REPORT ON THE UTILIZATION OF WASTE PLASTIC MATERIALS IN ASPHALT PAVEMENTS

by

Venkat Ramana Reddy Vootukuri

B. Tech, Gokaraju Rangaraju Institute of Engineering and Technology, 2016
MSCE, Southern Illinois University Carbondale, 2018

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TITLE: REPORT ON THE UTILIZATION OF WASTE PLASTIC MATERIALS IN ASPHALT PAVEMENTS

This paper is the study of some of the waste plastic materials which could be reused by some processing methods and it can be mixed with the asphalt while construction of road. These waste plastics are used as the partial replacement of aggregate in asphalt mix product. Plastic is a toxic and persistent material, the quantity of plastic it is getting increased day by day due the population, urbanization, development activities and frequent changes in the life style which is leading to increase the junk on the land. For example, the usage of water bottles, containers, plastic carry bags and packing strips etc. is increasing day by day as a result the amount of plastic is getting increased. Even though was have been recycling the plastic but 20% of the plastic is not getting recycled and due to their non-biodegradability, it is hazardous to human's health and has negative impact on the environment; consequently, rivers, gutters and roadsides are choked and filled with waste plastics. There are so many researches going on in the institutes and some of them have come to conclusion that waste plastic can be used in the construction of roads using asphalt. There are two main procedures in which we can mix plastic with asphalt they are Dry process and another one is Wet process. To prepare a plastic modified asphalt concrete mix, dry process involves direct incorporation of waste plastic, which is blended with aggregate before adding it with the bitumen and in the Wet

Process involves the simultaneous blending of bitumen and waste plastic. If we use the waste plastics in the construction of the asphalt road, we can reduce the cost of the road construction and the pollution index of the environment to an appreciable extent. This plastic can be used as a binder along with the bitumen. It may also result in better finish ability, stability, resistant to water, durability and binding property.

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Last but not the least, I am sincerely grateful to all my family members, mother (Anitha Reddy), father (Karunakar Reddy), sister (Vyshnavi Reddy), grandparents and friends for their unconditional love, eternal encouragement and their support throughout writing this report and my life in general. I would not have been able to complete this research report without their continuous support and encouragement.

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1) Introduction

Plastics are the materials which consists of a variety range of synthetic or semi-synthetic organic compounds with a high molecular weight, it is a solid in its finished state or it can be shaped by its flow when it is manufactured or processed in to its finished state. The production rate of plastic is getting increased day by day in all parts of the world since past few decades. Due to the tremendous growth in population, consumerism, industrialization and technological development there has been a rapid increase in the rate of the production.

Figure 1: Disposal of Plastic

In each and every day, a large number of items that are either partly or completely made of plastic are used and these plastics eventually end up in the landfills. It has been mentioned in the research done by Rajput, P. S., et al (2016) to break down the plastic which is present in the places where garbage and trash are dumped, it may take time either from a few days to several years depending on the quality of

the plastic, but it will never break down completely into particles that can be used in nature.

On the other hand nation progress is directly dependent on infrastructure, especially in the field of transportation. The amount of road traffic is raising day by day and the demands a similar small step forward in the increment of the load bearing capacities of the roads and its life span. In the research done by Appiah, et al. (2017) it been proven that the performance of the asphalt mixes used in the surfacing course of the road pavements can be improved with the help of different types of modifiers or additives to the asphalt such as crumb rubber, polymers, rubber latex, etc. For the particular project modifier can be chosen depending on many factors which includes expected performance, cost, availability, construction and ability. In the paper done by Dhundalwar, et al. (2017) said the best way for the modification of bitumen is accomplished by two main procedures; Dry Process which involves direct incorporation of plastic waste, which is then blended with aggregate before adding it in bitumen to prepare a plastic modified bituminous concrete mix. The second procedure is the wet process which involves simultaneous mixing of bitumen and plastic waste. The plastic modified bitumen show better properties for the construction of road and plastic waste can be used in this process and it may slightly reduce the pollution. There is not much pollution in the United States because here we have recycling plants for waste plastic which can be recycled, and it doesn't affect the environment too. Polymer modified bitumen is one of the newly trending construction materials for flexible pavements.

