Recent Trends in Civil Engineering and Built Environment Vol. 2 No. 1 (2021) 491-499

RTCEBE

Homepage: http://publisher.uthm.edu.my/periodicals/index.php/rtcebe
e-ISSN :2773-5184

A Review on the Use of Waste Plastic Material in Pavement

Muhammad Haqimi Zulkafle[1], Nasradeen . A . Khalifa[2,*]

[1]Faculty of Civil Engineering and Build Environment,
Universiti Tun Hussein Onn Malaysia, 86400 Parit Raja, Batu Pahat, Johor, MALAYSIA

[2]Smart Driving Research Centre, Faculty of Civil Engineering and Build Environment,
Universiti Tun Hussein Onn Malaysia, 86400 Parit Raja, Batu Pahat, Johor, MALAYSIA

*Corresponding Author Designation

DOI: https://doi.org/10.30880/rtcebe.2021.02.01.053
Received 30 January 2021; Accepted 28 April 2021; Available online 30 June 2021

Abstract: The constant growth in road traffic combined with a lack of maintenance owing to the lack of funds has culminated in the deterioration of Malaysia's road network. While plastics are beneficial items, the disposal of such waste has become a problem in worldwide. One of the usable disposals of plastic waste is that it is transformed into valuable items, such as those that may be found in the production of bituminous pavements. The aim of this research is to identify the stability of asphalt bitumen with plastic waste as addictive, based on the previous research and to compare the experimented result with the conventional pavement details and mixed pavement details.as well as to identify the optimum proportion of plastic waste to be applied to the bitumen mixture. To achieve these objectives, the researcher conducted a research review study, based on the data from up to 54 previous published research papers either with the same topic or with the related subject. Based on the review the result shows that adding plastic waste in the bitumen resulted in an increase in the properties of bitumen and aggregate Reduces the quantity of bitumen up to 9-10 % by weight. Therefore, the usage of plastic waste may also have positive environmental and economic advantages, taking into consideration the possible consequences of the elimination of many million metric tonnes of plastic waste is the potential money savings to construct a road.

Keywords: Plastic Waste, Road Pavement Condition, Bitumen Mixture, Road Maintenance

1. Introduction

In Malaysia, the road is one of the critical aspects of the transportation sector. The field of transportation plays a significant role in coordinating all countries' development program. The growth in human activity indirectly raises the need for different forms of cars. Around the same period, the

Corresponding author: nasradeen@uthm.edu.my

number of vehicles on the road is also growing, which can be seen by its rapid growth last year. There have been extensive improvements to the vehicle sector in the last fifty years, but the roads we drive on have not changed. The roads need to fit vehicles so they would be providing more efficient. Furthermore, our earth is paved with roads and by the year 2050, the number of roads currently in the world is increased by 60 percent [1].

Due to the rise in population, urbanization, development and lifestyle, plastic waste production has grown massively, causing solid waste disposal one of the world's main environmental concerns. These plastics are uncontrolled because of the significant rapid depletion of waste disposal sites creating big environmental problems. Plastic, a non-biodegradable substance, will live without decay on earth for 4,500 years [2].The risk of health involves individual, animal, and genital abnormalities of reproductive conditions. Besides, the dangerous impact of waste also poses a threat to bird and water animal populations. The problem of plastics waste cannot be resolved before practical steps on the ground are taken [2].

Concrete manufacturing was responsible for 8 percent of global carbon dioxide emissions. It is constructed of minerals such as sandstone, concrete, or limestone [1]. It may be seen in road construction. The field test of plastic wastes processed by sorting machine added improved the road's stability and solved pollution problems. With increased in urbanization and development, plastic waste production also has increased. It is dangerous to dispose of plastic because plastic is not biodegradable. For the problems listed above, the researcher thinks plastic pavement will be a better alternative. Simultaneously, we can save our environment and cost for maintenance a road will be more economical. Nowadays, the roads in Malaysia are facing a lot of damage. This is due to several factors such as soil conditions, weather factors and workers factors. Therefore, this study is designed to study how the researcher can identify the optimum proportion of plastic that can be add in the asphalt mix to the modify asphalt mix to find some improvements and differences that can be used to overcome road damage in Malaysia.

