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Illinois Asphalt pavement Association (IAPA)

Research paper

## **Recycled Material (Plastic)**

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## Introduction

Plastic has an important position in our life. We should consider the waste plastic in our environment. Every single minute approximately one truck of waste plastic adds to the ocean and there are lots of approved companies that break the waste plastic to smaller and smaller parts. Based on the reports and researches so far in the range, 5 to 50 trillion are in the oceans today in 2019 which could affect weather, oceans, and beaches. Most of waste plastic has been landfilled into the environment and remains there in some form [1].

Their versatility allows them to be used in everything like parts of vehicles, Televisions, mobiles, soft drink bottles that can be stored in refrigerators and lots of other things that we are using them daily in our life. How have those plastics become used? And how did plastic become a material of choice for us? There are many ways for production and recycling that have been completed in the world which had a sufficient result to make our life easier and better. Plastic Recycling is a very important concern in the world. Recycling plastics reduces the amount of energy and natural resources (like water, petroleum, and natural) needed to make new plastic. Based on American Plastics Council, the production of plastics account for 4 percent of U.S. energy consumption, and 70 percent of plastics on the United States are made from domestic natural gas [2]. Plastic drink bottles, plastic bags, and other waste plastic or pollution plastic have a considerable impact on the environment. In a result, there is a universal concern in recycling and reuse of plastic (waste plastic). Considerable steps have been completed towards the incorporation of recycled plastics into building and construction materials (This just has focused on cement and concrete) [3].

The fecundity and efficiency of a road design belong to the performance of the pavement. Most of the pavements material like aggregate are based on high quality for highways, airports, etc. As mentioned, environmental is a big concern of the world, and to reduce the environmental impact of pavement design, the increasing of pavement materials is desired. Based on test results and projects that had been completed in pavement design, the most useful and effective pavement is the use of waste materials. For instance, Reclaimed, Recycled, and waste products. Remarkably the quality of waste materials that can be used in pavement layers is different which needs to check the factor number before selecting the type of plastic materials in pavement design.

## Recycled Plastic Material

For the propose of how to recycle the plastic material in the best way it is important and necessary to understand the material of plastic and how it is likely to treat. As we know plastics are made of polymers (materials made of long, repeating chains of molecules) and additives. The percentage of a polymer contained within a plastic material can vary virtually 100% to less than 20% and depends on the application for which it is included.

Polymer-based materials are available in the United State of America alone over 18000 different measures. As we went over about the recycling of plastic these plastic materials can be subdivided into two main stages: thermoplastics and thermosets. This is a basic structure that could have a good result to understand which way of recycling can be applied. A virgin material means a plastic in first use. Common thermoplastics and their way to use are explained in Table (1). When warmed they liquate and when cooled they stiffen. This steps of warming and cooling could be applied for several times and the result is to repossess a thermoplastic material it is important and necessary to liquid the materials. HDPE (High-Density Polyethylene), LDPE (Low-Density Polyethylene), PP, and PS (Polystyrene) are used in an extensive amount to provide different items like bags, fast food packaging, lids, and carrier. PET (Polyethylene Terephthalate) is used for fizzy bottle drinks. PVC (Polyvinyl Chloride) material is used to make shoes, bottles, and flooring. First thermosets processed by liquating in a similar manner to thermoplastics cannot be liquidated again and will break down rather than melt. The reason is they are chemically connected to each other during the curing process. For instance, electrical insulation and adhesives are good examples of thermosets. Since thermosets cannot be recycled by melting them again, they are difficult to reprocess. However, they look after to have a long life something more than 10 years.

It was mentioned before the plastics are made of polymer (materials made of long, repeating chains of molecules) and additives. I would like to have a brief explanation of additives and their responsibility of recycling the plastics before we start our next part. There are multi additives available for plastic which eight of them have mentioned in Table (2). They are also could be possible to add with a range of percentages. As an example, glass fibre could be estimated from 5% – 80 % producing plastic with different uses. See Table (2) for eight additives. [4],[5].

## Plastic Road Material

Plastic roads are mostly made of plastic. As mentioned in this research most of them are made of recycled waste plastic like bottles, straws, and some other materials like rubber that taken from bike tires. There are a lot of ways for recycling the plastic. Landfilling on lands and in the ocean is a rise of excess overflowing. For this kind of issues, plastic roads have resolved the problem and answered to these new problems [6].