This idea of using waste plastic in the construction of the roads is gaining importance because of several reasons. One of them is the plastic Modified bitumen has shown some better propertied than normal asphalt for road construction. We have also got proven from various studies and also Aslam A, et al. (2009) that were carried out the quality of bitumen used asphalt road construction and another use of Polymer modified bitumen is this method would decrease the effect of water on the asphalt pavement. The main use of polymer modified bitumen to accomplish a better asphalt pavement performance which hasn't been observed for a long time. The scope of this research study is to utilize the waste plastic and to find its utility in Asphalt mixes for road construction. Some laboratory performances were conducted on asphalt mixes and it was proven that the properties of the asphalt mix were improved. The objective of this study is to utilize the plastic waste in the constructive way so that it would be beneficial to the society and to the ecosystem.

Materials Required

2.1 Bitumen: It is a black brown viscous material which is composed of hydrocarbons which has high molecular weight, it is the residue leftover from natural or refinery process of petroleum and also having adhesive properties. It is a kind of strong cement which is readily adhesive with high water proof. The overall aim of this research report is to show the feasibility of modified bituminous mixtures by adding plastic waste as a partial replacement of bitumen in any asphalt mix so as to get rid of potholes on the roads. It is shown by Jafar, (2016) it is essential to choose the right bituminous mixture that would display clearly about the benefits of the modification. Bituminous mixture is divided in to two categories: a) Hot rolled asphalt and b) Bituminous Macadam.

Figure 2: Rutting of Asphalt roads

Hot roll asphalt mixes rely completely on the bitumen and the filler content of the mixture for their strength. The material relies heavily on the smart ability of the sand/bitumen fraction. The mechanical properties are strongly influenced by the bitumen under extreme conditions, like the wearing course of hot roll asphalt may be rut. Bitumen is responsible for the viscoelastic behavior of the

Hot roll asphalt and plays a most common role in deciding the resistance of hot roll asphalt to rutting.

2.2 Plastic Waste: The plastic is the general common term used for the wide range of synthetic or semi synthetic organic solid materials derived from oil and natural gas. In the research done by Appiah, et al. (2017) he mentioned that in a marvel of polymer chemistry, plastics have become an extremely important part of our daily life, and we now made it as one of the essential need of the daily life. The development of plastics has come from the use of natural plastic materials such as chewing gum and shellac to the use of chemically changed natural materials, like rubber, nitrocellulose, gilalite which are strong, flexible, fiber-like protein and finally to completely produced by people but not by naturally-occurring molecules, e.g., Bakelite, epoxy, polyvinylchloride and polyethylene. So, the plastic which could be used as waste plastic bottles, wrappers, bags.

3) Methods

There are two different methods to incorporate plastic waste in to asphalt mixes namely Dry Process and Wet Process.

3.1 Dry Process: In this process the plastic is softened but not burning it completely because it will be used a coating material. In the paper written by Mir, A. H. (2015) it is proven that when the aggregate is coated with plastic the quality of the aggregates is increased and also it increased the quality with respect to voids, and the soundness and moisture absorption decreases porosity which in result gives the best performance of the pavement. The appropriate quantity of the dry shredded waste plastic is mixed with the hot aggregate prior to the production of the asphalt mixes at hot mix plant by changing the percentage of the plastic by weight of the mix.

Step1: Various types of plastic waste is collected and analyzed as per their type and then are sent to the specific storage.

Step2: The separated plastic wastes are further cleaned and dried to remove all the kind of impurities from the waste plastic. Then, they are cut into a size of 1.18-4.36 mm by using shredding machine, (Mostly PVC waste should be eliminated).

