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Use of Waste Plastic as a Replacement for Bitumen in Road Construction

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Abstract

Plastic waste pollution has become a global environmental crisis, particularly due to non recyclable and low-density plastics, which contribute significantly to landfill accumulation and environmental harm. This research investigates the use of plastic waste in road con-struction as a sustainable alternative to traditional materials like bitumen and aggregates. By integrating plastic waste into road infrastructure, this study explores methods such as plastic-coated aggregates, plastic-modified bitumen, and fully plastic based roads. These approaches not only enhance the mechanical properties of roads but also help reduce the environmental footprint of construction activities.

Plastic-coated aggregates and plastic-modified bitumen improve road durability, weather resistance, and load-bearing capacity, making them more suitable for high-traffic areas and harsh climates. Furthermore, plastic roads show lower maintenance requirements, resulting in long-term cost savings. From an environmental perspective, using plastic waste in road construction helps reduce plastic pollution, curtailing the burden on landfills, and decreas-ing the energy consumption and carbon emissions associated with conventional road-building materials.

This research underscores the potential of plastic waste integration as a dual solution: ad-dressing the plastic waste crisis and promoting sustainable infrastructure. The findings highlight the eco-friendly and cost-effective nature of using plastic waste in road construc-tion, presenting it as a promising approach for the future of sustainable infrastructure de-velopment. Using waste plastic as a replacement for bitumen in road construction reduces environmental pollution, enhances road durability, reduces construction costs, minimizes plastic waste, and lowers environmental pollution. However, potential drawbacks include microplastic release, health concerns during production, and the complex waste segregation requirements.

Keywords: *Plastic, low density plastic, Plastic-Coated Aggregate, Plastic Modified Bitumen.*

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Introduction

Nepal faces a growing issue with plastic waste, generating over 1,600 tons daily. This waste contributes to significant environmental and health challenges, overloading the country's waste management infrastructure. At the same time, Nepal's road infrastructure suffers from poor quality and inadequate maintenance. To address both of these issues, there is in-creasing interest in utilizing plastic waste in road construction.

Plastic roads, which use a mixture of plastic waste and bitumen, offer several advantages over conventional asphalt roads. These include enhanced durability, better weather resistance, and increased resistance to damage from heavy vehicles. Moreover, plastic roads can be constructed with less energy and at lower temperatures, leading to reduced green-house gas emissions and energy consumption (Manju, Sathya & Sheema, 2017)

The disposal of plastic waste is a major environmental concern, particularly due contribution to landfills and its potential to harm ecosystems. Plastic pavements offer a potential solution by providing more durable and weather-resistant surfaces for roads. Plastic materials, which include thermosets and thermoplastics, are highly resistant to degradation. When waste plastic is added to hot aggregates, it forms a fine plastic coat over the aggregates, improving their strength and resistance. Additionally, the use of plastic in pavements enhances abrasion resistance and reduces shrinkage.

This study aims to assess the economic, environmental, and sustainable benefits of using plastic waste in road construction in Nepal. Specifically, the research will compare the cost-effectiveness, environmental impact, and potential for waste management in using plastic-coated roads versus conventional asphalt roads (Poudyal, Amatya & Marsani., 2022).

Objectives

The objectives of this study are:

- To evaluate the potential use of low-density polyethylene (LDPE) plastic as a partial replacement for bitumen in road construction.
- To assess the impact of plastic-modified bitumen on the mechanical properties of asphalt.
- To analyze the environmental and economic benefits of using plastic waste in road construction.
- To determine the feasibility of incorporating waste plastic into road construction materials in Nepal.

Literature Review

Stated that the polymer bitumen blend is a better binder compared to plain bitumen. Blend has increased the softening points and decrease Penetration value with a suitable ductility. (Rajasekaran, Vasudevan & Paulraj, 2013)

Many researches on PMA mixture have been conducted for the past two decades. Although addition of virgin polymers to asphalt for the purpose of enhancing the properties of asphalt over a wide temperature range in paving applications was contemplated quite some time ago, recycled polymer added to asphalt have also showed almost the same result in improving the road pavement performance as compared to virgin polymers. This paper is a review of the use of polymers in asphalts pavement. In this study, a critical review on the history and its benefits of using waste and virgin polymer in asphalt is presented followed by a review of general studies on using polymers n asphalt in order to improve the properties of pavement (Kalantar,Karim & Mahrez, 2012).

