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Eco-Friendly Infrastructure Development: Employing Plastic Waste for Road Development: A Review

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Abstract - The issue of plastic waste creation is an environmental problem on a global scale. The current review collects literature regarding the use of plastic waste in road construction and its impact on ecological benefit and pavement performance. It has been noted that the introduction of plastic waste in bituminous mixtures enhances their binding properties, stability, density and water resistance while the replacement of traditional aggregates by plastic-coated ones and the application of modified bitumen enhances the roads limiting the emergence of potholes. The optimum percentage of plastic waste to be added varies from 5 to 15% by weight of bitumen based on the type of plastic and mix design. Coating plastic waste on aggregates has been shown to assist in increasing the bitumen-aggregate bond, reducing void content, increasing pavement life, decreasing the reliance on bitumen and improving resistance to heat and moisture degradation. This strategy resolves problems of plastic waste management and contributes to sustainable infrastructure advancement. However, there are still obstacles in the way of bringing the concept to practical applications segregate, automate and monitor the performance over time. It would be more beneficial for the future research to address smoothing and low temperature rutting effects of plastic waste, recyclable asphalt mixtures, and efficient production methods.

Key Words: Plastics waste, Highway engineering, Bituminous mixtures, Pollution, Pavement quality, Waste disposal, Sustainability, Modified bitumen, Polymer aggregate, Green building materials.

1. INTRODUCTION

Expansion of industry and increase in population have led to unprecedented generation of waste all over the globe. The wastes include non-biodegradable materials such as plastics, blast furnace slag, fly ash, steel slag, and scrap tires that are some wastes that are cumbersome to produce and dispose of socially and environmentally. The introduction of plastics as a material for packaging and numerous engineering components in recent times has compounded this problem. Moving to urban, the proper management of plastic waste especially bags has become more of an issue with problems such as (misuse, litter, blockage of drainage systems, negative impact to soil fertility, and aesthetic issues) arising.

There is a forecast of increase in plastic waste generation and therefore fresh strategies should be sought. The construction industry is an ideal sector for this approach as it acts as a market for plastic waste resources. At the same time, the rapid growth of the traffic volume and the structure of through traffic which included heavy-duty vehicles, high overloaded impact, and cyclic temperature changes, resulted in premature wear of the pavement, growth in the volume of restoration works, and emergence of safety problems.

This review synthesizes the available data on plastic waste reuse and recycling in road construction with emphasis on the management of plastic waste toward environmental pollution control, enhancement of pavement efficiency and providing an efficient resource recycling waste management system... This study explores the practicality, benefits plastic, and difficulties associated with the application of plastic waste in bituminous mixes, modified bitumen and flexible pavements, especially the need for standardization, scalability and performance in the long run.

2. Recent advancements

The road of 25 km length consisting of plastic modified bituminous concrete has been completed in the city of Bangalore. This road demonstrated better smoothness and stability of performance, as well as less rutting, compared to an ordinary roadway built at the same time which soon showed signs of ‘crocodile cracks’. This study was approved by the Central Road Research Institute of Delhi (CRRI) in 2003 November. Justo et al., (2002), also of Bangalore University, used waste plastic bags in some of the asphalt concrete mixes. They focused on investigating the properties of the modified bitumen and comparing them to the standard bitumen counterparts. For instance, as the amount of the plastic additive was increased gradually from 2 to 12% by weight of the modified bitumen, the penetration and ductility characteristics decreased. Mohammad T. Award et al., (2007) sought to find out which of the polyethylene characteristics would be optimum in quantity and type of polyethylene used. In the course of the study, the researchers used both high density and low density polyethylene coatings. It was shown in the results of the investigation that physically modified ground HDPE improved the performance properties. The modifier’s recommended proportion used was 12% in relation to the weight of the bitumen used. The mixing process affected improvement in stability, decrease in the density and slight increase in air voids and voids in mineral aggregates was observed. Shankar et al, (2009) used crumb rubber modified bitumen (Mod Bit CRMB 55) at specified ranges of temperature. They designed Marshall’s mix by keeping modified bitumen content at a fixed optimum rubber content and varying the quantity of modified bitumen in it and subsequently performed tests to ascertain other mix design characteristics as well as Conventional bitumen (60/70) The results have shown appreciable enhanced characteristics as

opposed to straight run bitumen, with lower optimum modified binder content (5.67%).

Wet process

For improved performance, polymer-modified bitumen was utilized. However, when the bitumen blend employed a higher proportion of polymer, then the dispersion of the polymer in the mixture increased further, such that it was released upon cooling. This separation could affect the properties and quality of the blend and could also affect the road surfaces constructed using these mixtures. For example, there are some specialized equipment which would be needed for efficient blending of materials. Change of certain concrete values of bitumen leads to improvement in the characteristics of bitumen which in turn affects the quality and durability of the road. Particularly in situations where modified bitumen has to be used at construction sites, the service temperature and blending conditions have to be kept within limits so as to prevent the polymer and the asphalt from separating.

Dry process

In the modified process plastic waste was coated over the aggregate which was treated in this case as the dry process. This helps in better adhesion of bitumen with the plastic waste coated aggregate due to enhanced bonding and increased area of interaction between polymer and bitumen. The polymer coating also decreases the amount of voids present. Moisture absorption as well as oxidation of the droplet into the bitumen due to entrapped air was also avoided. This resulted in reduced rutting, raveling, and pothole formation. This means that the road can handle large amounts of traffic and last longer.