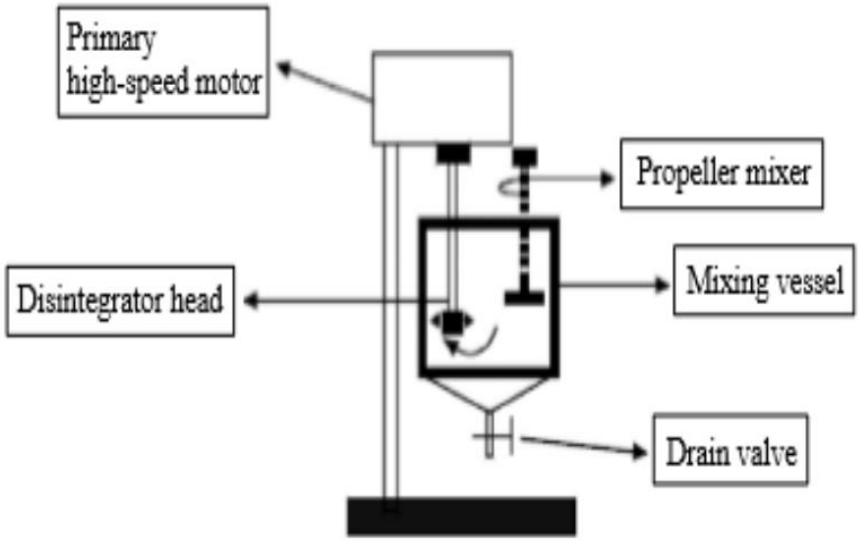

Figure 3: Polymer-bitumen mixing assembly

Step3: The aggregate mix is heated at 165^0C (as per the specification) and then we need to transfer it to the mixing chamber. Similarly, the bitumen should be heated up to a maximum temperature of 160^0C (as per the Specification) so as to have good binding and also to prevent from weak bonding.

Step4: After transferring the mix to the mixing chamber, the shredded waste plastic is to be added over the hot aggregate. Then the plastic gets coated uniformly over the aggregate within 30 to 45 secs, which will give a look of oily coating to the aggregate.

Step5: The aggregate which is coated with plastic waste is further mixed with hot bitumen which is at the temperature range of 150^0C-165^0C. The resulted mix will be at a temperature range of 130^0C-140^0C which is usually used for construction of the road. The road laying temperature is between 110^0C-120^0C.

Advantages of Dry Process:

1. This reduces the need of bitumen content by 10%.
2. In this process it is possible to utilize more than 15% of the plastic waste.
3. There won't be any degradation of roads even after years of construction.
4. Since the aggregates are coated by plastic waste, thus the surface property of aggregates will be improved.
5. Strength of the aggregates gets increased and the binding property has doubled.
6. This process avoids the use of the anti-stripping agents
7. This process avoids the disposal the waste plastic by incineration and landfill
8. It adds the value to the plastic and helps in developing a technology which is eco-friendly.

3.2 Wet Process: Waste Plastic is ground and made it in to powder 6 to 8%. The Ground plastic is added to hot bitumen which is at 180^0C. This process do not yield a homogenous mix with prominent segregated solid deposits of asphalt mix therefore the wet process was not adopted and some other waste material (crumb rubber) has been adopted to add to it. In the other way it is defined as the blending of the shredded waste plastic and bitumen prior to the production of the modified bituminous mixes. In the Figure 4 it shows the flow chart for the wet process of bitumen modification, the chemical processes which produce binders are

considered as a swelling of the plastic particles by absorbing some of the more volatile compounds from bitumen which is followed by the degradation of the waste plastic from polymerization and devulcanizing. In reference to the paper written by Dhundalwar, et al. (2017) these are the following factors which effect the rate of the reaction:

1. The time period for which the blend is kept at the reaction temperature. (longer the wait time greater the reaction)
2. The size of the particles (smaller the size of the particles, they swell quicker but lesser)
3. Temperature of the binder (higher the temperature of the binder quicker the reactions will occur)
4. The surface characteristics of the plastic which is going to be used (rougher the surface of the plastic quicker the reaction occurs)

In the Wet Process the important and main thing in bitumen modification is blending of the bitumen and polymers. It also requires a proper technique for blending to ensure a required quality of the blend, which could be accomplished by using the blending assembly as shown in the below Figure

