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A Review Of Waste Plastic Material In Bituminous Concrete Mixes

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Abstract— **This review paper clarify about the Waste management has become an issue of increasing concern worldwide. These products are filling landfills and reducing the amount of livable space. Leachate produced from landfills contaminates the surrounding environment. The conventional incineration process releases toxic airborne fumes into the atmosphere. Researchers are working continuously to explore sustainable ways to manage and recycle waste materials. Recycling and reuse are the most efficient methods in waste management. The pavement industry is one promising sector, as different sorts of waste are being recycled into asphalt concrete and bitumen. This paper provides an overview of some promising waste products like high-density polyethylene, marble quarry waste, building demolition waste, ground tire rubber, cooking oil, palm oil fuel ash, coconut, sisal, cellulose and polyester fiber, starch, plastic bottles, waste glass, waste brick, waste ceramic, waste fly ash, and cigarette butts, and their use in asphalt concrete and bitumen. Many experts have investigated these waste materials and tried to find ways to use this waste for asphalt concrete and bitumen. In this paper, the outcomes from some significant research have been analyzed, and the scope for further investigation is discussed.**

Keywords: Waste management, recycle waste materials, Flow value, concrete and bitumen, waste fly ash

1. INTRODUCTION

A million tons of waste are generated each day around the world. Landfills are used to dump most of this waste. Between 2014 and 2015, Australia produced over 27 million tons of waste [1]. These findings indicate a 6 million ton increase in landfill waste since 2007 [2]. Of the 27 million tons of waste disposed of in 2014–2015, approximately 6.5 million tons were of municipal waste, 13 million tons were of commercial and industrial waste, and 7.1 million tons were of construction and demolition waste [1]. Modern and comfortable lifestyles and innovations in technology, along with industrialization, have increased the quantity and variety of waste being generated, resulting in a severe crisis for proper waste disposal systems [3]. Conventional waste disposal methods are not always efficient and environmentally friendly. Incineration is one popular waste disposal method. However, from research it has been found that the emissions of CO_2 from incinerators are higher than those for coal, oil, or gas-propelled power plants. Incinerators produce 210 different types of toxic compounds, including mercury, fluorides, sulfuric acid, nitrous oxide, hydrogen chloride, and cadmium [4]. The world's population is increasing, depleting natural resources. Over recent decades, the retrieval of materials and energy from waste materials has received attention, with the aim of finding a sustainable solution to reduce the exploitation of natural resources and reduce landfill usage, [5]. Sustainability is a thriving field in this millennium [6]. The world is in needs to conserve its resources and determine innovative ways to recycle waste to ensure sustainability [7]. The concept of recycling waste has created a large sector for research. Researchers from various organizations have explored different types of waste materials with green material technologies to reduce environmental impacts and recycle waste in the construction industry [4,8–10]. Roads and highways are a critical sector for asset management worldwide. Most highways are flexible in type [11]. Australia has over 350,000 km of surfaced road, and produces over 10 million tons of asphalt concrete per annum [12,13]. Aggregates form up to 95% of asphalt concrete. Therefore, the introduction of alternative aggregates into the production of asphalt concrete and bitumen can help ease the pressure on the world's landfills and help create sustainable practices for upcoming major road projects around.

In this review paper section I contains the introduction, section II contains the bitumen details, section III contains the details about Waste plastic is a concern, section IV describe the related work, section V describe about basic material, section VI provide conclusion of this review paper.

2. Bitumen

Bitumen is a viscoelastic complex hydrocarbon that is black or brown. Although there are a few natural sources of bitumen available, bitumen is generally sourced from crude oil refineries [20]. Due to its waterproof and viscoelastic nature, bitumen is used as the binder for the construction of flexible pavement all over the world. Bitumen can be classified in three ways: through penetration grade, performance grade, or viscosity. Nowadays, bitumen classification based on viscosity grade is gaining popularity. The available types according to the Australian Standard (with a typical viscosity of bitumen of 60 _C) for the construction of flexible pavements. Around the world, researchers are working to improve the properties of these materials to ensure sustainability in the pavement construction sector [7,20,22]. The recycling of waste materials for use in asphalt is recognized as a very efficient method, as it improves the pavement quality, and, at the same time, helps to manage and recycle different waste products