2. Research Methodology process

Peer-reviewed academic papers written with the associated keywords were found using the search engines “Scopus” and “Google Scholar,” which are known as the most extensive citation and abstract collection of peer-reviewed literature, scholarly journals, conference proceedings, and books [3]. The first steps of the analysis. A study was undertaken to allow the formulation of the keywords used in performing searches. Figure 1 shows the diagrammatic representation of the methodology process. A comprehensive and systematic search is conducted under the title, abstract and keyword fields in both datasets utilizing the Boolean search technique and keywords. Boolean operators AND, OR and NOT are used to find perfect search criteria by merging or limiting terms [3]. The combination of the following keywords and the Boolean operators will be used for the first stage of the review: 'Bitumen AND plastic' OR 'pavement' OR 'construction AND pavement' OR 'bitumen AND asphalt.

A total of 54 papers were returned to the first step of the journal review process. It is important to make the error of collecting too many articles that may potentially be filtered out rather than collecting too few, which could result in certain articles being lost. The findings were then filtered by topic field and restricted to infrastructure, agricultural science, environmental engineering, highway engineering and technology. The subject areas used for the first stage of filtering were determined based on the observation that most of the search results initially returned 54 papers were written in the subject areas, contributing to the withdrawal of 6 articles. The findings were also filtered by a form of text, e.g., conference and journal articles, and the year of release (e.g., 1992-2019), which lead to the elimination of two documents, leaving 46 papers to progress to the next level.