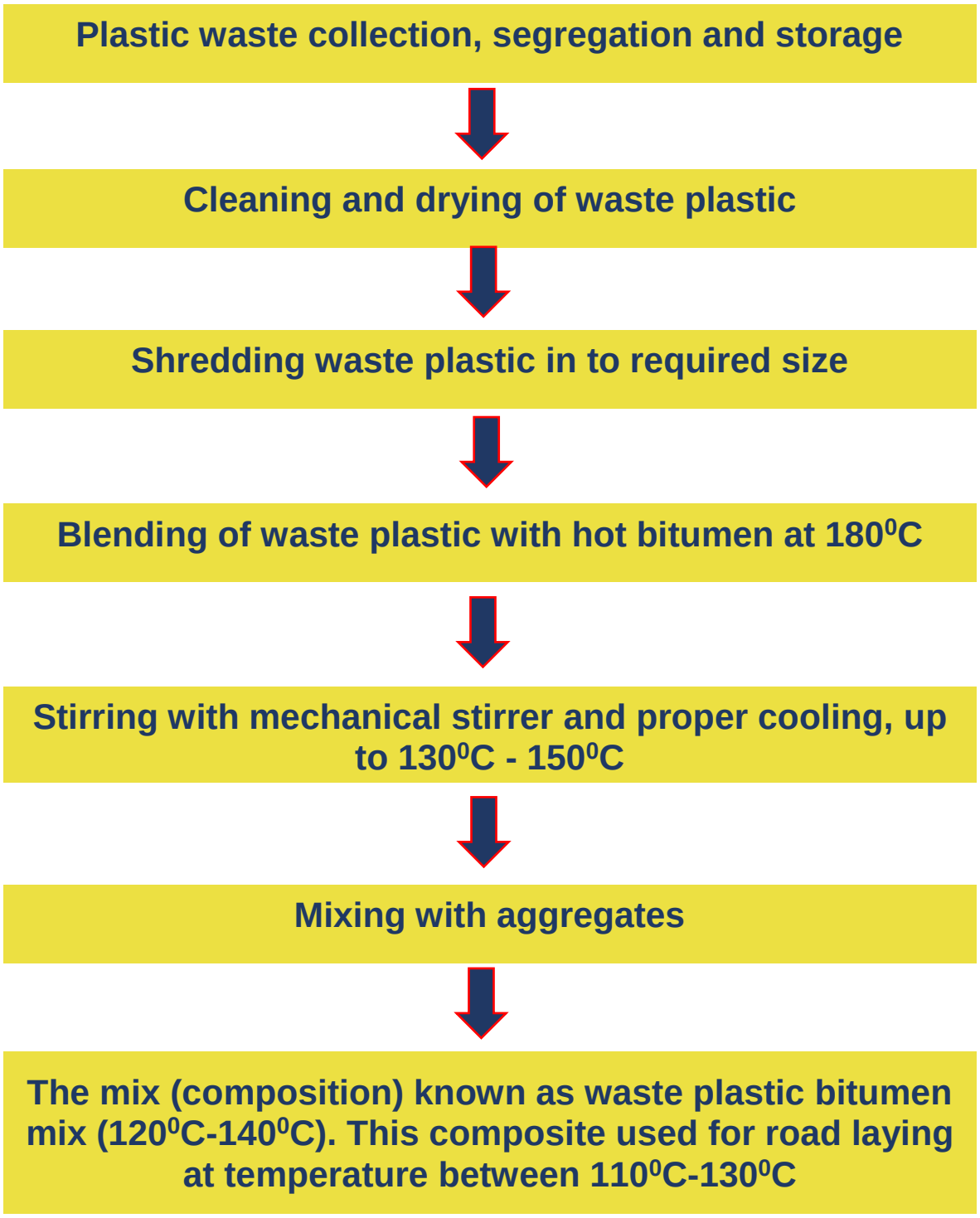

Figure4: Schematic flow diagram wet processes in reference to Dhundalwar, et al. (2017)

4) Procedure for Mixing and Construction of Plastic Road

This procedure is from the research done by Mir, A. H. (2015) and Dhundalwar, et al. (2017)

Step 1: Waste Plastics (i.e. bottles, cups, bags) made from Polypropylene, Polyethylene and Polystyrene are cut into a size between 2.36mm and 4.75mm using shredding machine, (Polyvinyl chloride waste should be eliminated).

Figure 5: Plastic after passing through shredding machine

Step 2: The aggregate mix is to be heated up to a temperature of 165^0C (as per the specification) and then it should be transferred to the mixing chamber. The amount of plastic to be added is around 8% of the bitumen.

Step 3: Similarly, at the same time bitumen is to be heated up to a maximum temperature of 160°C (as per the specification) to have a good binding and to prevent weak bonding. The main thing is monitoring the temperature is very important factor in this step.

Figure 6: Transferring the Bitumen to mixing chamber

Step 4: At the mixing chamber, the shredded waste plastic should be added to the bitumen and it gets coated uniformly over the aggregate with in a time of 30 to 60 seconds by giving an oily look the aggregates.

Figure 7: Mixing of plastic and aggregate at mixing chamber from Mir, A. H. (2015)

Step 5: The waste plastic coated aggregate is further mixed with hot bitumen and the final mix is used for the construction of the road and the road laying temperature will be between 110^0C to 120^0C.