[7]. Many researchers have investigated the use of different waste materials in bitumen. Plastic and polymer-based modifiers have been used extensively for a long time. Many industries have adopted plastic rubber and polymer-modified bitumen for the construction of roads [22–24]. In contrast, many researchers have investigated the use of regular household residues like waste cooking oil in bitumen. In some cases, they have recommended an optimum amount of waste cooking oil in bitumen of up to 5% (by weight) to ensure that any resultant compromise in the performance is minimized [22,25]. Intending to achieve better aging resistance, researchers have used palm oil fuel ash (POFA) to modify bitumen and found that POFA in bitumen can work as a rejuvenator for the binder [22,26,27]. Different types of fiber have been used in construction materials to alleviate the global waste management issue [28]. Several studies have found that fiber can improve the performance of bitumen [28–31]. Researchers have investigated the use of synthetic fibers like polymer fiber, steel fiber, and carbon fibers in asphalt concrete [28]. It has been found that carbon fiber can improve the electrical properties of asphalt but compromise the mechanical performance of asphalt concrete, while steel fiber improves the stability of asphalt [32,33]. Industry uses cellulose fiber to reduce binder drain-of during the transportation of the mix from the plant to the construction site [34,35]. As cigarette butt filters are made up of cellulose acetate-based fiber, they could represent a potential replacement for the natural cellulose fiber used in stone mastic asphalt. Recycling suitable waste in bitumen in a proper manner is a sustainable way to contribute to solving the worldwide waste management problem [36].

3. Waste plastic is a concern

Plastics are durable & non biodegradable cannot be decomposed the chemical bonds make plastic very durable & resistant to normal natural processes of degradation. Since 1950s, around 1 billion tons of plastic have been discarded, and that they may might persist for hundreds or even bunch of years. The plastic gets mixed with water, does not disintegrate, and takes the form of small pallets which causes the death of fishes and many other aquatic animals life as well as waster ecosystem. Today the availability of the plastic wastes is in huge amount, as the plastic materials have become the part of our daily life. Either they get mixed with the Municipal Solid Waste or thrown over a land area. If they are not recycled, their present disposal may be by land filling or it may be by incineration process. Both the processes have significant impacts on the environment. If they are incinerated, they polluted the air with very unwanted gases such as carbondioxide,nitrogendioxide etc, and if they are dumped into some place, they cause soil & water pollution. Under these circumstances, an alternate use for these plastic wastes is required.

4. RELATED WORK

4.1 Evolution of mix design concepts

- During 1900's, this technique, of using bitumen in pavements, was firstly used on rural roads in order to stop rapid removal of the fine particles such as dust, from Water Bound Macadam, which was caused because of fast growth of automobiles [Roberts et al. 2002]. At initial stages, heavy oils were used as dust palliative. An eye estimation process which is called pat test, was used to estimate the required quantities of the heavy oil, in the mix.
- The 1st formal technique of mix design was Habbard field method, which was actually developed on sand-bitumen mixture. Mixtures with larger sized aggregates particles could not be handled during this technique. This was one limitation of this procedure.
- Francis Hveem, 1942; who was a project engineer of California, Department of Highways enginering, has developed the Hveem stabilometer in 1927. He did not have any previous experience on judgement that, the required mix from its colour, hence he decided to measure various mixture parameters to find the optimum quantity of bitumen [Vallegra and Lovering 1985]. He had applied the surface area calculation concept, (which was already in use, at that time for the cement concrete mix design), to estimate the quantity of bitumen actually required.
- Bruce Marshall developed the Marshall testing machine just before the World War
- It was adopted in the US Army Corpes of Engineers in 1930's and subsequently modified in 1940's and 50's.

4.2 Polymer modification

- Bahia and Anderson, 1984; studied about the visco-elastic nature of binders and found that, the complex modulus & phase angles of the binders, need to be measured, at temperatures and loading rates with which different resemble climatic and loading conditions as well as past conditions.
- Shukla and Jain (1984) described that the effect of wax in bitumen can be decreased by adding EVA (Ethyl Vinyl Acetate), aromatic resin and SBS in the waxy bitumen. The addition of 4% EVA or 6% SBS or 8% resin in waxy bitumen effectively degraded the Susceptibility to high temperatures, bleeding at high temperature and brittleness at low temperature of the mixes.
- The findings of the studies conducted by the Shell Research and Technology Centre in Amsterdam indicated that the rutting rate is enormously reduced by the result of SBS modification of the binder. Button and Little (1998) on the basis of stress controlled fatigue testing at 20 and 0^0C, reported that SBS polymer exhibited superior fatigue properties as compared to straight AC-5 bitumen.
- Shuler et al. (1987) found that the tensile strength of SBS modified binder rised considerably as compared to unmodified asphalt mix at -21, 25^{and} ^{410}C.
- Collins et al. (1991) and Baker (1998) reported that SBS modified asphalt mixes have longer lives than unmodified asphalt mixes. The addition of SBS polymer to unmodified bitumen also increases its resistance to low temperature cracking.
- Denning and Carswell (1981) according that asphalt concrete using polyethylene modified binders were more resistant to permanent defor mation at elevated temperature.
- Palit et al. (2002) found improvement in stripping characteristics of the crumb rubber modified mix as compared to unmodified asphalt mix.
- Sibal et al. (2000) evaluated flexural fatigue lifetime of asphalt concrete modified by 3% crumb rubber as a part of aggregates.
- Goodrich (1998) according that fatigue life and creep properties of the polymer modified mixes

increased considerably as compared to unmodified asphalt mixes.
- The Indian Roads Congress Specifications Special Publication: fifty three (2002) indicate that the period of next renewal may be extended by 50% in case of surfacing with modified bitumen as comparing with unmodified bitumen.