The process of coating is not cumbersome and the minimum temperature required is the same as the road laying temperature.

Plastic was applied on the aggregate to which bitumen was first bonded. Assumed binders were coated plastics and strong binding of surfaced asphalt to the added binder was observed. Waste plastic was collected, shredded and used in hot-mix plants for road laying purposes. The same technologies were utilized and not new tech incorporated. There is no need to modify the existing mini-hot mix plants or Central Mix plants. The covered aggregate has shown higher bonding better than the bare aggregates.

Drying operation has been carried out in any climatic conditions. Process can be formulated by changing the % of plastic with respect to the environmental conditions such as Temperature, Rain, Snow, load, etc.

Any toxic species like dioxin were completely ruled out since the temperature does not reach any maximum. Temperature is only 170 ^{0}C

There are many advantages of using plastic waste in the construction of roads and highways which include:

- Better paving performance and life span
- Less bitumen usage (up to 10%)
- Better durability against thermal and moisture stress
- Lesser problems associated with disposal of plastic wastes

Development of infrastructure which is environmentally and ecologically sustainable. Despite that, the following challenges are still observed.

- Plastics waste processing and mix design standardization
- The potential to be adopted widely and to a large scale
- Monitoring and maintenance for extended periods

In terms of the directions that the next research activities should take, I would like to recommend the following.

- Study the impact of plastic waste on low-temperature fatigue and rutting performance of asphaltic concrete- Work to alternate more affordable types of asphalt mixtures (e.g., thin asphalt concrete, gap-graded one)
- Optimal and environmentally friendly approaches to plastic waste treatment and coating.

Table -1: Results of tests on aggregate

Stone aggregated	Plastic content (%)	Aggregate impact value	Los Angeles Abrasion value	Specific Gravity	Water Absorption	Stripping value
Without plastic	0	10.79%	12.85%	2.5	3.20%	1%
With plastic	10	9.27%	11.70%	2.66	2%	Nil
	15	8.94%	10.65%	2.7	1.10%	Nil

Fig.-1: Aggregate impact value and stone aggregate

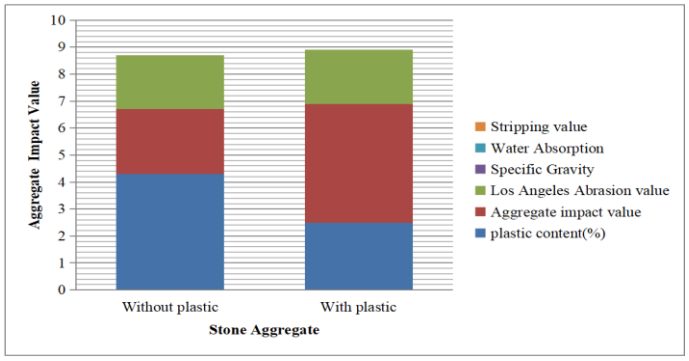

Table -2: Marshall Stability and flow value

Sample No.	Bitumen content (%)	Plastic content (%by Wt.)	Marshall stability (Kg)	Flow value(mm)
1	4	0	950	3.1
2	5	0	1170	3.3
3	6	0	1240	3.6
4	4	5	1560	3.9
5	5	10	1720	4.5
6	6	15	1980	5

Fig.-2: Stability (kg) and bitumen content (%)

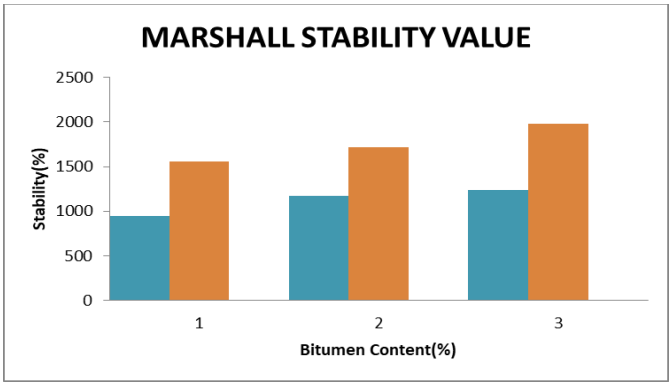

Fig -3: Plastic is used in road construction in Madurai

3. CONCLUSIONS

The use of plastic waste in road construction is a well-appeased solution which is environmentally friendly, increases the efficiency of the pavement and assists in the building of infrastructures. This review seeks to integrate the past studies done on the use of plastic waste in asphalt concrete and the outcome that was achieved with regards to its efficiency including the possible challenges.

These results suggest that the addition of plastic waste modification improved the Marshall stability, strength, fatigue resistance and also the durability of bituminous concrete mixtures. The amount of plastic waste that is mixed with the bitumen differs considerably ranging between 5 – 15 percent by weight of bitumen and plastic used in the mix. The aggregates treated with polymer have highly improved properties of binding, low moisture content ratio and greater ability to resist rutting and potholes. The adherence of plastic waste coatings on aggregates has shown potential effectiveness in causing the production of bitumen-aggregate adhesion and lacquer voids. This method also helps to avoid phase-separation problems which are common in the wet process blending.

As a result, construction of roads using plastic waste is one of the modern methods to solve the big problem of waste disposal, resilience of structural health of roads and sustainability. Continuous investigation and teaming up are important to find solutions and continue further seeking this innovative approach

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