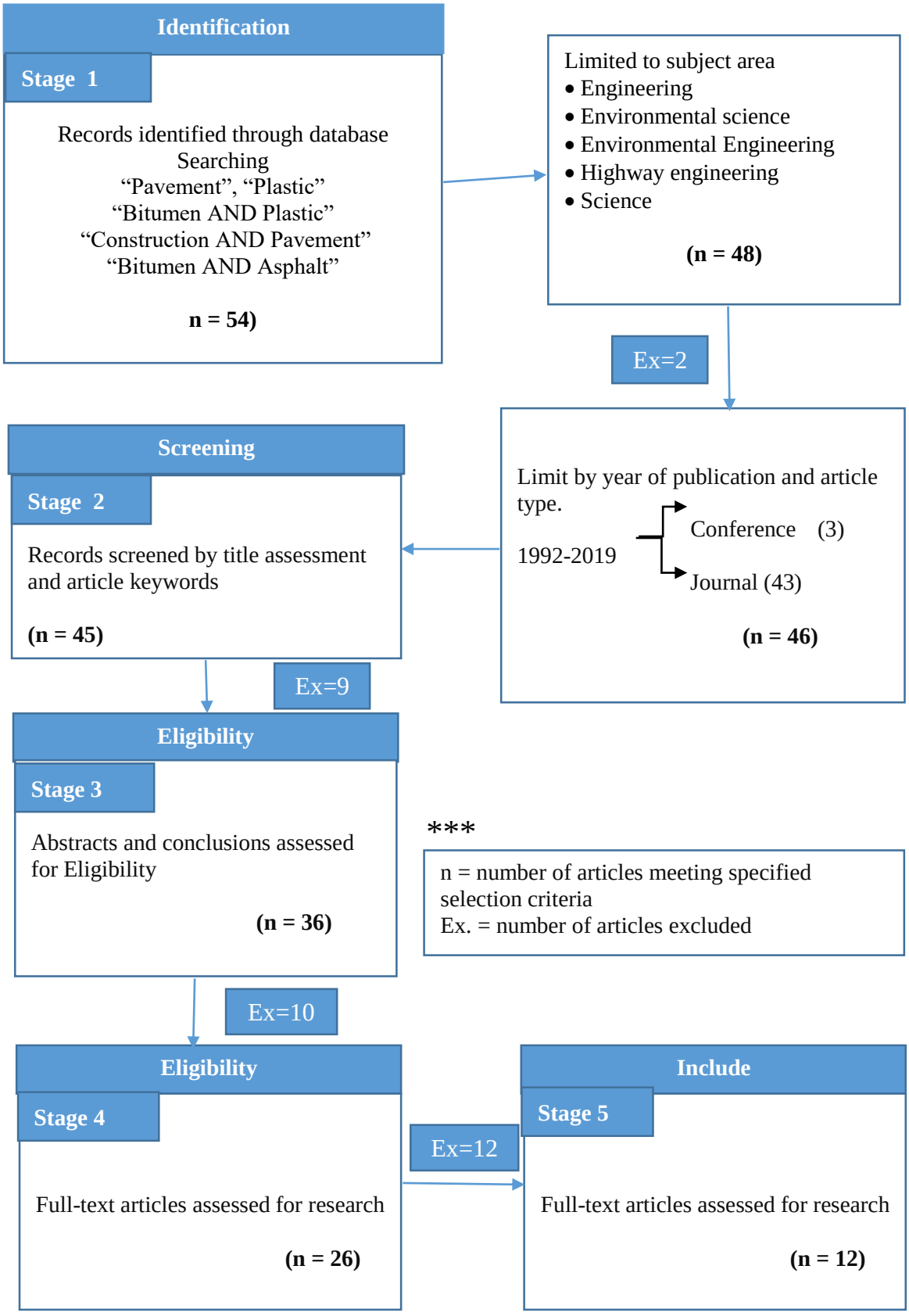

Figure 1: The procedure of methodology

The second stage of the systematic analysis phase included screening the search results by reviewing the titles and keywords of the publications and evaluating their eligibility for inclusion by determining the titles and keywords' appropriateness. This process contributed to the elimination of 9 papers, leaving 36 to proceed to the next level. In the third stage of the systematic review, the articles' abstracts and conclusions were read in detail to assess their eligibility for inclusion; this led to removing 10 documents, leaving 26 documents to proceed to the next stage. The fourth stage of the review entailed reading the full texts of all the selected papers. The introduction section's main aim, the methodology adopted, the gaps identified, and the papers' main contributions were given to the introduction section. This led to eliminating 12 articles, leaving only 12 articles in the fifth stage to do a final review and compare rising among base the research.

3. Results and Discussion

The number of previous published research papers as indicated above are discussed in this part and the findings of the analysis are presented in three main sections. The first part underlines the stability of asphalt bitumen with plastic waste as an additive. The second section discusses the effects of the experiment with traditional pavement details and mixed pavement details and, ultimately, identify the optimal percentage of waste plastic added to the HMA. The results for all sets of data are also compared. by making a comparison among data gathered from another sources.

Table 1 shows the results that waste polythene consumption in bituminous concrete mixtures shows the mixtures' improvement. The waste polythene consumed in the mix will get coated over aggregates of the mixture and improve the stability up to 2000kg. It decreases porosity, retains moisture, and increases binding properties. On that table also show the Optimum bitumen content (OBC) and optimum Plastic content (OPC). Moreover, there are several type of plastic that can be use in pavement such as High Density Polyethylene (HDPE), Low Density Polyethylene (LDPE),polypropylene (PE), Polyvinyl choloride (PVC) and Pulverised Tyre waste (PTW).

Moreover, this study aimed to identify efficient ways to recycle plastic waste as an additive material for flexible pavements. For such materials, the use of recycled plastic waste in asphalt pavement represents an important outlet. From the entire thesis above, It can be assumed that modified bitumen with the application of plastic waste of roughly 5-16% by weight of bitumen may significantly increase Marshall's stability, strength, fatigue life and other valuable properties of the bituminous concrete mixture.

Table 1: Summary table for Analysis of the asphalt bitumen's stability with plastic waste

No.	Materials	OBC/OPC	Remarks
1	plastic waste like carrying bags	OPC= 12% OBC= 5.4	The Marshall stability value is improved and a mixture containing 12% plastic by weight of bitumen is considered to have maximum stability. The stability value decreased at 14 per cent of the plastic content. [4]
2	plastic waste HDPE/LDPE	OPC for LDPE/HDPE =8% No OBC	The addition of 8% of the LDPE and HDPE plastic waste improves the mix's stability value, which increases the toughness of the mix [5].
3	Carry bags, cups, Hard foams (PS), Soft foams (PE&PP)	OBC=5% OPC=5-15%	The adjusted bitumen has a good result compared to the normal bitumen performance. Therefore, plastic waste will be used, eventually promoting road safety and efficiency. The Marshall stability shows a good value more than a standard value it’s found to be up to 2034.48 kg [6].