The quantum of plastic waste in municipal solid waste (MSW) is increasing due to increase in population, urbanization, development activities and changes in life style which leading widespread littering on the landscape. Thus disposal of waste plastic is a menace and be-came a serious problem globally due to their non-biodegradability and unasthetic view. Since these are not disposed scientifically and possibility to create ground and water pollution. This waste plastic partially replaced the conventional material to improved desired mechanical characteristics for particular road mix. In conventional road making process

bitumen is used as a binder. Such bitumen can be modified with waste plastic pieces and bitumen mix is made which can be used as a top layer coat of flexible pavement. This waste plastic modified bitumen mix show better binding property, stability, density and more resistance to water. (Gawande et al., 2012)

Minimization of waste material is important aspect of the modern growth and development initiatives. Plastic is used in various domestic and industrial applications. Use of plastic bags and bottles is very common. The disposal of plastic waste is major problem due to non-biodegradable nature of plastic. The plastic can be used as feedstock for ethanol like products. It can be used for road construction and other construction related activities. The current review summarizes the research on use of waste plastic (Kulkarni, 2017.).

In the highway infrastructure, a large number of original materials and technologies have been invented to determine their suitability for the design, construction and maintenance of these pavements. Plastics and rubbers are one of them. Also considering the environmental approach, due to excessive use of polythene in day to day business, the pollution to the environment is enormous. The use of plastic materials such as carry bags, cups, etc. is constantly increasing day by day. Since the polythene are not biodegradable, the need of the current hour is to use the waste polythene in some beneficial purposes. The use of these materials as a road construction proves eco-friendly, economical and use of plastic gives (Chhabra & Marik, 2014).

Methodology

The methodology section outlines the systematic process followed to integrate waste plastic into road construction materials. This process was designed to evaluate the potential benefits of using plastic waste as a substitute for bitumen, focusing on improving road durability and sustainability while addressing plastic waste management issues. The methodology consists of the following key steps:(see Figure 1 and 2)