The goal to build the road by recycled plastic is to reduce the amount of waste plastic through reclamation and reuse, was a great idea to a selling point for the kickoff that is now known as the plastic road. By comparing the modern asphalt or modern concrete road to this alternative, it resulted that the old method is harmful to the environment which is the world concern is about environmental. Plastic roads are 100 percent recyclable and have a better resistance compared to asphalt roads. Since a big segment of a road built it with plastic, and unable of absorbing water, it has the capability to stay against water weathering which decreases the cost of the project during maintenance. Based on experience and projects that have been completed so far most of the roads that made with plastic are flexible and able to keep a perfect surface for a long period of time.

These kind of roads are very popular and known and as mention, these roads are made of plastic and bitumen. These materials originated elsewhere and were originally created to serve a different goal. Water bottles are made of PET (Polyethylene terephthalate) which terephthalate created from petroleum hydrocarbons and it could be found in crude oil. Crude oil can be found in dug up beneath our feet. Water bottles are made from petroleum hydrocarbons and for more explanations in detail please see table (1) and table (2) [6].

Roads made of recycled plastic are not the only roads that the world needs to follow it and there are lots of materials that could have great resistance for roads. Many roads currently being used just as a test to see what will be the result and to work more on good and bad problems to improve them in the future. The concept design of recycled plastic road design will be a big step in decreasing but not removing completely the waste plastic [6].

## Tables

**Table 1. Common thermoplastics and their use in packaging**

Polymer	Application	Products
Low-density polyethylene (LDPE)	Film, coatings	Carrier bags, bin bags
High-density polyethylene (HDPE)	Film, bottles	Milk and fruit juice bottles, washing up liquid bottles, fabric conditioners. (Bottles are <i>not</i> transparent as per PET)
Polyethylene terephthalate (PET)	Bottles	Transparent drink bottles <i>e.g.</i> cooking oil, cordials, carbonated drinks
Polyvinyl chloride (PVC)	Film, containers	Chemical bottles (weedkiller, car polish sprays)
Polystyrene (PS)	Containers	Clear when unfoamed for food containers, also often foamed (fast food packaging)

**Table 2. Common additives for plastics**

Additive	Purpose
Calcium carbonate	Filler: generally used for cost reduction as much cheaper than polymer
Pigments	Give the plastic a colour. Generally for aesthetic properties
Glass fibre	Increased strength and stiffness
Flame retardants	Increase fire resistance
Heat stabilisers	Increased resistance to heat exposure
Light stabilisers	Increased resistance to light exposure
Plasticisers	Process aid which reduces viscosity
Foaming agents	Lightness and stiffness

## Thermoplastics Melt Operation

LDPE, HDPE, PET, PVC, and PS are thermoplastics, and in this section, we only want to give a piece of brief information about thermoplastics melt or liquid steps. These steps are defined in three parts: Melting, Forming, and Solidifying. Extrusion, Injection molding blow, and film blowing are used in different types of products. Extrusion responsibility is to put polymer and additives together and mix them. It is useful for the improvement of the product and helps to shape them. As an example, the sheet of plastic and profiles of the window could be a good instance. Injection molding could create more complex. Buckets, automotive door handles, mobile phone cases, and TV housing could be a good example of Injection molding. Blow molding is used to produce hollow articles such as bottles. Film blowing is used to produce thin films for wrapping or carrier bags. This is a brief explanation of the thermoplastics melt operation [7][8].

## Separation of Recycled Plastic

As mentioned in a plastic material that both thermoplastic and thermosets cannot be sorted and recycled together. PP, PET, PVC also need to be sorted separately from each other before they recycled. Just for instance if we would like to mix both thermoplastic and thermosets together and recycled them, the result will not be a good result if we compare it with separate recycling. It is all because of the chemical combination of plastics or polymers. The difference does not allow them to have a good result. See Fig.1. for the result of recycled plastic materials [7][8].



Figure 1. The color change in HDPE can be clearly seen after 10 process cycles. Virgin material (top left), material injection molded, and re-granulated 10 times (bottom left).