4	Plastic Bottles	OBC=4.2% OPC=15%	The total stability of the adjusted Margalla asphalt mixture when 15 per cent of PB waste was used is 13.8 per cent greater over standard asphalt mixtures. But when PB waste was used in reach of 15%, Marshall's stability saw a slow decrease [7].
5	PVC HDPE	OBC=5% OPC=10%	The stability of bituminous mixtures (10 per cent bitumen substituted by plastic) is better than that of normal bitumen. [8]
6	plastic materials such as carry bags, cups	No OBC OPC=9%	polymer gives better results as compared to plain bitumen. The percentage of Marshall stability for 9% of adding plastic is higher than the normal bitumen. [9]
7	HDPE LDPE	OBC=4% OPC=6-8%	The stability values will be improved by increasing the proportion of plastic and the amount of binder will be minimized. The plastic-coated aggregate samples are more stable based on stability values than polymer-coated bitumen and can be used in higher plastic percentages. [10]
8	HDPE LDPE	OBC=5.4% OPC=12%	The study results indicated that the modified mixture has higher stability and VMA percentage compared to the non-modified mixtures. With polyethylene usage in asphalt, the pavement's deformation is reduced, fatigue resistance is improved. [11]
9	Plastic Waste	OBC=5.5% OPC=10%	The optimal bitumen content of the bituminous concrete mixtures was 10% greater compared to the adjusted semi-dense bituminous concrete mixtures with plastic waste. Marshall Stability of 12.5 per cent of plastics indicates higher results than the 0 per cent plastic bituminous concrete mixtures applied. [12]
10	polythene carry bags	No OPC No OBC	The results indicated that the consumption of waste polythene in bituminous concrete mixtures shows improved property of the mixtures thus formed. It is found that the Marshall Stability value rises with a polythene volume of up to 4.5 per cent and then declines. [13]

Table 2 show that the strength of roads with shredded plastic waste is far greater than that of roads with asphalt with a typical mixture. Although the usual 'highway standard' road lasts from four to five years, it is reported that plastic-bitumen roads will last up to ten years [22]. Rainwater will not seep through because of the plastic in the tar. The price of plastic road construction can be marginally higher than the typical process. Maintenance costs are small compared to the typical method. Its initial cost is slightly more as compared to the conventional method. Road strength is twice as high as standard roads resistance to water stagnation, and no potholes are created, less bleeding during summer, plastic waste can be prevented and does not require any new machinery, it does not increase the price of road construction; and it helps to minimize the use of bituminous mixture by lowering costs.

Table 2: Summary table for Analysis of the experimented result with the conventional pavement details and mixed pavement details

No.	Materials	OBC/OPC	Remarks
1	PTW LDPE	OBC=5.22% OPC= 8%	This study concluded that the addition of PTW and LDPE waste had improved the properties of penetration, ductility, and the modified bitumen's softening temperature. As the material's stiffness is improved, it can take the high load and increase the pavement ruts' resistance. Therefore, the pavement's durability is improved using waste material to use waste efficiently. [14]
2	Waste plastic/polymer	OBC=5.6% OPC=8%	inter-molecular bonding between bitumen and waste PP coated aggregate enhanced strength and thus the quality of bituminous concrete mixes. Significant improvements were observed in performance parameters in Marshall stability, ITS, Rutting, and retained stability of bituminous concrete mixes. Thus, waste PP modified bituminous concrete mixes are expected to be more durable and improved performance. [15]
3	HDPE	OPC=8% OPC=8%	Mixture modification using 8% shredded HDPE improves the Marshall Stability of the mixture by 70%, increasing its rutting resistance and load-carrying capability. HWT test results also confirm that the modified mixture has a higher resistance to permanent deformation (rutting). Dry Process (polymer coating of aggregates) is more useful than Wet Process (adding polymer in the binder) for manufacturing modified mixtures. It can accommodate a higher amount of waste plastic as a modifier and results more stable mixtures. [16]
4	HDPE	OBC=5.2% OPC=7%	The use of HDPE in asphalt concrete mixtures caused an increase in resilient modulus values at high (25 C) temperatures; and Results indicated that flexible pavement with high performance, durability and more economical could be obtained with 5% HDPE. [17]
5	HDPE and PVC	OBC=5.4% OPC=7-10%	This investigation shows that the penetration, ductility, and solubility value of modified asphalt mixture decreased with polyethylene and PVC modifiers. On the other hand, the softening point increases with the rise in the modifier. [18]

