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USE OF RECYCLED PLASTIC WASTE AS BITUMEN ALTERNATIVE IN ROAD CONSTRUCTION

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Abstract

This research project explores the innovative integration of plastic waste into road construction materials as a viable Bitumen replacement. With the escalating environmental concerns associated with plastic pollution and the growing demand for sustainable infrastructure development, this study investigates the feasibility, performance, and environmental impact of incorporating plastic waste in road construction. This study evaluates the environmental impact of the utilization of plastic waste as bitumen replacement and identifies the effects derived from the utilization of plastic waste as bitumen replacement in road construction. The methodology involves a comprehensive analysis of different types of plastic waste, their chemical compositions, and compatibility with road construction materials, preparation and processing of plastic-modified Bitumen, hot mix Asphalt (HMA) production, Marshall Stability test, and environmental impact assessment. The environmental impact of this innovative approach was analyzed through life cycle assessments, comparing the ecological footprint of traditional road construction methods with those incorporating plastic waste, and the cost-effectiveness of plastic waste utilization was assessed. The study revealed that utilization of plastic waste as a bitumen replacement in road construction shows promise as an environmentally sustainable solution.

Keywords; Plastic Waste; Plastic-Modified Bitumen; Marshall Stability Test; Hot Mix Asphalt (HMA)

Introduction

Urban areas have experienced a sharp economic growth in the past two decades, which has finally led to a rapid growth of vehicle usage on urban roads. It causes a vehicle-centric urban mobility environment, which has triggered a number of transport related problems. Such problems have made transportation policy makers realize the importance of public transport system in improving urban mobility (Coasta et. Al. 2013). In majority Nigerian cities, bus transportation is often treated as a predominant public transport (Chen et.al, 2021) service. But, the success of the same depends not only on urban transportation network being served by it and its service quality; but also to a great extent on service condition of facilities (Biber et. Al., 2019) provided at urban roads. Road construction is a crucial aspect of infrastructure development, and bitumen has traditionally been the primary binder used in road pavement construction. In today's lifestyle we see plastic in every spot. Plastic is used daily for packaging, protecting, serving, and even disposing of all kinds of consumer goods. India consumption of plastics will grow more than 15 million tons by 2015 and is set to be the third largest consumer of plastics in the world.

Plastics are commonly used as packing materials, but their wastes can be used in the construction industries to produce construction materials, such as floor tiles, roof tiles, building blocks, etc.

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This can reduce construction costs and minimize environmental pollution [Omosebi T. O. and Noor Faisal 2022]. For instance, plastic wastes can be mixed with sand and other additives to produce constructional materials [Hundermark et. al., 2020]. Presently, recycled plastic wastes are gradually replacing natural materials such as fiber, metal, wood/timber, and sand, thereby preserving the natural environment. Proper management of solid wastes through recycling into new products will help to promote a sustainable environment, conservation of natural resources, and cheap raw materials [Jambeck et. al., 2018]. On the other hand, the lack of adequate management of solid wastes will add to the existing environmental problem; hence, solid wastes must be properly managed by recycling them into new useful products [Singh et. al., 2016]. Plastic wastes cannot decompose easily and are produced in huge quantities, their deposition into landfills may not be a permanent solution [Gupta, et. al., 2020].

Several studies have identified the possible suitability of plastic waste as building materials. Mehdi et al. [2019] stated that when mixed with sand, high-density polythene (HDPE) plastics can be used to make roof tiles. After research, the results of their study showed that composite tiles made with 70% HDPE performed and were of higher quality. Several experimental studies on the use of recycled PET bottles as a replacement for natural aggregates in concrete, as well as resin in polymer concrete, have recently been released. Akinwumi et al. [2019] demonstrated the development of stabilized soil blocks from shredded plastic waste, concluding that 1% finely shredded PET waste (size 6.3 microns) by weight could be used for active block stabilization. Mustafa et al. [2019] looked at using PET waste as a partial substitute for fine aggregates in the manufacture of high-impact resistance building materials. The impact resistance of mortars made with a 20% plastic content increased by 39%. Kumi-Larbi et al. [2018] announced the efficient production of sand blocks using plastic waste, and their results showed that solid and durable sand blocks can be created without the use of additional water, using only plastic waste. Yang et al. [2012] explored the possibility of creating eco-friendly door panels by mixing plastic waste with wood dust. Utilizing plastic waste bottles as construction materials could significantly reduce construction costs while also providing a waste diversion solution, thereby mitigating environmental pollution caused by plastic waste [Omosebi et al., 2021].

`MATERIALS & METHODS

Materials

The plastic wastes used in this study were shredded plastic bottles wastes collected from a Waste dump site at Federal Polytechnic, Ado Ekiti, Ekiti State. Figs. 1 showed the bags of shredded PET wastes samples. The utilization of plastic waste as a bitumen replacement in road construction involves incorporating recycled plastic materials into the asphalt mix. Various plastic materials can be used in this process, and the selection depends on factors such as compatibility with bitumen, performance requirements, and environmental considerations. Here are some commonly used materials; Plastic (high density and low density), Stone dust, Filler, Granite (12mm) and Bitumen. Plastic wastes were collected from various sources, ensuring a diverse range of polymer types. The

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plastic wastes were sorted and categorized based on polymer type (e.g. high density polymer and low density polymer). It was cleaned and shredded into small, uniform pieces after which the shredded plastic was mixed with bitumen in ratio 1:2:3 (HLS) where ratio 1 represent the high density, ratio 2 represent the low density and ratio 3 represent the sp of the Polyethylene using a

high-temperature mixer and ensured thorough and homogeneous blending of plastic and bitumen which the weight was measured and documented.