## Recycled Plastic Roads

A European team has worked on the recycled-plastic road that moves forward in Australia and Europe. The European team said that this project is ready to be launched on the market after over one and a half years of working and testing and continued development into a design for industrial projects. The plastic road is now ready and available for design with first deliveries being completed at the beginning of 2021. The plastic road design will start in 2021 and the European team said that the plastic road has proven that they are enough strong to design for a load of heavyweights like trucks and offers a great solution to water management with heavy precipitation [13].

## Waste Plastic Effectiveness of Asphalt Mixture

The matter is to reduce the waste plastics by using them in something useful and effective. Like plastics used in PET bottles, disposal glasses, handbags, and the cover of various appliances at 160, More information about HDPE, PE, LDPE, PVC, LLDPE, etc. have explained in plastic material section[4],[5],[8].

As mentioned at the beginning that plastic in today's life is a concern for all of us because it could make a lot of problem cases if we don't treat it and there are lots of solutions to use the recycled plastic in a different correct way. One of them is an asphalt mixture that could be containing recycled plastic by weight of bitumen. Based on tests that have been completed and published since 2012, show that the asphalt mixture with 4% plastic will have the highest solidity. However, the solidity could decrease with the increase of plastic additive.

The properties of bitumen by adding the polymers like rubber has resistance to temperature and water. Recycled waste plastics in the bituminous mix and using in the surface and base mix design could be able to improve the performance of the road which the result is a stable road. Using the waste plastic like polyethylene terephthalate in asphalt mixture could replace the mineral aggregate of an equal size (2.36 – 4.75mm) and changed it to a maximum amount of 6.6%. “This method led also to a reduction of bulk compacted mix density.” [9].

## Pictures



Figure 2.

Source: <https://www.bbc.com/news/uk-scotland-south-scotland-47454719>



Figure 2(a).

Source: <http://www.earthdecks.net/plastic-roads/>

## Waste Plastic Effectiveness of Asphalt Mixture (Continue)

Designing asphalt with polymers is one of the best designs that could help to have a safe road, high-quality road with less cost compared with materials that used before [8]. A test has reported that using recycled waste plastic in pavement asphalt could have a valuable result in materials. Using modified bitumen with the recycled waste plastic about five percent – ten percent by weight of bitumen could be effective in life strength, concrete mix. Waste plastic usage in the manufacture of roads material and laminated roofing also helps to use a large quantity of waste recycled plastic [9]. It has been reported that the world generates a million plastic bottles every minute. Less than half of those collected for recycling and less than seven percent updated back to useable bottles. Oceans will have more mass of plastic than fish in 2050 [10]. In most countries, the plastic bags are a notable contributor to overall waste plastic with over numbers of plastic bags using in the environment each year [11]. One of the recycled plastic ways, as mentioned is to use the waste plastic in asphalt mixture. I would like to explain in detail in this section about what kind of product, using as a binder replacement, use of intending, and some pictures of them that had been tested in the laboratory. The high temperature that could liquid the waste plastic and resistance to UV (Ultraviolet) radiation effectively expand waste plastic while reducing the quantity of new bitumen required for asphalt production. There are also waste plastic-based modifiers of a binder for the material of asphalt with enhanced performance detail. See Table (3) explains waste plastic-based asphalt modifier [12]. Performance evaluation of MR6, MR8, and MR10, White and Reid accomplished in a laboratory test. For all samples, the optimum percentage that used is 6 percentage. Based on results the rut depth decreases significantly due to the incorporation of waste plastic as shown in Figure 3. In figure 3 shows MR6 changed samples had a minimum rut depth. MR10 and MR8 explained lower rut depth, respectively. There are a couple of reasons and one of them that had a good result is the incorporation of waste plastic can help the asphalt binder which could be very helpful to increase the structural capacity of the mixture. Besides, figure 4 explains that the fracture toughness of samples that include MR was 22 percent higher than the control mix, showing higher fracture toughness. The result is MR6 changed asphalt crack as well as deformation resistance with conventional polymer for bituminous [12]. In figure (3) the effect of MR6, MR8, and MR10 on the efficiency of the mixture, plotted based on data that had completed by White and Reid [13].