Table 3 show the appropriate amount of plastic waste or polyethylene was determined to be (4-16%) by weight of the optimum bitumen content (4-5.5%) by reviewing previous experimentation. Adding Polythylene Terephthalat (PET) plastic waste in the bitumen increased the properties of bitumen and aggregate. It reduces the optimum bitumen content up to 9-10 % by weight and cuts the pavement

construction cost. Moreover, using plastic waste in the construction of flexible pavement can reduce the impact on the environment

Table 3: Summary table for Analysis of the optimum proportion of waste plastic added to the bitumen mix

No.	Materials	OBC/OPC	Remarks
1	PET plastic waste	OBC=4% OPC=16.7%	PCA-modified BAC improved better PET recycling with a higher OPC of 16.7% compared to 9% OPC with PMB-modified BAC. At the same time, PMB-modified BAC increased the Marshall stability at comparable plastic content. It seems better to use the plastic waste PET in PCA-modified BAC [19].
2	polythene milk packets	OBC=5% OPC=4%	It is observed that the Marshall stability value increases with polyethylene content up to 4% and after that decreases. The polymer-modified bitumen show improved properties for pavement constructions. This can also reduce the amount of plastics waste that otherwise is considered a threat to the environment's hygiene. [20]
3	PP LDPE PE form	OBC=4.5% OPC=10%	performance of plastic bitumen road conclusively proves that it is good for heavy traffic due to better binding, increased strength, and better surface condition for a prolonged period of exposure to variation in climatic changes. The quantity of bitumen needed for a good mix can be reduced to the extent of 0.5% of the total weight, which accounts for 10% reduction in the use of bitumen. [21]
4	Waste polymer	OBC=5.4% OPC=12%	By increasing the percentage of waste plastic in the mix the Marshall stability value is increased and maximum stability is found for the mix containing 12% plastic by weight of the bitumen. At 14% plastic content the stability value has decreased [22].

4. Conclusion

In the research of polythene with asphalt modified behavior, it was noticed that the modified mixture possesses better Marshall Characteristics, as shown in the data review. The Marshall stability value is found to be increased and with a polymer amount of up to 4 percent to 16 percent and after that decrease. This study has demonstrated the value of environmentally road construction in our pursuit of sustainable growth in the twenty-first century. It shed light on the idea of environmentally sustainable road construction. It described the reasons responsible for its development, stakeholders' challenges in its implementation, and green road construction advantages. the usage of plastic waste will have positive environmental and economic advantages, taking into consideration the possible consequences of the reduction of many million metric tonnes of plastic waste from the river and the potential financial gains arising from the long operating life of the highways, the prevention of accidents, the protection of natural materials and the profits from the trade of such waste.

Acknowledgement

The authors would like to thank the Faculty of Civil Engineering and Build Environment and Smart Driving Research Centre, Universiti Tun Hussein Onn Malaysia for their support.

References

[1] Meijer, J. R., Huijbregts, M. A. J., Schotten, K. C. G. J., & Schipper, A. M. (2018). Global patterns of current and future road infrastructure. *Environmental Research Letters*, *13*(6).

[2] Song, J. H., Murphy, R. J., Narayan, R., & Davies, G. B. H. (2009). Biodegradable and compostable alternatives to conventional plastics. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *364*(1526), 2127–2139. https://doi.org/10.1098/rstb.2008.0289

[3] Martín-Martín, A., Thelwall, M., Orduna-Malea, E., & Delgado López-Cózar, E. (2020). Google Scholar, Microsoft Academic, Scopus, Dimensions, Web of Science, and OpenCitations' COCI: a multidisciplinary comparison of coverage via citations. In Scientometrics.

[4] Rokdey, S. N., Naktode, P. L., Nikhar, M. R., & Professor, A. (2015). Use of Plastic Waste in Road Construction. *International Journal of Computer Applications*, *2*(10), 975–8887. Retrieved from www.ijcaonline.org

[5] Tiwari, A. V., & Rao, Y. R. M. (2019). Study of plastic waste mixed bituminous concrete using dry process for road construction. *Selected Scientific Papers - Journal of Civil Engineering*, *13*(1), 105–112.

