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Review on the Development of Plastic Road

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Abstract. Disposal of waste plastics is a serious global problem as they are not biodegradable and harmful to human health, and since these waste plastics are not scientifically treated, they cause ground and water pollution. If waste plastics are applied to road construction, it can not only solve the problem of disposal of waste plastics, but also improve the phenomenon of long construction period, frequent repairs and environmental pollution of traditional roads, and achieve the sustainable development. This article mentions two methods, one of which is to add waste plastic to bitumen, and this modified asphalt mixture and aggregate have better cohesion, stability, density and more water resistance, thus increasing the road the durability of the road increases the wear resistance and tear resistance of the road. Another method is to use waste plastics instead of bituminous mixes, with the introduction of newer industrially produced products to the market, the plastic road is making a circular infrastructure made from plastic waste a reality.

Keywords. Waste plastic, bitumen, plastic road, sustainable development

1. Introduction

The threat of plastic disposal will not be addressed unless practical steps are taken on the ground. Plastic is a non-biodegradable material, different kinds of plastic can degrade at different times, but the average time for a single-use plastic bottle to completely degrade is at least 450 years, and some bottles even take 1000 years to biodegrade [1]. From 1950 to 2015, about 8 percent of plastic was incinerated, while only 7 percent was recycled. Most of the plastic produced (about 55%) is discarded and accumulated in landfills or the natural environment, while the rest is still in use today [2]. China is a big importer of plastic waste, however, in 2017, China implemented a new policy to ban the import of most plastic waste, making plastic waste unmanageable [3-4]. Incineration is the most established way to reduce the amount of plastic waste, and it accepts mixed plastics. However, it produces carcinogens and releases environmental pollution [5]. Looking ahead to the way we live today, a complete ban on plastics is impossible. Therefore, converting plastics into useful products will be a long-term solution to the problem of plastic pollution [6]. Although the waste plastic plays the devil's role for present and future generations, we can't avoid use of plastic but we can reuse it.

The traditional road construction method is to pour a layer of bituminous on the basis of pouring concrete. The construction period is very long and this construction method damages the environment and causes pollution. The pollution to the atmosphere

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is mainly manifested in the fugitive dust pollution at the construction site, which increases the inhalable particulate matter in the air and reduces the air quality [7]; In addition, the bituminous material used in the road construction process will generate toxic gas after heating, and its volatilization will pollute the atmosphere. Research shows that from 2015 to 2019, the concentrations of PM10 and PM2.5 in the Beijing-Tianjin-Hebei region decreased by 30% to 33% [8], but near roads, their concentrations were 2 to 3 times higher than those in residential areas [9]. Urban road dust has been identified as the main source of urban atmospheric particulates [10]. Urban construction activities will produce a large amount of particulate matter and initially deposit on the road around the construction site, a small part of which is resuspended into the atmosphere due to human activities and natural factors, causing air pollution near the site, which endanger human health [11]. In addition, the durability and bearing capacity of traditional road surfaces are not good. After a long time or being continuously crushed by large trucks, the road surface will have more or less cracks or potholes. At this time, more money and manpower are required to repair, if things go on like this, it will only waste more manpower and time.

Traditionally, road construction uses materials such as soil, stone, sand, asphalt, cement, etc. Natural materials are depletable in nature and their quantities are gradually decreasing. In addition, the cost of extracting high-quality natural materials is also increasing. In view of this, the scientists are looking for alternative materials for road construction to achieve sustainable development and ecological benefits of road construction, and plastic wastes products are one of them. If these materials can be properly used in road construction, it will improve the sustainability of roads and partially reduce pollution and disposal problems. The classification of waste plastics used in roads is presented in Table 1.

Table 1. Classification of waste plastics used in roads.

Types of plastic used	Example
Modify	Dry process
	Wet process
	Combined process
Replace	-

2. Use of Waste Plastic in Construction of Bituminous Road

2.1. Modifying Bitumen with Waste Plastic

This section describes the use of waste plastics to improve pavement performance, provide low-cost roads and protect the environment.

