Illinois Asphalt Pavement Association Scholarship

The Use of Recycled Plastics in Hot Mix Asphalt

Megan Spaunhorst

Junior Civil Engineering Student

January 2021

Bradley University

1501 W Bradley Avenue, Peoria, IL 61625

Abstract

This paper is a literature review on completed research concerning the use of recycled plastics in hot mix asphalt. This paper does not discuss any laboratory experimentation performed by the student. It provides an analysis of the effectiveness of recycled plastic modifiers, which ultimately indicates promising results of said modifiers. Additionally, the paper discusses cost considerations and environmental implications. This discussion ultimately leads to a conclusion that more research is required before the technology should be implemented on a widespread scale.

Table of Contents

Introduction

In a global market driven by consumerism, people often focus more on the product's usefulness than its lifecycle. The production of waste across the globe is at an all-time high, and single-use plastics are a large contributor to this growing pile of trash. The global population produces so much waste that astronauts can see the Great Pacific Garbage Patch from outer space. According to the Environmental Protection Agency (EPA) and the American Chemistry Council, the United States produced more than thirty-five million tons of plastic just in 2017 (EPA 2019). Of that, only three million tons were recycled. Even with Americans recycling less than ten percent of their plastic, engineers struggle to find applications for this recycled plastic material.

At the same time, roads in America are continually deteriorating. Varying climates present unique challenges for pavement engineers in every region of the country. On top of that, state budgets for road maintenance can limit maintenance and upkeep for the pavement. The American Society of Civil Engineers (ASCE) gives letter grades to various infrastructure aspects in America. The most recent letter grade for the nation's transportation infrastructure and the road system is a solid D, which leaves much room for improvement. With slim budgets as a limiting factor, pavement and asphalt engineers must develop and implement cost-effective asphalt materials better suited for harsh weather fluctuations.

Much in the same way two negatives result in a positive, the combination of these two problems – the buildup of plastic waste and America's worsening transportation infrastructure – could result in a solution. Asphalt engineers already use plastic-like polymers to modify their mix designs to improve strength and elasticity. Additionally, asphalt binder is derived from crude oil, a base product of plastic. More than a decade ago, asphalt engineers connected the similarity of recycled plastic material and asphalt binder, which led to an obvious conclusion. Use recycled plastics to modify asphalt binder. Numerous studies ensued, resulting in promising data and conclusions.

Analysis of Laboratory Studies

Comparing recycled plastic materials

Karmakar and Roy (2016) compare how different types of recycled plastics affect the durability of asphalt using several laboratory tests, including a penetration test, softening point analysis, standard elastic recovery test, and more. They call the recycled plastic materials modifiers because they are melted down and mixed into the asphalt binder to increase durability. This study considers six different types or mixtures of recycled materials: plastic bags (PB), disposal plastic teacups (PC), plastic milk pouches (PMP), a plastic mixture (MP) containing equal parts of PB, PC, and PMP, and tire rubber ash (TRA). Examples of recycled plastic materials from the journal article are shown in Figure 1.

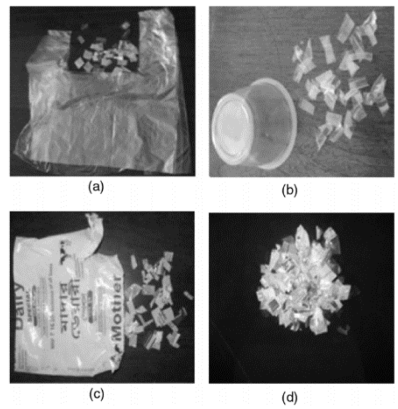

Figure 1 - Examples of recycled plastic materials (Karmakar and Roy, 2016)

