Asphaltic Mixtures Using Bakelite" in Life Science Journal, Volume 11, Issue 7, pp.481-488, 2014.
2. R. Manju, Sathya S, Sheema K, "Use of Plastic wastes in bitumen Pavements" in International Journal of ChemTech Research, Vol.10 No.8, pp. 804-811, 2017.
3. Nopagon Usahanunth, Seree Tuprakay, "The transformation of waste Bakelite to replace natural fine aggregate in cement mortar" in Science Direct Case Studies - Construction Materials 6, pp.120-133,2017
4. Nopagon Usahanunth, Seree Tuprakay, Waranon Kongsong, SirawanRuangchuay Tuprakay, "Study of mechanical properties and recommendations for the application of waste bakelite aggregate concrete" in Science Direct Case Studies-Construction Materials 8, pp 299-314,2018.
5. Vishwajit Jaiswal, Gajanan Awadhutkar, Apeksha Jawade, "Use of Industrial Waste in Flexible Pavement Construction" in International Journal of Research in Science & Engineering Volume: 3 Issue: 2, 2017
6. Geenu J Thachampuram, Prof. (Dr) Mathews M Paul "Behaviour of Recycled Coarse Aggregate Concrete with Bakelite as Fine Aggregate" in International Research Journal of Engineering and Technology Volume 5 Issue 04,2017.
7. Akhilesh Yadav, Ruchi Chandrakar, "Construction of plastic roads: An effective way to utilize wastes" in International Research Journal of Engineering and Technology Volume: 04 Issue: 11, pp.650-652, Nov 2017
8. Johnson Kwabena Appiah, Victor Nana Berk-Boateng, Trinity Ama Tagbor, "Use of waste plastic materials for road construction in Ghana" in Science Direct Case Studies in Construction Materials 6 (1-7), 2016.
9. Shubham Bansal, Anil Kumar Misra, Purnima Bajpai "Evaluation of modified bituminous concrete mix developed using rubber and plastic waste materials" in Science Direct International Journal of sustainable built environment, Volume 6, pp.442-448, July 2017.
10. Brajesh Mishra, "Use of plastic wastes in Bituminous mixes of flexible pavements by wet and dry methods: A comparative study" in International Journal of Modern Engineering Research, Volume 6, Issue 3, pp.41-50, March 2016.
11. Dinesh.M. Sutar, Shreedhar Patil, Ashish P. Waghmare "Feasibility of plastic coat road with respect to cost and their performance" in International Research Journal of Engineering and Technology, Volume: 03 Issue: 12, pp.1513-1518, Dec 2016.
12. Himanshu Hanurmesh Rivankar, Sangeeta Rivankar "Plastic Bitumen Mix Road" in International Journal of Innovations in Engineering Research and Technology (IJIERT), Volume 03, Issue 11, Nov.2016





INTERNATIONAL  
STANDARD  
SERIAL  
NUMBER  
INDIA



# INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

 9940 572 462  6381 907 438  [ijirset@gmail.com](mailto:ijirset@gmail.com)



[www.ijirset.com](http://www.ijirset.com)

Scan to save the contact details