Utilization of Bakelite And Waste Plastic In Flexible Pavement Construction – A Review

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Abstract- *India places 3rd in the world for the consumption of plastic wastes. The road transport system gives many benefits to people, communities and the local economy. The road sector produces the highest level of greenhouse gases directly, through fossil energy used in mining, transportation, paving works and indirectly through the emissions coming from vehicles. Non bio-degradable products plastic and rubber stay for a long time on site and cause environmental pollution. As an alternative, bakelite and plastics can be used for the road and pavement construction. This paper also helps us to know about the general properties and characteristics of waste plastics and bakelite.*

Keywords- Bakelite, waste plastics, aggregates, bitumen, modifier, flexible pavement.

I. INTRODUCTION

A plastic can be defined as any non-metallic material that can be molded to desired shape. The plastics are manufactured from natural substances such as coal, cellulose, natural gas, salt and crude oil through polymerisation or poly condensation process. Plastics are classified into two types. Thermoplastics are the plastics that do not undergo chemical change in their composition when heated and can be molded easily. Thermosets can be once hardened and set they do not soften with the application of heat; these materials cannot be remelted.

Bakelite is the world's first synthetic plastic, a thermosetting kind of plastic material. It is manufactured from the reaction of phenol and formaldehyde using a basic catalyst. The flexible pavement construction involves the construction of the following layers:

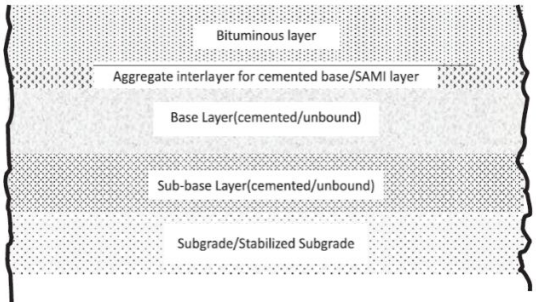

Fig.1: - Layers in Flexible Pavement

II. LITERATURE REVIEW

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, TiO2 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 (E-plastic 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.

Akhilesh Yadav & Ruchi Chandrakar [2017] identifies that plastic wastes can be used in road construction to reduce the waste storages around the city. The plastic roads increase the durability and strength of the road. The waste plastics was reduced in size by dry process and wet process and mixed with bitumen. This paper concludes that polymer modified bitumen gives better performance, reduced rutting, ravelling and no potholes formation.

S. Rajasekaran et al. [2013] deals with the reusing of waste plastics coated aggregates and bitumen mix composite for road application followed by green method. Various waste by products are analysed and their characteristics were listed. The waste plastics were melted and coated to conventional aggregates and tested. The results conclude that the performance of plastic-tar road is good for heavy traffic due to better binding with increased strength and better surface condition for a prolonged period of exposure to variation in climatic changes.

Johnson Kwabena Appiah et al. [2017] illustrates about the road construction carried out in Ghana by using Poly-Ethylene Terephthalate (PET) and High Density Poly-Ethylene (HDPE). The materials which are needed for pavement construction are selected and undergone laboratory testing. This concludes that when adding the thermoplastic modifiers to the conventional bitumen to improve the elastic behaviour of the bitumen. This study has also shown that waste plastic modified bitumen carries great promise as an alternative recycling method for plastic waste management in Ghana, as well as a non-traditional, modified binder for road construction.

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.

Axay Shah et al. [2015] illustrates the paper about the usage of waste which are not capable for landfilling, incineration and not eco-friendly. All the major bitumen tests are done and the optimum polymer content is determined by marshall stability point. This paper concludes that behaviour of polymer modified bitumen is improved by various factors, the waste polymers in a pavement it improves the pavement performance and reduces the environmental pollution which is cost saving method.

Dinesh. M. Sutar et al. [2016] discusses the recycling of waste plastic into a useful road pavement and their cost and performance are studied in detail. The main objective of this paper is to compare the cost of bitumen coat road and plastic coat road and their performance and to use the plastic as road seal coat material. The waste plastic carry bags, polyester fibres, bottles and jars are collected from municipal solid waste dumping yards and streets. All the basic process such as cleaning, shredding, collection, seal coating is done. The paper concludes that the re-use of waste plastics in roads, increases the durability and shining of road by plastic seal coating and acts as a modifier in the bitumen.