Scientists and engineers commonly use a penetration test to gauge the durability of an asphalt design. The experiment is essentially conducted by forcing a large needle into the asphalt at a specific force and known temperature. Having a lower penetration value means the asphalt is stiff, and stiffness is an important gauge of asphalt's strength. The resulting depths of penetration are shown in Figure 2. These results are quite promising. Already at two percent of the added recycled plastic modifiers, the penetration value drops significantly. However, after four percent of the added modifier, the penetration value shows no improvement. The asphalt's stiffness does not improve beyond this point, which means a maximum amount of recycled plastics is added to the asphalt binder. Stiffer roads are more resistant to heavier traffic loads one might find on highways and interstate roads. The penetration test results indicate that the addition of recycled plastic materials dramatically increases the asphalt's strength and durability.

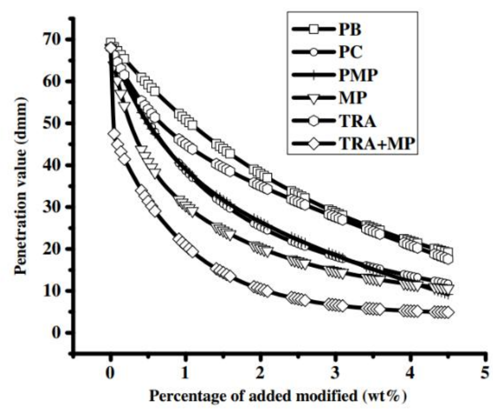

Figure 2 - Penetration values versus percentage of added modifiers (Karmakar & Roy, 2016)

Another critical indicator of asphalt's durability is its softening point. Engineers define the softening point as the temperature at which the asphalt binder changes from a semi-solid and transitions into the liquid phase. Asphalt binder is a unique material because it exists as a semi-solid at moderate temperatures in the environment. However, it can change phases with fluctuations in temperature, and its cement-like properties are dramatically lessened when temperatures increase beyond its softening point. Figure 3 compares the various recycled plastic added modifiers' effects on the binder's softening point. Asphalt with a higher softening point is less susceptible to fatigue cracking and rutting, resulting in higher temperatures. Once again, a sharp increase in the asphalt's softening point occurs until around two percent of the added modifiers. The curve levels off again around four percent, which helps the experimenters narrow the adequate amount of recycled plastic modifiers. The softening point test further shows how the recycled plastics increase the asphalt binder's longevity, and therefore the pavement.

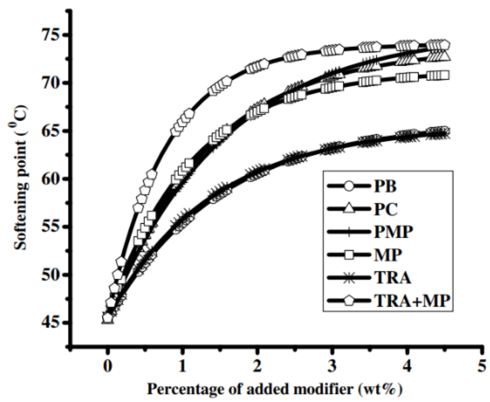

Figure 3 - Softening point in degrees Celsius versus percent of added modifier (Karmakar & Roy, 2016)

Thirdly, the elastic recovery test is an indication of the asphalt quality, often called flow. This describes how easily and at what percentage the asphalt springs back into place after a heavy force moves away, such as a car driving over the pavement. The elasticity of asphalt is a little less straightforward than the penetration value and softening point indicators. As shown in Figure 4, the recycled plastic modifier's addition does indeed increase the elasticity, which means the modifier successfully allows for the asphalt to return closer to its original shape. However, around three percent of the added modifier, the elasticity starts decreasing. Adjusting the percent of recycled plastic modifiers to achieve the maximum elasticity will be one of the more challenging aspects of implementing this technology (Karmakar & Roy, 2016).