## Tables and Diagrams

**Table 3** Engineering properties and physical states of waste plastic-based asphalt modifier.

Product Name	Binder Replacement	Intended Use	Physical Appearance
MR6	6–10%, with 6% recommended as optimal	Performance enhancement with a focus on deformation resistance	
MR8	6–10%, with 6% recommended as optimal	Cost reduction with similar or better performance	
MR10	6–10%, with 6% recommended as optimal	Performance enhancement with a focus on fracture resistance	

Table (3)

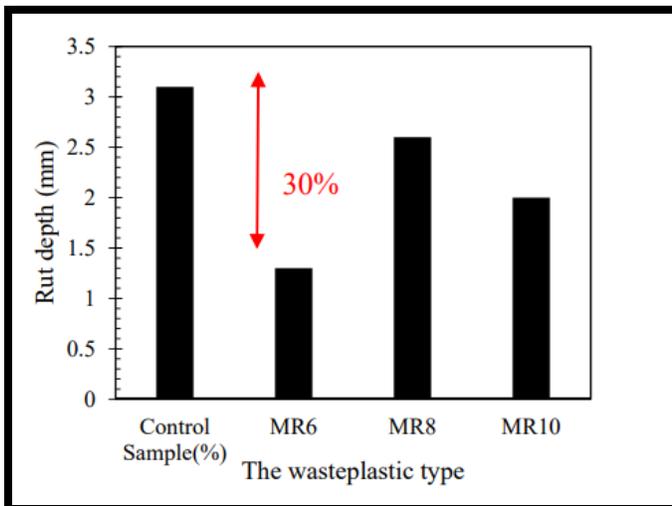


Figure (3)

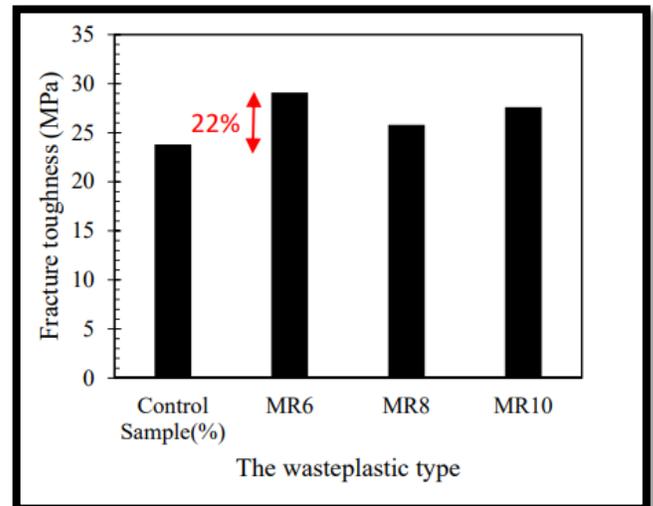


Figure (4)

## Conclusion

Plastic recycling is very important in our lives and we should be responsible for every plastic that we use them daily because it could affect the environment. Lots of vehicle's part, mobiles, bottles of water, etc. are made of plastic that we use them daily and that's why they are important to be recycled once we used them. Plastic recycling could decrease water, Petroleum, and natural in our life. Plastic like bottles, bags, and other pollution plastic have a bad effect on the environment.

Recycled plastic materials have different materials but as I mentioned the two main stages of them, thermoplastic and thermoset. Common thermoplastic is LDPE (Low-Density Polyethylene) like Bin and carrier bags, HDPE (High -Density Polyethylene) like Mike bottles and washing up liquid bottles, PET (Polyethylene terephthalate) like Cooking oil and carbonated drinks, PVC (Polyvinyl chloride) like chemical bottles, PS (Polystyrene) like fast food packing. Common thermoset plastic is synthetic materials that strengthen when heated. This means that this will not liquid or melts even when exposed to extremely high temperatures. Electrical insulation and adhesives are good examples of thermosets.

Based on test results and projects that have been done in the road and pavement design, using waste materials like reclaimed, recycled, and waste products especially the quality that waste materials have can help the resistant of pavement layers.

Using the plastic for the asphalt mixture is another way to recycle them correctly. In the asphalt mixture, it could be including plastic by weight of bitumen. Based on a test asphalt mixture with 4 percent of plastic will make high quality. By adding the polymers (Rubber) that could help the pavement to be resistant to temperature and water. Improving the performances of the asphalt mixture using the bitumen and plastic on the surface will make the road or the pavement stable. This kind of design is still under process, but it can be an effective solution to reduce the impact that waste plastic has on the environment.

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