[6] Meti, A. (2018). *Study of Performance of Plastic Waste in Flexible Pavement*. 2603–2605. *Journal of Engineering Research and Applications.*

[7] Jan, H., Yusri Aman, M., & Karim, F. (2017). Plastic Bottles Waste Utilization as Modifier for Asphalt Mixture Production. *MATEC Web of Conferences*, *103*, 1–10.

[8] Manju, R; Sathya, S. S. K. (2017). Use of Plastic Waste in Flexible. *International Journal of ChemTech Research*, *10*(8), 804–811.

[9] Srinivas, G. A. K. A. S. I. S., & GOpi, P. G. (2018). Application of Waste Plastic as an Effective Construction Material in Flexible Pavements. *Ijitech.Org*, (01), 276–283.

[10] Sultana, S. K. A., Prasad, K. S. B., & Sultana, S.A., and Prasad, K. S. B. (2012). Utilization of Waste Plastic as a Strength Modifier in Surface Course of Flexible and Rigid Pavements. *International Journal of Engineering Research and Applications (IJERA)*, *2*(4), 1185–1191.

[11] Awwad, M. T., & Shbeeb, L. (2007). The use of polyethylene in hot asphalt mixtures. *American Journal of Applied Sciences*, *4*(6), 390–396.

[12] Hake, S. L., Damgir, R. M., & Awsarmal, P. R. (2020). Utilization of Plastic waste in Bitumen Mixes for Flexible Pavement. *Transportation Research Procedia*, *48*(2019), 3779–3785.

[13] Soni, K., & Punjabi, K. K. (2015). Improving the Performance of Bituminous Concrete Mix by Waste Plastic. *Journal of Engineering Research and Applications Www.Ijera.Com*, *3*(5), 863–868.

[14] R.Sathishkumar, S. P. J. (2013). Comparison of Strength Properties of Bitumen Mixed With Waste Materials As Modifier. *International Journal of Civil Engineering and Technology (IJCIET).*

[15] Sabina, Khan, T. A., Sangita, Sharma, D. K., & Sharma, B. M. (2009). Performance evaluation of waste plastic/polymer modified bituminous concrete mixes. *Journal of Scientific and Industrial Research*, *68*(11), 975–979.

[16] Khurshid, M. B., Ahmed, S., Irfan, M., & Mehmood, S. (2013). Comparative analysis of conventional and waste polyethylene modified bituminous mixes: A new dimension of effective environmental & waste management. *International Conference on Remote Sensing, Environment and Transportation Engineering, RSETE 2013*, (Rsete), 346–349.

[17] Attaelmanan, M., Feng, C. P., & Ai, A. H. (2011). Laboratory evaluation of HMA with high density polyethylene as a modifier. *Construction and Building Materials*, *25*(5), 2764–2770.

[18] Nobinur Rahman, M., Ahmeduzzaman, M., A. Sobhan, M., & U. Ahmed, T. (2013). Performance Evaluation of Waste Polyethylene and PVC on Hot Asphalt Mixtures. *American Journal of Civil Engineering and Architecture*, *1*(5), 97–102.

[19] Sojobi, A. O., Nwobodo, S. E., & Aladegboye, O. J. (2016). Recycling of polyethylene terephthalate (PET) plastic bottle wastes in bituminous asphaltic concrete. *Cogent Engineering*.

[20] Prusty, B. (2012). Use of waste polyethylene in bituminous concrete mixes Department of Civil Engineering National Institute of Technology Rourkela-769008 (ODISHA) *International Journal of Civil Engineering and Technology (IJCIET).*

[21] R. Vasudevan', Velkenned, R., & A. Ramalinga Chandra Sekar, B. S. (2010). Utilization of Waste Polymers for Flexible Pavement and Easy Disposal of Waste Polymers. *International Journal of Technical Research and Applications*, 120–160.

[22] Ahmed Trimbakwala. (2017). Use of waste plastic in road construction" Indian Highways. *International Journal of Scientific and Research Publications*, *7*(4), 31–32