Modification of asphalt and asphalt mixtures to improve the performance of asphalt concrete mixtures. At this stage, there are two processes for producing asphalt concrete. The wet process utilizes an existing modified bitumen mix, while the dry process involves adding waste plastic (in powder, chip or pellet form) to the aggregate and then adding bitumen during the mixing process in a hot mix plant [12]. The effect of this modification is determined by the type and percentage of the modifier. Overall, the resistance to rutting, heat, and fatigue cracking is improved, so the utilization of these wastes in the highway sector is an effective disposal method, reducing disposal costs and

reducing environmental pollution. As a result, the service life of the road is extended as the durability and resistance to deformation of conventional bitumen mixtures are improved [13, 14]. Vasudevan [15] pointed out that polymer-coated aggregate bitumen mixtures performed better on flexible pavements. It may be that intermolecular bonding between waste polymer-coated aggregates and bitumen improves the strength and quality of bituminous concrete mixtures [16]. Chavan [17] said that the mixed use of plastic waste helped reduce the amount of asphalt by about 10%, improve the strength and performance of the road, avoid the use of anti-stripping agents, avoid plastic waste incineration and landfilling and eventually develop an environmental technology. Dr. Vasudevan [18] stated that the polymer bitumen blend was a better binder compared to plain bitumen. Characterization of waste plastic were presented in Table 2. The blends have increased softening point and reduced penetration values with appropriate ductility. This means that when it is used in road construction, it can withstand higher temperatures and loads. A plastic coating can fill more pores and improve stability. Polymer-coated aggregate-asphalt mixtures are more suitable as materials for flexible pavements as the mixtures show higher Marshall stability values and suitable Marshall coefficients. At the same time, it responds to the national call for energy conservation and emission reduction to achieve sustainable development. Punith [18] pointed out that pavement waste plastics have adhesive properties and can be used as adhesives in road construction. Because the waste plastic softens at around 130°C, and it can be seen by thermogravimetric analysis that no gas escapes in the temperature range of 130-180°C. Al-Haydari et al. [19] reported the use of expanded polystyrene (EPS) to improve the performance of pavement mixtures. The mechanical and physical properties of asphalt pavement mixtures were evaluated for EPS at 1%, 2%, 3%, 4% and 5% by weight of asphalt. The results of this test show that increasing the EPS ratio leads to an increase in the tensile strength of the samples. Therefore, the results indicated that EPS would increase the mechanical properties of the pavement. Jasim et al. [20] studied the properties of asphalt mixtures after using plastic waste. In this study, plastic waste at 5%, 10%, 15%, 20% and 25% by weight of the asphalt was added to the asphalt mixture. The results showed that the addition of 15% by weight of plastic waste asphalt significantly improved Marshall stability and moisture resistance. Therefore, 15% plastic waste was added to the asphalt to improve the sufficient stability and moisture resistance of the asphalt. Sabina et al. [16] tested the properties of asphalt concrete mixtures containing plastics and polymers (PP). The deformation resistance of asphalt concrete modified with 5% LDPE (low density polyethylene) was improved compared to the conventional one. The prepared concrete mixture containing 8% by weight of bitumen plastic and 15% by weight of bitumen polymer had improved Marshall stability, indirect tensile strength and stability. Sarkar et al. [21] used brick aggregate and plastic modified asphalt to prepare asphalt concrete and study its properties. The results showed a 32% increase in stability and a 65% increase in tensile strength for the mixture with 8% plastic. The smallest peel values were observed for the mixes of 8% and 10% plastic modified bitumen. Ravishankar et al. [22] used processed plastics to modify asphalt concrete to meet the needs of different climatic conditions and heavy axle loads on pavement. Adding waste plastic to the mixture, the Marshall stability value increases with the percentage of waste plastic up to 6%, and the indirect tensile strength value increases by 38%. Parrick et al. [23] studied the properties of modified asphalt mixtures. The results showed that the indirect tensile strength was 20% higher than that of the conventional blend and the value of Marshall stability was increased by 27%. The research shows that the anti-rutting performance, anti-cracking performance and indirect tensile strength of asphalt concrete mixture are