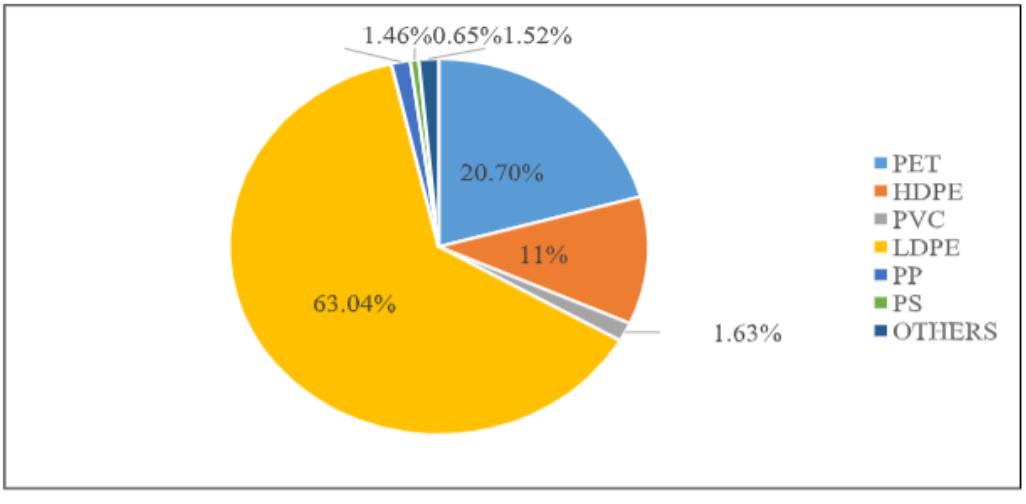

Figure 1: Percentage of different category of plastics

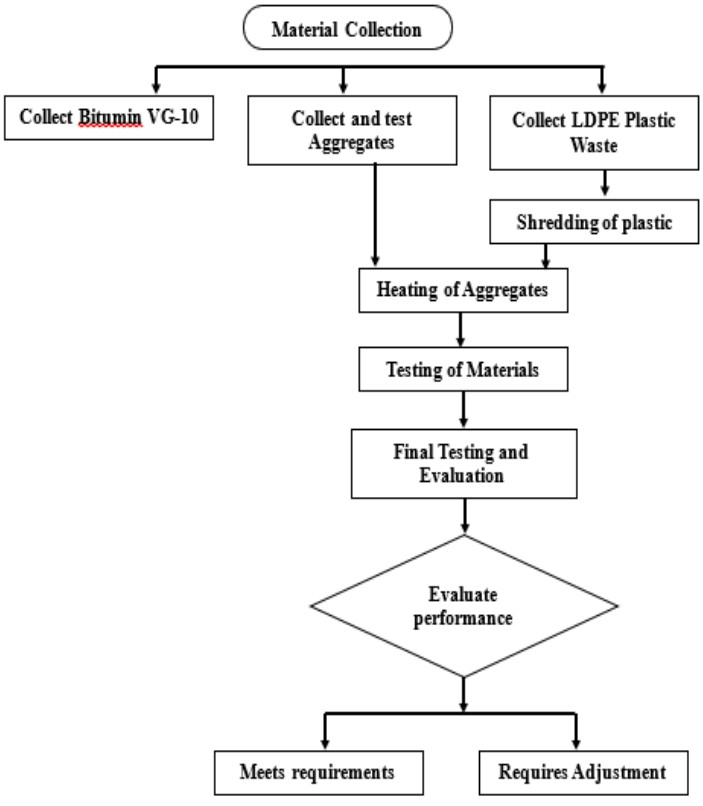

Figure 2: ***Flowchart illustrating the methodology for integrating plastic waste into road construction.***

Results and Discussions

Results of the Tests Conducted on Normal Aggregate with Plastic-Coated Aggregate

a. Aggregate Crushing Value

The crushing value reduces from 28.80% to 19.20% for normal and plastic-coated aggregate.

The Lower the aggregate crushing value, the higher is the strength.(see Table 1)

Table 1: Test result of Aggregate Crushing Value of Normal Aggregate Vs Plastic-Coated Aggregate

Test	Normal Aggregate (%)	Plastic-Coated Aggregate (%)
Aggregate Crushing Value	28.80	19.20

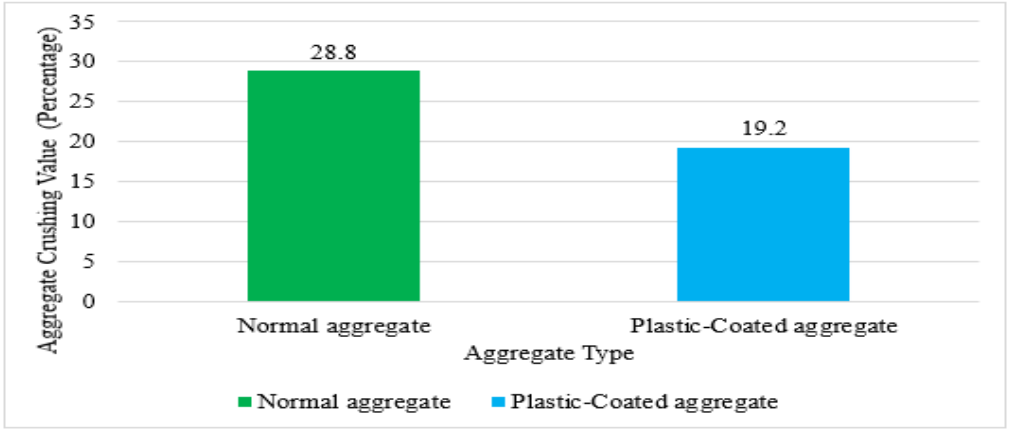

Figure 3: Bar chart illustrating aggregate crushing value of Normal aggregate Vs Plastic-coated aggregate

Discussion: The results show a significant reduction in crushing value when plastic-coated aggregates are used. The lower crushing value indicates that the plastic-coated aggregates have higher strength and better resistance to crushing compared to the normal aggregates.(see Figure 3)

b. Los Angeles Abrasion Test

The Los Angeles Abrasion value reduces from 30% to 17% for normal and plastic-coated aggregate. Lower the Los Angeles value, higher is the strength.

