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Application of Plastic-Coated Aggregate (PCA) in the construction of flexible pavement in an eco-friendly way

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Abstract

Plastic waste is a major environmental issue that poses a significant threat to wildlife on land and in the ocean. Despite taking hundreds of years to break down, most plastic waste ends up in landfills or the natural environment, harming wildlife in the process. Common types of plastic waste, such as water bottles, cold drink bottles, biscuit covers, plastic cups, and foam, are typically made of Polyethylene terephthalate (PET), Polyethylene (PE), and Polystyrene (PS), which have a softening point that varies between 110-180°C. To address this issue, this study intended to explore the use of waste plastics (PET) as a coating or layer for aggregate surfaces. By heating aggregate and adding shredding plastics over the aggregate surface, a coat or layer is formed. The coated aggregate was then cooled and tested to investigate its improvement in mechanical properties. A reduction of aggregate impact value and Los Angeles abrasion by 1.64% and 1.88% respectively was observed. Overall, this approach shows promise for mitigating the bad environmental influences of plastic waste while improving the properties of aggregate and bituminous concrete as well.

Keywords: *waste plastics, PCA, flexible pavement, bitumen mix, Marshall stability test.*

1 Introduction

The environment is a fragile ecosystem, constantly impacted by human activities and one of the biggest challenges facing the environment today is the problem of plastic waste. Plastic waste is a major environmental issue that is only getting worse. In 2019, the world produced 380 million tonnes of plastic, and best 9% of that was recycled. The rest ended up in landfills, incinerators, or the surroundings (Al-Hadidy and Yi-qiu, 2009). Every day, the six biggest cities in Bangladesh (Dhaka, Chittagong, Khulna, Rajshahi, Barisal, and Sylhet) produce around 8000 tons of solid plastic waste. The world is now approaching towards recycling and reuse of the different solid wastes, e-waste, and industrial byproducts (Shirin et al., 2020). Plastics are synthetic organic polymers that are extremely durable and resistant to degradation, making them popular for use in a variety of applications, from consumer products to packaging. However, the very properties that make plastics useful also make them a serious threat to the environment. Plastic waste is a major source of pollution, both on land and in the ocean. Plastic debris can be ingested by marine wildlife, resulting in injury and death, and can also accumulate in ocean currents, creating giant floating patches like the Great Pacific Garbage Patch.Plastics also pose a threat to soil and groundwater by releasing toxins into the environment as they break down over time. This poses a health risk to humans and animals. There are different kinds of plastic waste like PET, HDPE, PE and PS. The scope of plastics waste is vast and encompasses a wide range of sectors and industries. Plastic waste includes all discarded plastic materials, including packaging, single-use plastics, plastic products, and industrial waste from manufacturing and production processes. The production of plastics has increased exponentially over the past few decades, and the disposal and management of plastics waste have become significant environmental issues. By coating on aggregates, it's the mechanical properties should improve over virgin aggregates. Plastic waste in the form of flexible pavements could provide a solution to the problems associated with the disposal of plastic waste. A lot of work has been carried out in the field of using plastic waste in the construction of bituminous roads (Singh and Yadav,2016). Plastic modified bitumen showed a phenomenal result in terms of stability, Softening point, and Penetration value (Islam et al., 2021). Plastic coating is used on aggregates to improve road performance. Plastics are used to improve bitumen binding with plastic waste coated aggregate. Plastics increase bitumen binding and increase the surface area between polymers (Awwad and Lina, 2007). Plastics also reduce voids. Plastics prevent moisture absorption and bitumen oxidation by entrapping air. This reduces rutting and raveling and prevents the formation of potholes consequently, these potholes result in Capacity Loss (Islam et al., 2019). Plastics make roads more durable and able to withstand heavy traffic (Chavan, 2013) Using waste plastic to coat aggregates helps to prevent moisture from evaporating. Utilizing waste commodity plastics for binder modification offers a cost-effective, technologically advanced method of improving conventional binder performance, as well as an alternative approach to plastic waste management. This has helped to reduce the amount of plastic waste that is thrown away, because it is a method that helps protect the environment (Jayaram et al., 2017). To bring economy in road construction without compromising the quality use of unconventional and waste materials is proven to be a great alternative and it is also being so popular all over the world (Rashid and Islam, 2019). Using waste plastic in road construction has a lot of benefits. It helps bitumen bond better with plastic, which means fewer voids. It also makes roads more durable and can handle heavy traffic. Not only does it make the road stronger, but it also extends its life and helps the environment (Gandhiraj et al., 2018). The main objective of this study is to investigated the improvement of aggregate properties after coating the waste plastic (Polyethylene terephthalate commonly known as PET) materials

