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Case study

Use of waste plastic materials for road construction in Ghana

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ABSTRACT

This paper forms part of research to solve two main problems in Ghana: firstly, the management of municipal solid waste (MSW), particularly with regards to used plastics which have overwhelmed major cities and towns; secondly, the formation of potholes onroads due to excessive traffic and axle weight. This study examines the effect of blending waste thermoplastic polymers, namely High density polyethylene (HDPE) and Polypropylene (PP) in Conventional AC-20 graded bitumen, at various plastic compositions. The plastics were shredded and blended with the bitumen 'in-situ', with a shear mixer at a temperature range of 160 °C–170 °C. Basic rheological parameters such as penetration, ring & ball softening point and viscosity tests were employed to determine the resulting changes from base bitumen.FTIR spectroscopy was also employed to study the chemical functionalities present in the bitumen composite. The properties of the unmodified bitumen were found to be enhanced with the changes recorded in the rheological properties of the polymer modified bitumen (PMB). It was observed that polypropylene polymer, showed profound effect on homogeneity and compatibility with slight linear increment in the viscosity, softening and penetration values as against relatively high changes for HDPE modified bitumen.The viscosity of unmodified bitumen was enhanced with the addition of the polymers and thixotropic effect was observed for both HDPE and PP at 60 °C. For all modified binders prepared, the penetration values decrease as polymer-bitumen ratio increases whiles softening temperature generally increases as polymer ratio increases. The most compatible and incompatible blends for HDPE were respectively observed at 2% and 3% polymer loading. The most enhanced, homogenous blend is achieved with PP at 3% polymer loading. Three prominent peaks were identified in the spectrum of the unmodified bitumen, occurring at the 3000–2850 cm^{-1} IR frequency range, typical of aliphatic —C—H symmetrical and asymmetrical stretches in alkanes. CH_2 and CH_3 bends were also observed at the characteristic frequencies of 1465 cm^{-1} and 1375 cm^{-1} respectively. A low intensity peak was observed within the 2400 cm^{-1}–2100 cm^{-1} range, indicating the presence of a very weak $-C\equiv C-$ or $-C\equiv N$ group with an absorbance of precisely 0.12.The use of waste commodity plastics in binder modification carries the advantage of a cheap and effective means of enhancing conventional bitumen binder performance characteristics and is an alternative way to utilise plastic waste.

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1. Introduction

In the year 2000, one of the millennium development goals (MDGs), which Ghana appended to was the promotion of environmental protection and sustainability; However, for well over a decade which has seen the transformation of the MDGs in to Sustainable Development Goals (SDGs), the country is still grappling with the proper disposal and management of its Municipal solid Waste (MSW), especially plastic waste.Currently, the common waste disposal methods employed are land filling, incineration and haphazard littering in the cities, municipalities and the countryside. These disposal methods have a negative impact on human health and the environment; consequently, rivers, gutters and roadsides are choked and filled with waste plastics.

Polyethylene Terepthalate (PET) and High density Polyethylene (HDPE) are used in most bottling applications of water, yoghurt and soft drinks, but in terms of littering, however, one of the worst culprits is polyethylene (or "polythene") bags, for food packaging and sachet water bags. Every day, a multitude of items that are either partly or completely made of plastic are used and these plastics eventually end up in the landfills. Depending on the quality of the plastic, it may take anywhere from a few days to several years to break down in landfills, but it never breaks down completely into particles that can be used in nature. As such, plastic is one of the worst offenders when it comes to environmental pollution [1].

On the other hand, the volume of road traffic is increasing and demands a corresponding increment in the load bearing capacities of the road and its service life span. It has been proven possible to improve the performance of bituminous mixes used in the surfacing course of road pavements, with the help of various types of additives or modifiers to bitumen such as polymers, rubber latex, crumb rubber, etc.

The choice of modifier for a particular project can depend on many factors including construction ability, availability, cost, and expected performance. Modification is achieved by two main procedures; Dry process involves direct incorporation of waste plastic, which is blended with aggregate before adding in bitumen, to prepare a plastic modified bituminous concrete mix and the Wet process which involves, simultaneous blending of bitumen and waste plastic.The use of polymer modified bitumen to achieve

better asphalt pavement performance has been observed for a long time [2,3]. Zoorab&Suparma [4] reported the use of recycled plastics composed predominantly of polypropylene and low density polyethylene in plain bituminous concrete mixtures with increased durability and improved fatigue life. Resistance to deformation of asphaltic concrete modified with low density polythene was improved in comparison with unmodified mixes. The thrust of this study is to generate scientific data which will form basis for using plastic modified bitumen in the construction and repair of roads in Ghana, as well as provide scientific data on the alternative recycling options for managing plastic waste.

2. Materials and methods

2.1. Materials

2.1.1. Bitumen

The bitumen used, AC-20 grade, was obtained from a local road contractor in Kumasi.

Physical properties of this bitumen are presented in Table 2. After the experimental procedures, the modified properties were compared with the Ghana Highway Authority (G.H.A) bitumen specifications (Table 1).

2.1.2. Plastic

The plastic used was waste plastic bottles, bags, wrappers, etc collected from the Department of Chemistry, KNUST and from residential areas on the campus.

2.2. Method

2.2.1. Modified bitumen preparation

The wet process was employed; Samples were prepared, using melt-blending technique. Bitumen (400 g) was heated in oven till fluid condition and polymer was slowly added. The speed of the mixer was kept above 120 rpm and temperature, between 160 °C and 170 °C. The concentration of PP and HDPE, ranged from 0.5% −3% by weight of blend with an increment of 0.5%. Mixing was continued for 30mins-1hr to produce homogenous mixtures. The polymer modified bitumen (PMB) was

Table 1
Ghana Highway Authority Specifications for unmodified bitumen (AC-20 Grade).

Penetration (dmm) at 25 °C, 100 g,5 s	–
Softening Point,°C	48–56
Kinematic Viscosity at 135 °C, cSt.	300
Viscosity at 60 °C, cP	2000 ± 400
Specific Gravity	1.01–1.06