Table 2: Test result of Los Angeles Abrasion Value of Normal Aggregate Vs Plastic-Coated Aggregate

Test	Normal Aggregate (%)	Plastic-Coated Aggregate (%)
Los Angeles Abrasion Value	30	17

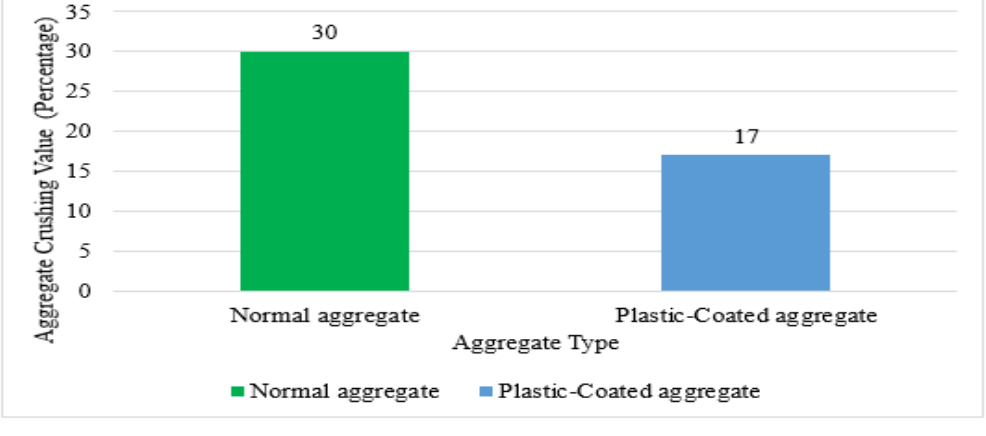

Figure 4: Bar chart illustrating los angeles abrasion value of Normal aggregate Vs Plas-tic-coated aggregate

Discussion: The results show that plastic-coated aggregates perform better than normal aggregates in terms of abrasion resistance. The reduction in abrasion value suggests that the use of plastic in aggregates enhances the material's resistance to wear, making the roads more durable.(see Figure 4)

c. Impact Test

The aggregate impact value reduces from 21.97% to 5.71% for normal and plastic-coated aggregate. Lower the aggregate impact value, higher is the strength.

Table 3: Test result of Aggregate Impact Value of Normal Aggregate Vs Plastic-Coated Ag-gregate

Test	Normal Aggregate (%)	Plastic-Coated Aggregate (%)
Aggregate Impact Value	21.97	5.71

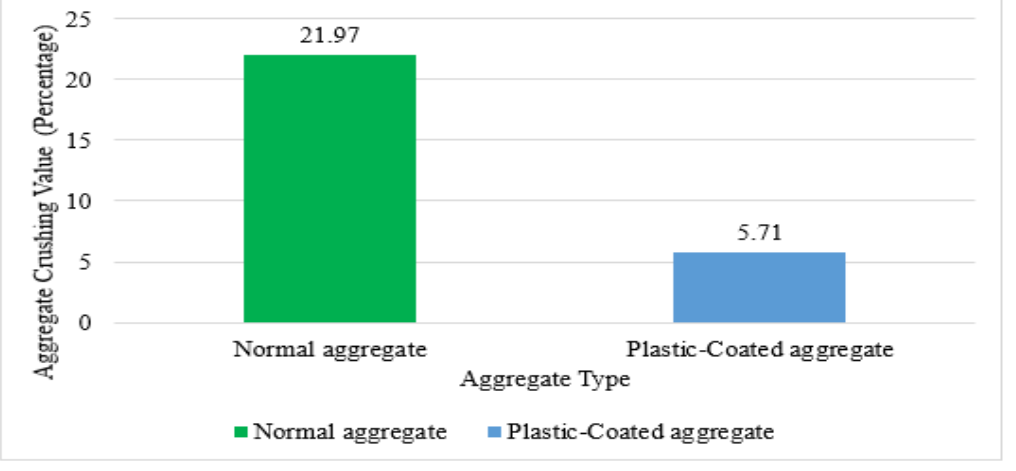

Figure 5: Bar chart illustrating aggregate impact value of Normal aggregate Vs Plastic-coated aggregate

Discussion: The impact test results show a significant improvement when using plastic coated aggregates. The lower impact value indicates higher resistance to sudden shocks or impacts, which enhances the durability and longevity of the road.(see Figure 5)

Results of the Tests Conducted on Normal Bitumen with Plastic-Modified Bitumen

1) Penetration Test

Table 4: Test result of Penetration Value of Bitumen vs Penetration Value (mm) Modified Bitumen