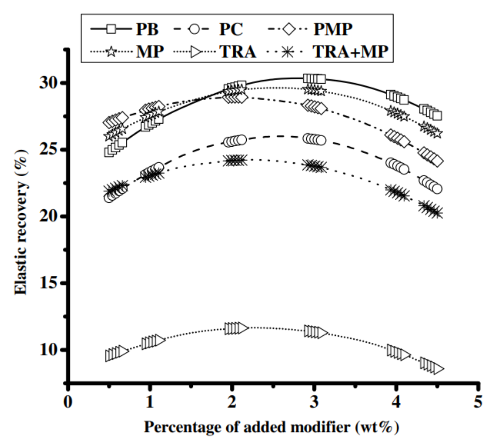

Figure 4 - Percent of elastic recovery versus percent of added modifier (Karmakar & Roy, 2016)

This laboratory study helps prove how recycled plastics in hot mix asphalt can significantly increase asphalt longevity. However, one goal of the experimenters was to determine the best kind of recycled plastic to use, and the performance of the various plastic materials varied from test to test. This could mean a mixture of plastics would be best, which would require fewer resources because the plastic mixture would require time and energy to sort the plastic materials before manufacturing. Considering the Unites States has almost three million miles of paved roads, this is potentially a massive use for the relatively unusable recycled plastic materials ("Public Road," 2018). Studies conducted by Khan et al. (2016) and Costa et al. (2013) produced similar results to Karmakar and Roy (2016), further proving the potential benefits of using recycled plastic materials to strengthen asphalt.

Cost considerations

Scottish company MacRebur is perhaps best known for its recycled plastic pellets. The use of these plastic pellets is the same as the recycled plastic modifiers in the previously mentioned studies, but the pellets are designed for a dry process in which the pellets are incorporated into the asphalt mixture as solids materials. MacRebur offers three types of plastic pellets: MR6, MR8, and MR10, each of which is best suited for different traffic loads. For example, the blue-green pellets shown in Figure 5 are best suited for asphalt roads with high traffic loads. MacRebur recommends these as modifiers for asphalt on highways and interstates. The pink pellets are best suited for residential roads, and the off-white pellets are best for intermediate roads. (White & Reid, 2018). This Scottish company has contracts worldwide, indicating the success of their recycled plastic asphalt binder modifiers.

(a) (b) (c)

Figure 5 - MacRebur's recycled plastic pellets: (a) MR6, (b) MR8, (c) MR10 (White & Reid, 2018)

MacRebur's success can be attributed to their extensive product research, which considered the cost benefits of using recycled plastic waste. Researchers note, "Any waste or by-product recycling technology is only viable if either the performance is improved for similar cost, or comparable performance is achieved at reduced cost" (White & Reid, 2018). This is unfortunate because practicing sustainability is not necessarily sustainable for companies until sustainable practices are more economically rewarding than current practices. Though MacRebur has found profitable success with their recycled plastic products, they note profit margins are minimal at best on a small-scale. Using recycled plastics to modify HMA will only be genuinely profitable on a more widespread scale.

However, it is essential to note that MacRebur made these assumptions within the context of Europe. The plastic modifiers' shipping costs are dramatically less than other typical asphalt binder modifiers, assuming the plastic modifiers are initially dry mixed at a manufacturing plant before being trucked to a construction site where the asphalt mixture is heated and combined. In America, transportation costs might significantly impact recycled plastic modifiers' cost-effectiveness because of the more considerable distances between binder modifier manufacturing locations and project locations.

At the very least, using recycled plastics to modify asphalt binder will not cost any more than traditional asphalt binder modifiers. The recycled raw materials are dirt cheap, and the manufacturing process of these materials is relatively the same as typical modifiers. As the MacRebur researchers noted, the next steps in implementing this technology will require more regulations that encourage sustainable practices before more companies will invest. Again, results from this study are promising.