significantly improved after adding polymer modified asphalt. Purnys et al. [24] Studies have shown that adding 5% PE to asphalt concrete can provide indirect tensile strength. The results show that the tensile strength of the modified mixture is increased to 95.9%, which indicates that the PE modified mixture is not easily damaged by moisture and therefore not easily damaged by atmospheric conditions. Tiwari et al. [25] studied the addition of plastics to asphalt concrete in a dry mix process. This study shows that the use of waste plastics in asphalt concrete has many advantages for road construction, such as being safe and sustainable. From the study it can be concluded that the addition of 8% LDPE and HDPE improves the Marshall property and stability values of the asphalt mixture, thereby increasing the toughness of the mixture. Roads can withstand higher loads and show longer life. According to Tiwari et al. [26] Plastic materials can be used as adhesive materials for road construction. Polyethylene is one of the most commonly used plastic materials and has proven to be one of the most effective additives in road construction. From the study of plastics as asphalt concrete additives using the wet mixing process, it can be concluded that the addition of plastics can effectively improve the Marshall performance of asphalt mixtures. The bituminous mixture after adding waste plastic increases the overall flow value and thus improves the processability. The addition of plastic waste results in less voids in the asphalt concrete, thereby reducing the seepage of the asphalt. The volume and Marshall properties of the mixture showed good trends and could meet the specified limits. Tiwari [27] used dry, wet and combined waste plastic mixing processes respectively during the experiment. The study found that the tensile strength ratio (TSR) of LDPE and HDPE-type waste plastics was increased by 8%, 6% and 12% in dry, wet and combined methods, respectively. Table 3 describes some of the work done by researchers in recent years and discusses the experimental procedures, results achieved, and important findings observed.

Table 2. Characterization of waste plastics.

% of plastic coating over aggregate	Compressive strength (MPa)	Bending strength (MPa)
10	250	325
20	270	335
30	290	350
40	320	390

2.2. Replacing Bitumen with Waste Plastics

This part presents a circular and modular road made all from recycled plastic.

According to a new study published by McKinsey (2021), in the next few years, the traditional road construction industry will gradually develop into four key trends through self-driving cars, automated production, digitalization and the adoption of new road construction materials. Automated, digitized industries utilizing new materials. As a result, future roads will not only look different, but they will also be faster and easier to produce and build. For example, the use of new materials, recycled plastics, has made the Road to Plastics a sensation in the field of traditional infrastructure development. With the market launch of newer industrially produced products, the company is making a circular infrastructure made from plastic waste a reality.

Table 3. Overview of work done in the area of modified plastics in road construction in recent years.

S. no.	Experimental conditions	Remarks	Reference
1	1%, 2%, 3%, 4% and 5% of Expanded Polystyrene (EPS) by the weight of bitumen were experimented	increasing the EPS ratio leads to an increase in the tensile strength of the asphalt mixture	[19]
2	using plastic waste from different bottles, adding 5%, 10%, 15%, 20% and 25% of the asphalt weight	addition of 15% bitumen weight plastic waste improves Marshall stability and water damage resistance	[20]
3	low density polythene at 5%	improved resistance to deformation	[16]
4	1%,3%,6%,8% and 10% waste plastic by the weight of bituminous added to hot bitumen	The blend with 8% plastic showed a 32% increase in stability and a 65% increase in tensile strength.	[21]
5	the waste plastic was added at 3%, 6%, 10%, and 14% by weight of bitumen to the mix	after adding 6% plastic waste, the indirect tensile strength value increased by 38%.	[22]
6	polymer modified bitumen mix	Marshall Stability (increase by 27%), indirect tensile strength (increase by 20%)	[23]
7	5% PE added to asphalt	the tensile strength ratio of the modified mixture is increased by 95.9 %	[24]
8	the addition of plastic waste in bituminous concrete using dry process. The waste plastic LDPE, PVC and HDPE was added varying from 0%, 2%, 4%, 6%, 8%, 10% and 12% by the weight of bitumen	Marshall characteristics have been improved. 8% of the LDPE and HDPE plastic waste improves the stability value of the bituminous mix	[25]
9	wet process of mixing	Marshall characteristics have been improved. The addition of LDPE and HDPE increases the stability value of the asphalt mixture	[26]
10	dry process wet process combined process	The optimum plastic indirect tensile strength values for the dry, wet and combined methods were 8%, 6% and 12%, respectively. Tensile strength ratio (TSR) values increased by 8%, 6%, and 12% for the three methods with the addition of LDPE and HDPE, respectively.	[27]

The team behind the Plastic Road have been working towards the target- the world's most sustainable road. The company's products include a variety of circular and modular elements made from recycled plastic. Rainwater is directed to the overflow via diversion, from where it drains into the underground element. During heavy rains, these spaces in the substructure can efficiently store excess water. This water then gradually penetrates into the soil, thereby promoting water recycling in the surrounding area. The porous geotextile allows water to flow through to the base layer, while the retaining profile prevents the plastic road from floating to the ground. The connectors of the components of the plastic circuit are very important. Not only do they have the function of connecting different elements, but they also have a certain elasticity that allows them to adapt to expansion and contraction. In addition, they should also satisfy the convenience of changing elements. To reduce components to the original, components can be removed without actually damaging the connector. This means that elements can be fully recycled at the end of their service life. These products have a lightweight deck that provides the required grip for the car and other users. The wear layer consists of a thin layer of aggregate, similar to the surface of a bridge. It is available in a variety of colors and themes. The wear layer of this surface is sufficiently solid to shield the underlying plastic from direct contact with road traffic. Therefore, it is not subject to wear and tear. In addition, the plastic elements are protected from sunlight and therefore do not degrade due to UV exposure. This helps extend the life of the product.