S. No	Penetration Value (mm) Normal Bitumen	Penetration Value (mm) Modified Bitumen
1	114	37
2	140	41
3	142	44
Mean	132	40.67

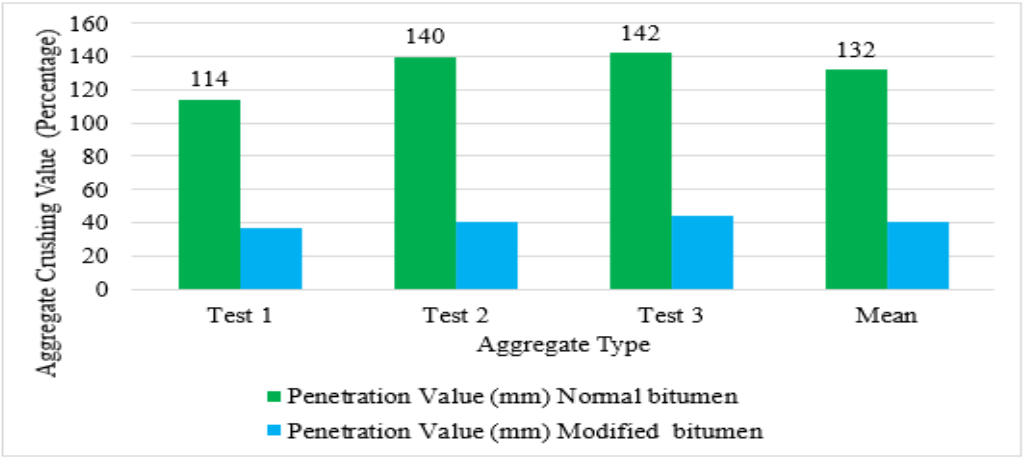

Figure 6: Bar chart illustrating the penetration value of Normal Bitumen Vs Plastic Modified Bitumen

Discussion: The penetration value of bitumen mixed with plastic is lower than that of conventional bitumen. A lower penetration value indicates better durability and quality, sug-gesting that the plastic-modified bitumen has enhanced resistance to deformation.(see Figure 6)

2)Ductility Test D

Table 5: Test result of Ductility Value of Bitumen vs Ductility Value (cm) Modified Bitumen

S. No	Ductility Value (cm) Normal Bitumen	Ductility Value (cm) Modified Bitumen
1	85	28
2	90	29
3	87	32
Mean	87.33	29.67

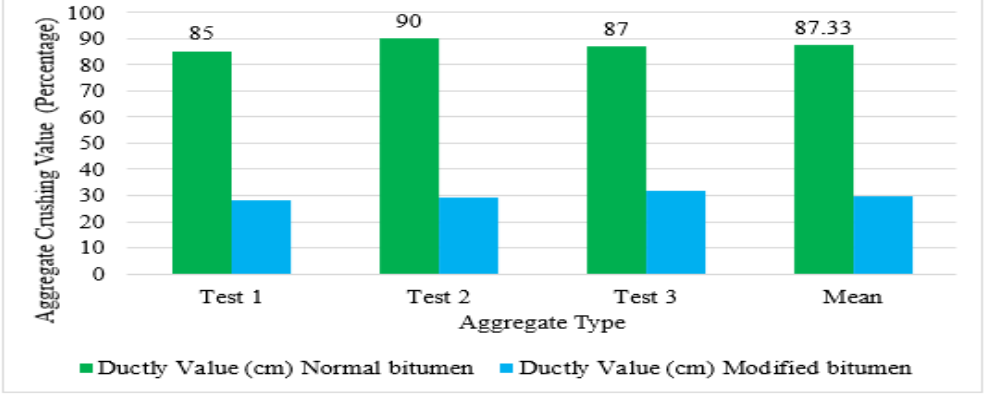

Figure 7 : Bar chart illustrating the ductility value of Normal Bitumen Vs Plastic Modified Bitumen

Discussion: The ductility value of bitumen decreases when plastic is added. This indicates that the plastic-modified bitumen is less flexible, but it can still offer greater strength and resistance to weathering.(see Figure 7)

3) Marshall Test

Table 6: Test result of Marshall and Flow Value of Conventional Asphalt Vs Plastic-Coated Asphalt