4.3 Recent applications

- A 25 km plastic changed bituminous concrete road was set in Bangalore. This plastic road showed superior smoothness, uniform behaviour and fewer rutting as compared to a plastics-free road which was laid at same time, which began developing terrible “crocodile cracks” very soon after. The process has also been approved, in 2003 by the CRRI (Central Road Research Institute Delhi).
- Justo et al (2002), at the Centre for Transportation Engineering, at Bangalore University used processed plastic luggage bags as associate additive in asphalt concrete mixes. The properties of this modified bitumen were compared to that of ordinary bitumen. It was noted that penetration and ductility values, of modified bitumen was decreasing with the rise in proportion of the plastic additive, up to 12 % by weight.
- Mohammad T. Awwad et al (2007), polyethylene as synthetic resin collectively variety of polymers employed to research the potential prospects to boost asphalt mixture properties. The objectives also include determining the best type of polyethylene to be used and its proportion. Two types of polyethylene were added to coat the aggregate
- High Density Polyethylene (HDPE) and Low Density Polyethylene (LDPE). The results indicated that grinded HDPE polyethylene modifier provides better engineering properties. The recommended proportion of the modifier is 12% by the weight of bitumen content. It is found to extend the stability and soundness, reduce the density and slightly increase the air voids and the voids of mineral aggregate.
- Shankar et al (2009), crumb rubber modified bitumen (CRMB 55) was blended at specified temperatures. Marshall’s mix design was applied by ever changing the modified bitumen content at constant optimum rubber content and subsequently tests have been performed to determine the different mix design characteristics and for conventional bitumen (60/70) additionally. This has resulted in much improved characteristics when compared with straight run bitumen and that too at reduced optimum modified binder content (5.67%).

5. Basic materials

5.1 Aggregate

Aggregate constitutes the granular part in bituminous concrete mixtures which contributes up to 90-95 % of the mixture weight and contributes to most of the load bearing & strength characteristics of the mixture. Hence, standard of the quality and physical properties of the aggregates should be controlled to ensure a good pavement. The properties that aggregates should have to be utilized in pavement are shown below-

- Aggregates should have minimal plasticity for better output. The presence of clay fines in bituminous combines can result in problems like swelling and adhesion of bitumen to the rock which may cause stripping problems. Clay lumps and friable particles should be limited to utmost 1%.
- Durability or resistance to weathering should be measured by sulphate soundness testing.
- The ratio of dust to asphalt cement, by mass should be a maximum of 1.2 & a minimum of 0.6.It is suggested for better result AASHTO T-209 to be used for determinant the maximum specific gravity of bituminous concrete mixes.

5.2 Mineral Filler

Mineral filler consists of, very fine, inert mineral matter that is added to the hot mix asphalt, to increase the density and enhance strength of the mixture. These fillers should pass through 75μm(micron) IS Sieve.
The fillers may be cement or fly ash.

6 CONCLUSION

The revolution of advanced materials has brought a new dimension to the pavement industry. New methods and procedures have been introduced to ensure the sustainability and efficiency of the roads. Research work is ongoing to investigate the suitability of different types of waste for incorporation as road construction materials. Materials like polymer and plastic have shown increased Marshall stability and flow. In past research, plastic was incorporated in the binder and improved rutting and fatigue performance. Waste from quarries provides a way to replace conventional aggregates for medium traffic conditions. The use of building demolition waste in the base and sub-base layers of asphalt concrete reduced pollution and gave a second life to the materials. Tire rubber powder has been used in many research and improved high-temperature properties. Waste cooking oil along with palm oil fuel ash helped in replacing up to 5% of conventional bitumen binder for asphalt concrete. Fiber-based waste like coconut, sisal, and cellulose prevented drain-down of bitumen and improved resilient modulus. Asphalt binder modified with starch performed better than the binder modified with SBS. Waste glass, bricks, and ceramics have been used as alternative aggregates and exhibited better mechanical properties. Fly ash has been used as filler in asphalt concrete, and the result showed the potential of fly ash into cold mix asphalt mixture. The use of bitumen with encapsulated cigarette butts in asphalt concrete is a new method of managing waste, which will lead to sustainable waste management with improved asphalt concrete.

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