Figure 1: Sample of PET Wastes


Figure 2: Crushed Stonedust


Figure 3: Mixing of Melted Wastes

RESULTS & DISCUSSIONS

A. Marshall Stability Test

The polymer bitumen blend is a better binder compared to plain bitumen. The blend increased softening point and decreased penetration value with a suitable ductility. When used for road construction it can withstand higher temperature. Hence it is suitable for tropical regions. It has decreased Penetration Value, hence its load carrying capacity is increased. The blend with aggregate has no Stripping Value. So it can resist the effect of water. The Marshall Stability Value is high. The bitumen required can be reduced depending upon the % of polymer added. It is a good saving too. No toxic gas is produced. The binding properties of polymer also improve the strength of mastic flooring. The result coincides with [4 and 5].

Table.1. Marshall Stability test

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MAX LOAD VALUE	PROVING RING FACTOR	STABILITY (KN)	AVERAGE STABILITY (KN)
114	0.125	14.25	
105		13.13	13.69
109		13.69	
123		15.38	
171		21.38	18.38
147		18.37	
169		21.13	
166		20.95	20.94
167.7		20.94	

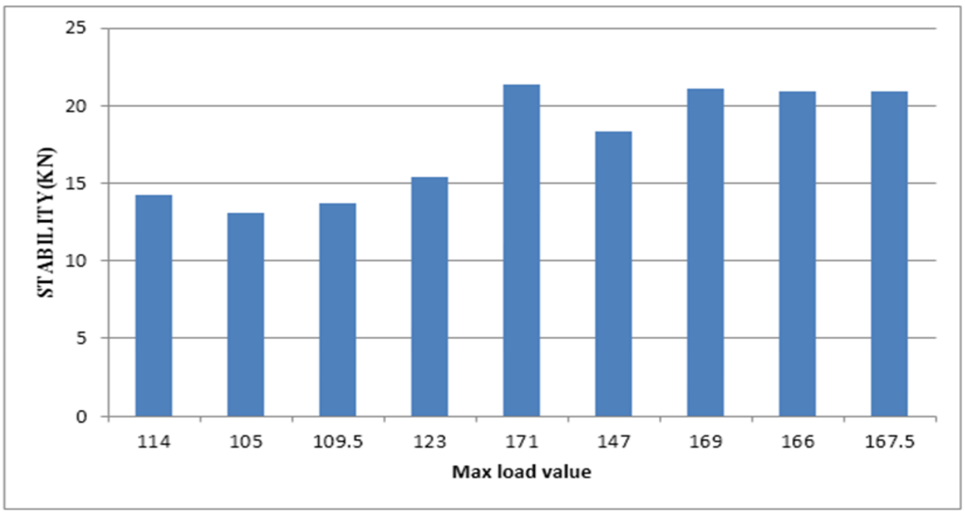

Figure 4. Marshall Stability chart against max load value

B. Adhesion and Stripping Test

The adhesion tests and stripping evaluations suggest a good adhesion regarding the interaction between the bitumen (including plastic waste) and the aggregate. Addressing any issues related to adhesion is essential for preventing moisture-induced damage. The addition of waste plastic modifies the properties of bitumen. The polymer modified bitumen shows good result when compared to standard results. The optimum content of waste plastic to be used is between the ranges of 5% to 10%. The problems like bleeding are reduce in hot temperature region. Plastic has property of absorbing sound, which also help in reducing the sound pollution of heavy traffic. The waste plastics thus can be put to use and it ultimately improves the quality and performance of road. The observation is in line with [1, 3, and 4].

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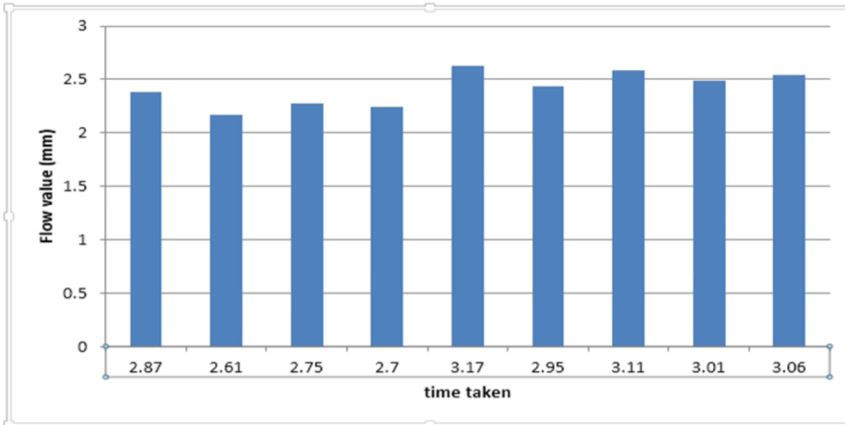

Figure 5. Flow value vs. Time Taken

C. **Mechanical Properties:** The mechanical property testing has demonstrated that the asphalt mixture with plastic waste as a bitumen replacement exhibits positive performance characteristics compared to conventional asphalt, which was also reported by Costa [5].

Figure 6. Compaction test

D. Moisture Sensitivity test:

The moisture sensitivity testing, due to the hydroscopic nature of plastic, it has good moisture resistance. This is a critical aspect to ensure the long-term durability of the road infrastructure, also reported by [4 and 5].

Figure 7. Sample in water

CONCLUSION

The study reveals that plastic waste is an effective substitute for bitumen in road construction, offering improved strength and zero water absorption. Plastic waste as a bitumen replacement in road construction provide an innovative and eco-friendly solution. The polymer's binding properties improve the strength of mastic flooring, while the approach provides a sustainable way to manage plastic waste, reducing reliance on harmful disposal methods like landfilling and incineration.

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