2 Materials & Methods

2.1 Normal Aggregate Collection and Preparation

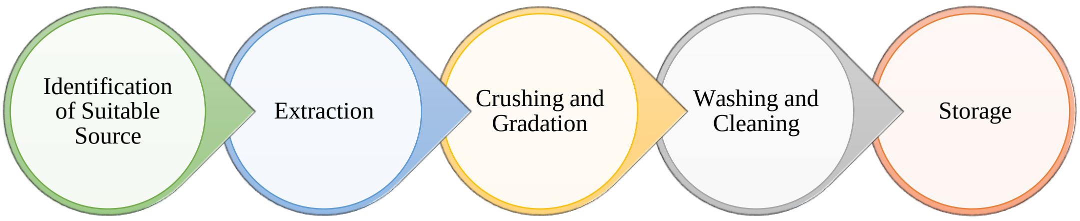

Figure 1. Normal Normal Aggregate Collection and Preparation

As it shown in Figure 1. firstly, as a source of aggregate natural aggregate was chosen. Local suppliers were surveyed for the proper aggregate. In the process of extraction, from the chosen supplier aggregate was procured and transported to transportation engineering laboratory, RUET. All the aggregate that procured were not of our required size. The aggregate was then crushed and screened to remove any oversized or undersized particles. The aggregate was cleaned by washing to remove the impurities and dust generated during crushing. Prepared aggregate was then stored for use.

2.2 Preparation Plastic Coated Aggregate Sample

The plastic-coated aggregate preparation procedure typically involves several steps. While the specific details may vary depending on the study or project, the steps involved is presented in Figure 2. In the first-place waste plastic bottles (PET) were collected. Plastics waste was washed and dried to remove any dirt and other chemicals. The clean plastic bottle was then shredded into smaller pieces (Figure 4). This process helps to increase the surface area of the plastic particles, making it easier for them to adhere to the aggregate. Shredded plastic was of around 3/4th inch to ½ inch in size. The aggregate is heated to a temperature of 200 °C to 220 °C, which allows the plastic to melt and coat the surface of the aggregate. Maintaining this temperature, 1% the shredded plastic was added slowly and continuously to the hot aggregate. During this process the aggregate was stirred continuously to create a homogeneous mixture. As a result, the plastic melted and created a coat on surface of the aggregate. After the coating process plastic coated aggregate was put to cool down and air curing at room temperature (Figure 4).

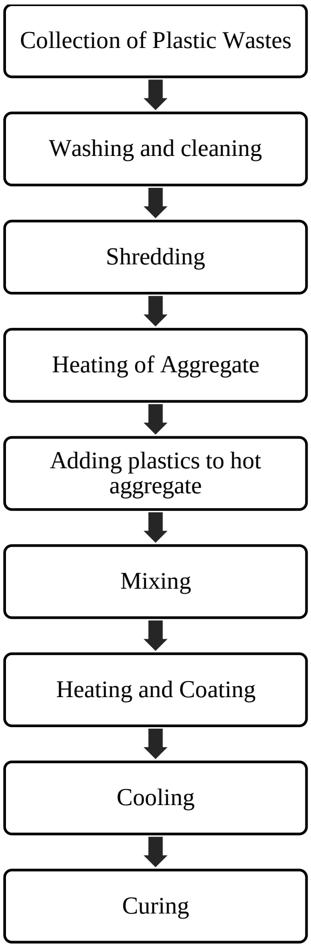

Figure 2. Plastic Coated Aggregate Preparation

Figure 3. Shredded plastic waste

Figure 4. Plastic-coated aggregate

3 Results and discussion

3.1 Aggregate Impact Value Test

The aggregate impact test is a way to measure how well aggregates can withstand impact. The aggregate impact value is a way to measure how the impact affects the aggregate. It is different from how the aggregate resists higher levels of compressive stress. The average impact value for the pavements should not be more than 30% for the top layer of the pavements. However, the highest allowed value for the paving material is 35% for bituminous Macadam and 40% for water bound Macadam base course (Khanna and Justo, 2011).