S. No	Marshall value (Conventional Asphalt)	Marshall Value (Plastic Coated Asphalt)	Flow Value (Conventional Asphalt)	Flow Value (Plastic Coated Asphalt)
1	8	11.2	2.5	3
2	9	11.7	3	3.2
3	9.07	11.6	2.9	3.1
Mean	8.69	11.5	2.8	3.1

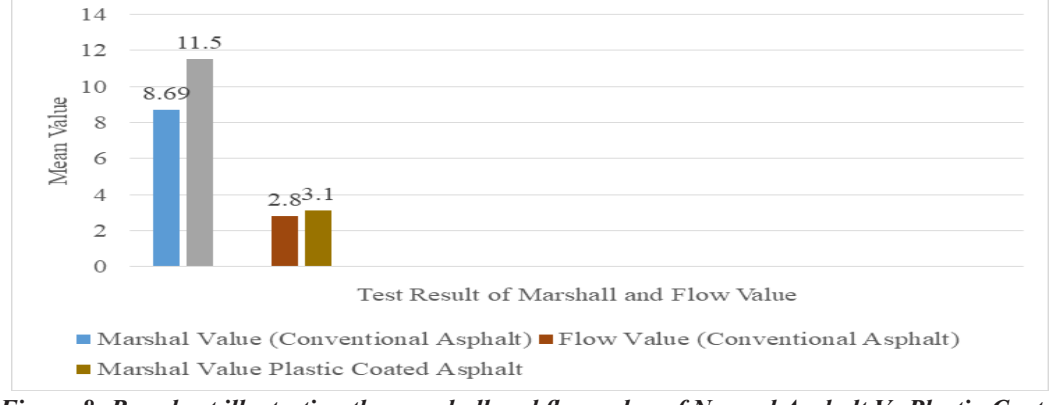

Figure 8: Bar chart illustrating the marshall and flow value of Normal Asphalt Vs Plastic-Coated Asphalt

Discussion: The results of the tests show that plastic-coated asphalt performs better than conventional asphalt in terms of both Marshall Stability and Flow Value. Plastic-coated asphalt shows improved resistance to deformation under load and higher stability, while also offering a more flexible and durable road surface. The mean values for Marshall Sta-bility and Flow Value demonstrate the advantage of using plastic waste in road construction, highlighting both mechanical and economic benefits. The results suggest that incorporating plastic waste into asphalt can lead to longer-lasting roads with reduced maintenance costs and enhanced performance.(see Figure 8)

Economic Analysis

One of the primary factors to be considered in any technology, especially in the global market, is the economic aspect. To compare the cost of construction between a conventional asphalt road and a plastic-coated asphalt road, we consider a road with the following dimensions:

- Width of road: 3.75 meters

- Distance of road: 1 kilometer

Cost of Bitumen:

The cost of bitumen is Rs. 120 per kg (current rate in Nepal). Generally, for constructing 1 km of a conventional asphalt road, 10 tons of bitumen is required. Therefore, the cost of bitumen per km for a conventional asphalt road is:

Cost of bitumen per km = 10,000 kg × Rs. 120 = Rs. 1,200,000

Cost of Plastic-Coated Bituminous Road:

It has already been discussed that 15% of plastic is used in the construction of a plastic coated asphalt road. The bitumen required for this type of road is:

- Plastic-coated bituminous road:
- Amount of bitumen required = 9,000 kg
- Cost of bitumen for plastic-coated bituminous road = 9,000 kg × Rs. 120 = Rs. 1,080,000
- Amount of plastic required = 1,000 kg (15% of bitumen required).

Therefore, the total cost for the plastic-coated bituminous road is:

Cost of plastic-coated bituminous road = Rs. 1,080,000 (bitumen 85% and 15%plastic)

Savings in Construction Per Km:

The savings when using plastic-coated bituminous road construction compared to conven-tional asphalt road construction can be calculated as:

Savings per km = Cost of bitumen for conventional asphalt road – Cost of bitumen and plastic for plastic-coated asphalt road

Savings per km = Rs. 1,200,000 – Rs. 1,080000 = Rs. 120,000

Therefore, using plastic-coated bitumen roads results in a savings of Rs. 120,000 per km of road constructed.(see Table 7)