Environmental impacts

Already, environmentalists are wary because there is evidence of asphalt binder chemicals leaching into the environment. Consider the Circle C subdivision project above the Barton Springs aquifer in Austin, Texas. The city of Austin was forced to close the popular swimming hole fed by the Barton Springs aquifer for three months after receiving reports of harmful levels of hydrocarbon pollution in the water. Experts said the pollution source was asphalt from roads and parking lots linked to the Circle C subdivision project (King, 2012). Adding recycled plastic modifiers to asphalt could easily result in harmful chemicals from the plastic materials leaching into the environment. Though all the referenced laboratory reports mention environmental gains of using recycled plastics that would otherwise end up in landfills, none specifically address the potential harms of plastic chemicals leaching into the environment beyond briefly mentioning how this aspect is beyond their scope of research.

Engineers are currently working to address this issue because the leaching risk could harm the environment rather than improve it. The National Asphalt Pavement Association (NAPA) recently posted a journal article summarizing all known research on using recycled plastics in HMA. The article also performs a gap analysis, meaning the authors address areas where engineers require more research to fully understand its effectiveness and possible consequences (Willis et al., 2020). Additionally, the University of Texas at Arlington recently received a large grant to conduct further research, including but not limited to environmental consequences of recycled plastic binder modifiers (Halsey, 2018). Engineers and researchers are on the right path to safely implement recycled plastic asphalt binder modifiers in American roads.

Conclusion

Using recycled plastic to modify and strengthen asphalt has proven to be promising. Recycled plastic modifiers reduce the penetration value and increase the softening point. When applied correctly, these recycled modifiers significantly improve the elasticity of asphalt. These tests are important indicators of how well the asphalt will resist cracking, rutting, potholes, and other signs of fatigue, and the results of research articles from the past decade prove recycled plastic increases the strength and durability of asphalt. The success of the company MacRebur shows there is much economic potential from this technology, but before moving forward, engineers need to know more about potential environmental impacts. It seems recycled plastics are the future of asphalt binder technology and possibly an end to the growing amount of unused recycled plastic materials in landfills across the globe.

References

Costa, L., M.B., Silva, H., M.R.D., Oliveira, J., R.M., & Fernandes, S., R.M. (2013). Incorporation of waste plastic in asphalt binders to Improve their performance in the pavement. *International Journal of Pavement Research and Technology*. doi:10.6135/ijprt.org.tw/2013.6(4).457

This article discusses the best types of plastic to use as additives in HMA based on performance parameters like viscosity and storage stability. The researchers compare plastics in their virgin and recycled states to show how recycled plastics are very much comparable in performance to their virgin counterparts. The researchers conclude that SBS, HDPE, and EVA type plastics will best improve the strength and resilience of HMA. Additionally, the article discusses possible environmental impacts from using recycled plastics as modifiers in HMA binder, which is relatively unique compared to other research articles.

EPA. (2019, October 30). Plastics: Material-specific data. Retrieved October 26, 2020, from https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/plastics-material-specific-data

The EPA provides statistics concerning plastic consumption, disposal, and recycling in the United States. Though the article does not discuss asphalt, it provides the social context in showing a need to use the supply of recycled plastics in America. Essentially it provides the data to back up a call to action.

Halsey, A. (2018, October 29). Where does your recycled plastic go? Perhaps into future highways. Retrieved November 02, 2020, from https://www.washingtonpost.com/local/trafficandcommuting/where-does-your-recycled-plastic-go-perhaps-into-future-highways/2018/10/28/2aa3f5c4-d157-11e8-8c22-fa2ef74bd6d6_story.html?noredirect=on

This article from Washington Post summarizes the research grant given to UTA, and it gives a more in-depth explanation of possible implications the use of recycled plastics in HMA could have on society. Specifically, the article explains how the market for recycled plastic materials is small, but using recycled plastics in asphalt roads is a possible way to increase the demand for recycled plastic materials dramatically.