Table 1. Aggregate Impact value test on Virgin Aggregate

Sample No.	Aggregate Impact Value, AIV (%)	Average Aggregate Impact Value
1	6.86	
2	8.26	**7.44%**
3	7.20	

Table 2. Aggregate Impact value test on Plastic Coated Aggregate (PCA)

Sample No.	Aggregate Impact Value, AIV (%)	Average Aggregate Impact Value
1	5.83%	
2	5.79%	**5.80%**
3	5.77%	

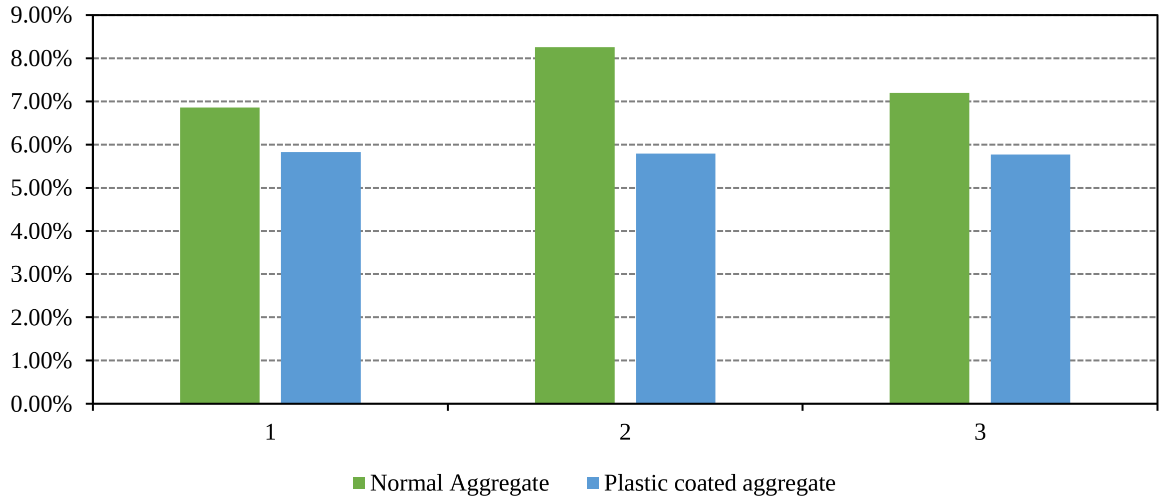

Figure 3. Aggregate Impact Value (Normal aggregate VS Plastic coated aggregate)

3.2 Aggregate Abrasion Value Test

The purpose of conducting abrasion tests is to assess the hardness of the aggregates and determine their suitability for various road construction projects. However, the most commonly used test is Los Angeles abrasion test. This test has been proven to be connected to how well a pavement will perform.

Table 3. Los Angeles Abrasion value test on Virgin Aggregate

Sample No.	Aggregate Abrasion Value, AAV (%)	Average Aggregate Abrasion Value
1	14%	
2	15.1%	14.50%
3	14.4%	

Table 4. Los Angeles Abrasion value test on Plastic Coated Aggregate (PCA)

Sample No.	**Aggregate Abrasion Value, AAV (%)**	**Average Aggregate Abrasion Value**
1	12.50%	
2	12.15%	**12.62%**
3	13.20%	

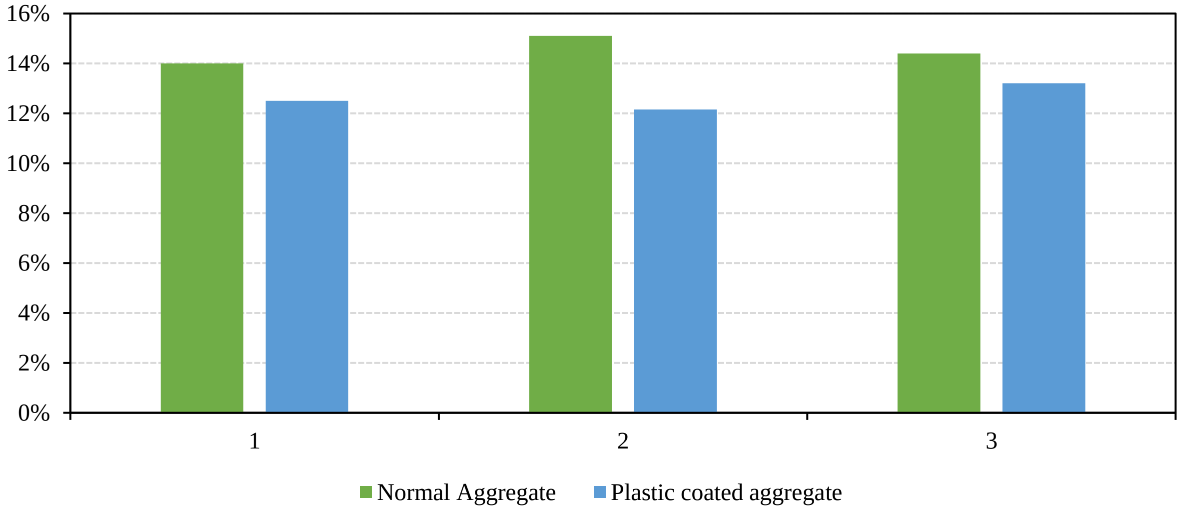

Figure 4. Aggregate Abrasion Value (Normal aggregate VS Plastic coated aggregate)