The first plastic road in the world has been applied in the Dutch city Zwolle since 2018 as shown in Figure 1, and it has withstood all the conditions and overloads it has faced since its installation. In addition, plastic highways achieve at least 52% lower carbon emissions compared to conventional driveways. This product is dedicated to reducing plastic waste to protect the environment. The amount of plastic in the 30-meter-long lane is equivalent to 218,000 plastic cups or 500,000 plastic bottle caps.

Figure 1. The first plastic road in the world.

The products were also pilot in Mexico as shown in Figure 2, The plastic road in Mexico City has the function of temporary water storage and drainage. It is ideal for facilitating water storage during rain and flood conditions and has sensors installed for monitoring and surface management. The impact of dry periods in the region is also reduced by the gradual infiltration of rainwater into the ground. In addition, the advantages of durability and low maintenance compared to traditional road structures mean up to 72% less carbon emissions over its lifetime.

Its advantages can be summarized as follows:

- With its excellent storage and drainage capabilities, this product eliminates or reduces the need for auxiliary works such as earthworks, storm drains, storm drains and house connections.
- Minimize the use of raw materials and increase the strength of materials to reduce raw material and transportation costs.
- Based on circular principles, elements are made from waste plastics.
- Circular and detachable elements can be easily reused in new locations or in completely different applications.

- Easy maintenance. These elements are interchangeable due to unified dimensions.
- All components are recyclable at the end of their useful life.
- Each part of the series is removable. Individual elements can be easily replaced.
- Long lasting-50 years.
- Sustainable cities. Installation of lightweight, wear-resistant elements requires far less heavy machinery and transportation than conventional road construction.
- Address climate change. It directly contributes to meeting the Paris climate goals: reducing CO_2 emissions by up to 72%.

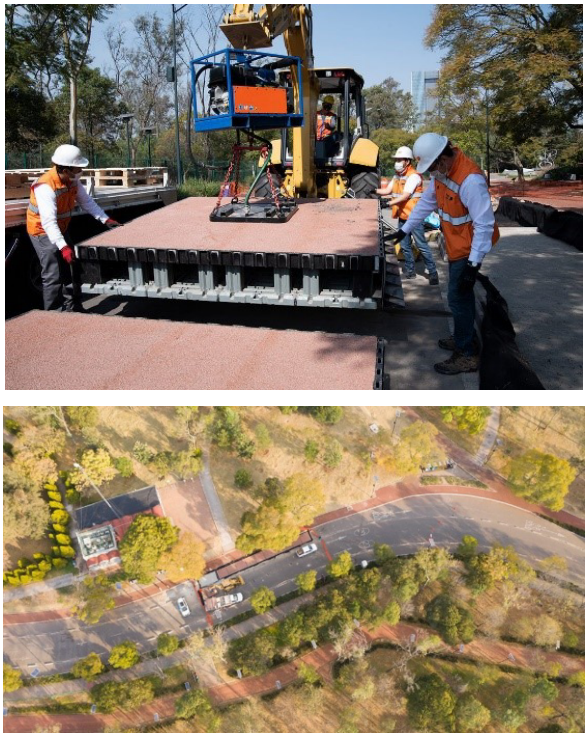

Figure 2. Polit in Mexico.

3. Conclusions

Scientists and engineers are always looking for different ways to improve the performance of asphalt pavements. Numerous studies have demonstrated the applicability of plastic waste modifiers in asphalt mix construction. This paper studies the use of waste plastics to modify or replace asphalt, and the results show that the use of waste plastics to modify bitumen can improve the performance of bitumen. The team of the Plastic Road developed a circular and modular road made from recycled plastic, which is more recyclable and lighter. Making full use of waste plastics in road construction can improve ecological and economic benefits, promote the ecological and

green development of road construction technology, and promote the concept of sustainable development.

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