Karmakar, S., & Roy, T. K. (2016). Effect of waste plastic and waste tires ash on mechanical behavior of bitumen. *American Society of Civil Engineers*. http://dx.doi.org/10.1061/(ASCE)MT.1943-5533.0001484

Karmakar and Roy’s journal article is more extensive than other journal articles referenced in this literature review due to the number of laboratory experiments they perform and discuss. The researchers perform laboratory tests such as the penetration test, standard elastic recovery test, high temperatures storage stability test, and morphological analysis by optical microscopy test. These four tests and the resulting data show tangible results that help prove the success of using recycled plastics in HMA. The journal article was published in 2016. Being published so recently further increases the article’s reliability as it most likely contains the most up-to-date information. Furthermore, the American Society of Engineers published this research, which proves its credibility.

Khan, I. M., Kabir, S., Alhussain, M. A., & Almansoor, F. F. (2016). Asphalt design using recycled plastic and crumb-rubber waste for sustainable pavement construction. *Procedia Engineering, 145*, 1557-1564. doi:https://doi.org/10.1016/j.proeng.2016.04.196

The journal article describes how using recycled plastics as an additive in HMA binder can help solve two issues – failing asphalt due to extreme temperature variations in Saudi Arabia and using the never-ending supply of plastics. Specifically, the article discusses two tests that gauge the asphalt’s ability to resist rutting, those tests being dynamic shear rheometer tests and bending beam rheometer tests. Though this research addresses Saudi Arabia's climate, it very much applies to this literature review research paper. America’s climate is not always as severe as that in Saudi Arabia, which proves that using recycled plastics in HMA in binders could be even more successful in America.

King, M. (2012, August 3). The Battle for Barton Springs: A Brief Timeline. Retrieved December 01, 2020, from https://www.austinchronicle.com/news/2012-08-03/the-battle-for-barton-springs-a-brief-timeline/

This article discusses Barton Springs's case, an extensive battle still being fought in Austin, Texas, between environmentalists and private property protection advocates. The case is a specific example of the harmful consequences of chemicals from asphalt binder leaking into the environment, providing context for the section discussing environmental impacts of using recycled plastics in HMA.

Public Road and Street Mileage in the United States by Type of Surface. (2018). Retrieved December 02, 2020, from https://www.bts.gov/content/public-road-and-street-mileage-united-states-type-surfacea

The United States Bureau of Transportation provides the most accurate and up-to-date information regarding the quantity of paved and unpaved roads in America. This motivates the purse to use recycled plastics in hot mix asphalt as a viable option for recycled plastic materials.

White, G., & Reid, G. (2018). Recycled waste plastic for extending and modifying asphalt binders. *8th Symposium on Pavement Surface Characteristics*. Retrieved 2020.

This article is particularly relevant for two major reasons. The first reason of significance is because the researchers posted the article just over two years ago, meaning the information they present in the article is very much up-to-date and relevant. Additionally, researcher Gordon Reid works for MacRebur, one of the most established companies specializing in using recycled plastics to modify binder in HMA. This provides a unique point of view into the plastic pellets' actual production they add to the binder to modify it and the extensive experimentation the company performed before taking their technology to the market. With MacRebur being a for-profit organization, the article naturally addresses the benefit-to-cost ratio of using recycled plastics, making it unique compared to other journal articles. Overall, this article provides insight into the sustainability and applicability of using recycled plastics in HMA.

Willis, Richard, et al. (2020). “Recycled Plastics in Asphalt Part A: State of the Knowledge.” *National Asphalt Pavement Association*, 2020, pp. 1–33., member.asphaltpavement.org/Shop/Product-Catalog/Product-Details?productid=%7b314FA049-911F-EB11-A813-000D3A4DF1CD%7d. Accessed 2020.

This journal article addresses the lack of knowledge concerning recycled plastics in HMA and recommends further research on possible environmental consequences of recycled plastic asphalt binder modifiers. This article comes from the National Asphalt Pavement Association, which sets the standard for American asphalt practices, thereby proving the article’s credibility.