In the given scenario, the AIV value for normal aggregate is 7.44%, while for plastic coated aggregate (PCA), it is 5.80% (Table 1 & Table 2). This suggests that the PCA has a lower AIV value, indicating that it is more resistant to impact compared to the normal aggregate. In Table 3 & Table 4, the results of the Aggregate Abrasion Value (AAV) test show that the normal aggregate has a higher AAV value of 14.50% compared to the PCA with a lower AAV value of 12.62%. This difference suggests that the PCA is more resistant to abrasion than the normal aggregate. So, it is said that plastic coat on aggregate improves the resistance to impact load and abrasion.

4 Conclusion

Based on the results of both the Aggregate Impact Value (AIV) and Aggregate Abrasion Value (AAV) tests, it can be concluded that the plastic-coated aggregate (PCA) performs better than the normal aggregate in terms of impact resistance and abrasion resistance. The lower AIV value of 5.80% for PCA compared to 7.44% for normal aggregate indicates that PCA is more resistant to impact forces, suggesting a higher strength. Similarly, the lower AAV value of 12.62% for PCA compared to 14.50% for normal aggregate suggests that PCA experiences less material loss and wear during the abrasion test. This indicates a stronger and more durable structure, using PCA can be a suitable choice for applications where resistance to abrasion and impact load is crucial.

References

Al-Hadidy, A.I. and Yi-qiu, T. (2009). Effect of polyethylene on life of flexible pavements. Construction and Building Materials, Vol. 23.

Awwad M.T. and Lina, S. (2007). The Use of Polyethylene in Hot Asphalt Mixtures. American Journal of Applied Sciences 4 (6) pp-390-396.

Chavan, M. (2013). Use of Plastic Waste in Flexible Pavements. Ijaiem.Org, vol. 2, no. 4, pp. 540–552.

Gandhiraj, J., Karthikeyan V., Rajasekar, K., Rajesh Kumar, N., Santhosh Kuma, S., Sathya, P. (2018). Experimental Investigation on Road Pavement with Partial Replacement of Plastic Waste Bitumen. vol. 3, no. 4, pp. 127–133.

Islam M.M., Islam M.S., and Rahman, F.I. (2019). A Brief Study on Capacity Loss at Major Rajshahi City Roads, Bangladesh. Proceedings of International Conference on Planning, Architecture and Civil Engineering (ICPACE), Rajshahi, Bangladesh. https://doi.org/10.5281/zenodo.8263516

Islam, M.M., Shirin, M.S., Tonoy, T.R., Sweet, S.A. (2021). Modification of Bitumen PropertiesUsing Waste Polymer in Context of Bangladesh. International Journal of Mineral Processing and Extractive Metallurgy. Vol. 6, No. 1, pp. 6-11. doi: http://dx.doi.org/10.11648/j.ijmpem.20210601.12

Jayaram, R., Babu P.K., Poojaari N., Shetty A., Sanjith B. J. (2017). Partial Replacement of Bitumen by Waste Plastic in Road Construction. vol. 3, no. 6, pp. 7–12.

Khanna, S.K. and Justo, C.E.G. (2011). Highway Engineering. Nem chand & Bros. India,

Rashid, G.M.H., and Islam, M.M., (2020). A Review Paper on: Effect of Different Types of Filler Materials on Marshall Characteristics of Bitumen Hot Mix. International Journal of Materials Science and Applications. Vol. 9, No. 3, pp. 40-46.doi: http://dx.doi.org/10.11648/j.ijmsa.20200903.11

Shirin, M.S., Islam, M.M., Kumruzzaman, M., (2020). Stabilization of Coal Mine Waste and Its Practical Application as a Road Subgrade. American Journal of Traffic and Transportation Engineering. Vol. 5, No. 5, pp. 51-56.doi: http://dx.doi.org/10.11648/j.ajtte.20200505.11

Singh, P. and Yadav, R.R.K. (2016). Effect of Plastic Waste on Properties of Road Aggregate. International J. Innov. Res. Sci. Technol., vol. 2, no. 11, pp. 2012–2015.

Vasudevan, R. (2011). A technique to dispose waste plastics in an ecofriendly way – Application in construction of flexible pavements. Construction and Building Materials Vol. 8 Department of Chemistry, Thiagarajar College of Engineering, Madurai, Tamil Nadu, India, pp 311–320.

Vinoth, N. (2008). Use of plastic wastes in road construction. Central Institutes of Plastic Engineering and Technology Dhodapkar a N. Use of waste plastic in road construction. Indian Highways, Technical paper, journal, P No.31-32.