Mercy Joseph Poweth et al. [2013] carried out the paper which aims at proposing a new method of disposal of plastic, quarry dust and tyre waste by using them in the sub grade of pavements. CBR tests were conducted in the laboratory on soil sample mixed with different percentages of waste materials. The required percentage of waste plastics/waste tyre rubber chips/quarry dust by dry weight of soil was mixed uniformly with the soil, water content corresponding to OMC was added to the soil. This paper concludes when increase in percentage of quarry dust resulted in increase of maximum dry density and CBR value.

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 outlet 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 marginal saving in bitumen usage.

Mahesh M Barad [2015] carried out a paper which involves the use of plastic in bituminous road construction, the experimental tests were carried out to determine the bitumen characteristics and plastic coated aggregates characteristics. This paper concludes that polymer modified bitumen can be used for lower percentages, the plastic coated aggregates prevents from moisture absorption, rutting, ravelling and no pot-hole formation.

III. MATERIALS & PROPERTIES

a. Bakelite: The bakelite wastes are produced from the various components such as cars, telecommunication workshops, industrial manufacturing units, etc… from various areas.
b. Properties: Strong, rigid and dimensionally stable; heat resistant, chemical resistant; less weight and it is resistant towards electricity.
c. Waste plastics: The waste plastics includes plastic bottles, containers, film, thermo-cole, blister packs, toys, trays, carry bags, cups, household articles, pipes, etc. These plastics are subjected to heat and pressure and remolded.
d. Properties: Low water and moisture absorption, excellent fatigue and wear resistance, excellent impact resistance.
e. Bitumen: Bitumen is a sticky, black and highly viscous liquid/ semi-solid. It is composed of highly condensed poly cyclic aromatic hydrocarbons, containing 95% carbon and hydrogen, 5% sulphur, 1% nitrogen, 1% oxygen and 2000 ppm metals.
f. Properties: It is used for its excellence binding property, water-repellent and thermos-plastic in nature.
g. Aggregates: Aggregates is used for base and sub-base courses in flexible pavement, such as sand, gravel and crushed stone, etc. The function of aggregate in bituminous mix is to provide a rigid skeleton and to reduce the space occupied by the bitumen content and fines. The physical properties of the aggregates generally refer to the structure of the articles that form the aggregate.

IV. SIZE REDUCTION OF WASTE BAKELITE AND WASTE PLASTICS

Waste bakelite size reduction

- Hammer-mill cutting machine: The hammer-mill cutting machine is a horizontal axis type. It consists of parts: - motor, fixed blades, rotating blades, screen mesh. The waste bakelite is placed into the machine and broken into smaller size particles and then flown through the mesh at bottom of the milling machine.
- Aggregate classification by sieve: After the size reduction process, the waste bakelites gets separated

by coarse and finer particles, by using sieve classifications.

Waste Plastics size reduction

- Shredding machine: The cutting of waste plastics into small sizes can be done with the help of shredding machine such as agglomerator and scrap grinder were used. In agglomerator, thin films of plastics and carry bags can be shredded and in scrap grinder some solid plastics (i.e.) plastic bottles, drip lines, electric cables, etc. are shredded.

Fig. 2: - Hammer-mill cutting machine

Fig.3: - Plastic shredding machine

V. TESTING OF MATERIALS

Tests on Bakelite	*Tests on Plastic Coated aggregates*	*Tests on Bitumen*
i)Wheel Tracker test ii)Dynamic Modulus test	i)Soundness test ii)Aggregate Impact value test iii)Los angel's abrasion test iv)Moisture absorption & void measurement v)Specific gravity test vi)Stripping value test	i)Marshall Stability test ii)Penetration Index test iii)Softening point test iv)Viscosity test v)Ductility index test vi)Flash and Fire point test

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℃.

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.

VI. RESULTS & DISCUSSIONS

Based on various researchers, the following points were observed:

- From the wheel tracker test results, the rutting is evaluated by comparing the rut depths obtained by four mixtures. The rut depth is obtained only after 20,000 passes, with the modified mixtures (bakelite:6% up to 38%) in hot mix asphalts class A along with binder the resistance to rutting is improved.
- The plot between the temperature and dynamic modulus shows that, at lower temperature the value of dynamic modulus is high compared to other dynamic modulus values. The voids are reduced, when the bakelite of 6% and at 0% bakelite the voids in mixes are more as compared to others.
- The tests on plastic coated aggregates has no soundness, minimum water absorption and voids, less aggregate impact, less crushing value and less abrasion value than normal conventional aggregates.
- The plastic waste mix will help to reduce the need of bitumen by around 10% by increasing the strength and performance of roads.

VII. 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.

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