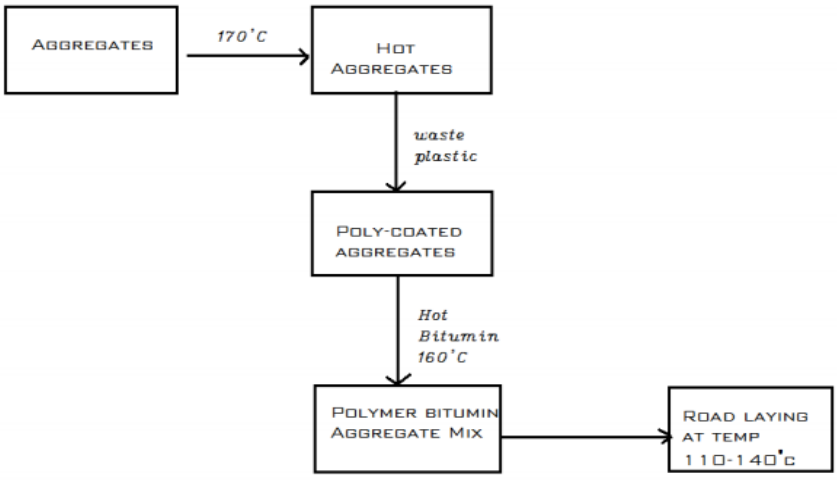

Figure 8: Flow chart of plastic coated bitumen mix from Mir, A. H. (2015)

Figure 9: Some of the Texas Roads Made from Plastic

5) Cost Comparison and Salient features of Plastic Road

Re using the waste plastic to pave roads is one of the leading research that has been successfully conducted in many places and one among them is Mir, A. H. (2015), the mixing of these waste plastic bags with other degradable waste organic materials have been the major cause of the problem in handling the wastes that are collected in the construction of the roads. It has been observed from one of the researcher that even after two years of the construction of the road, they haven't developed cracks and it still provides the smooth riding surface displaying much better durability. It almost saved 8% by the weight of the bitumen which results in increase in the compressive strength. The indirect tensile strength values were increased by three times, it is also providing the smooth surface displaying and much better in durability.

5.1 Salient features of Plastic Road:

- The Strength of the road is twice stronger than the normal roads
- This road has less bleeding during summer then the normal roads
- It doesn't involve ant extra machinery
- We could avoid throwing of waste plastic which can also reduce polluting the environment
- It helps to decrease the consumption of the bituminous mix and to reduce the cost.

- Resistance towards water stagnation (i.e. No potholes are formed as shown in the Figure 10)

Figure 10: Potholes were formed in front of the ENGR Building, SIUC

Figure 11: Macrebur is a company in UK constructs Plastic roads

6) Conclusion

My research on the performance of the plastic modified bitumen in asphalt mix conclusively proves that it is perfect fit for the heavy traffic due to increase in strength in comparison with normal mix, it also has best binding and surface conditions for the long period of exposure to the various climatic conditions. Polymer Modified Bitumen is used due to its better performance than normal bitumen and in addition to the above-mentioned point plastics will also increase the melting point of the bitumen which is best during high temperatures (i.e. summer season)

I would suggest re-examining and formulating new guidelines and specifications with regards to the design and construction of the plastic roads. My report intended to find the different ways to utilize the waste plastic as a bitumen modifier for the construction of the pavements. The use of recycled waste plastic in the asphalt pavements represents a valuable outlet for such materials and it also shows to the public how the government is taking care of the ecosystem and by using this kind of the innovative technology in the construction of road will not only increase the strength of the road, but it also increases the life of the road as well as the quality of the road. We can also pass a rule to the community that you will be waived 10% of your water bill or electricity bill if they donate the waste plastic to the government. At least by this way it changes the mindset of the people in our country and they start saving the plastic instead of throwing them in the trash.

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Figure References

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Figure 9: http://www.dykespaving.com/blog/texas-roads-made-from-plastic/

Figure 10: Picture taken by Venkat Ramana in front of SIUC Engineering Building

Figure 11: http://www.macrebur.com/the-product/

VITA

Graduate School
Southern Illinois University

Venkat Ramana Reddy Vootukuri

ramana.vootukuri@gmail.com

Gokaraju Rangraraju Institute of Engineering & Technology
Bachelor of Technology, Civil Engineering, May 2016

Special Honors and Awards:
IAPA Scholarship Recipient for 2017 - 2018 School Year

Research Paper Title:
Report on the Utilization of Waste Plastic Materials in Asphalt Pavements

Publications:
Srinivas. T, Venkat Ramana Reddy (2016). “Experimental Investigation on Strength Property of Low Calcium Fly Ash Based Geopolymer Concrete.”