Economic Comparison

Table 7: Economic Comparison of Conventional Asphalt Vs Plastic-Coated Asphalt

Road Type	Bitumen Required (kg)	Cost of Bitumen (Rs.)	Cost of Plastic (Rs.)
Conventional Asphalt	10,000	Rs. 1,200,000	N/A
Plastic-Coated Asphalt	9,000	Rs. 1,080,000	N/A

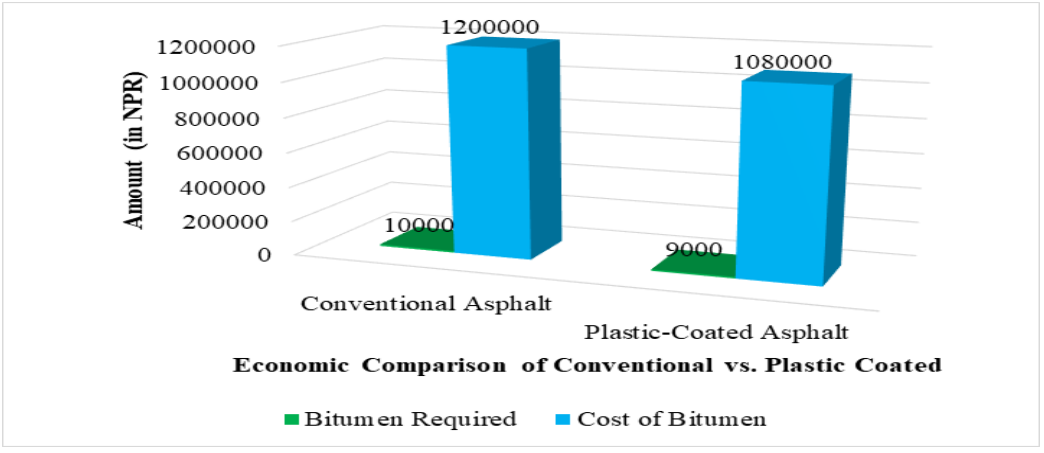

Figure 9: Bar chart illustrating the economic comparision of Conventional Asphalt Vs Plas-tic-Coated Asphalt

Discussion: The economic analysis shows that using plastic-coated asphalt roads results in significant savings in construction costs. By using 15% plastic waste as a replacement for part of the bitumen, the cost of bitumen per kilometer of road is reduced by Rs. 120,000. This reduction in cost is due to the lower amount of bitumen required and the eco-friendly nature of using waste plastic in road construction. The incorporation of plastic waste reduces not only the cost of road construction but also contributes to waste management, offering dual environmental and economic benefits.(see Figure 9)

Summary of Findings and Comparison

The following table summarizes the key properties of Plastic Asphalt Roads and Conven-tional Asphalt Roads based on a comparison of their performance in various tests. The findings from the comparison indicate significant differences in key aspects such as compressive strength, impact value, abrasion value, and economic impact.

Comparison of Properties

Table 8: Comparison of Properties of Conventional Asphalt Vs Plastic-Coated Asphalt

S.N	Properties	Plastic Asphalt Road	Conventional Asphalt Road
1	Compressive Strength	More	Less
2	Impact value	Less	More
3	Abrasion Value	Less	More
4	Penetration Value	Less	More
5	Ductility	Less	More
6	Marshall Stability Value	More	Less
7	Durability	More	Less
8	Economic	More	Less

Conclusion

In conclusion, the integration of plastic waste into road construction is a promising strategy that can lead to more durable, cost-effective, and environmentally friendly infrastructure solutions. The findings of this study support the idea that plastic-modified bitumen can serve as a practical alternative to traditional materials, offering substantial benefits in terms of mechanical properties, economic savings, and environmental impact. This approach has the potential to revolutionize road construction practices, providing a sustainable path for-ward for countries grappling with plastic waste and infrastructure challenges.(see Table 8)

Recommendations

The implementation of these recommendations will help improve the efficiency, sustainability, and performance of plastic-modified asphalt in road construction. Further research, optimized usage of plastic, and supportive policy frameworks will contribute to the wide-spread adoption of this innovative solution. By addressing both the challenges of plastic waste management and road infrastructure development, plastic-coated bituminous roads offer a sustainable and cost-effective alternative to traditional road construction methods. The combination of technological innovation, economic savings, and environmental benefits makes plastic roads a viable solution for the future of infrastructure development, particularly in countries with significant waste management challenges.

References

Chhabra, R. S., & Marik, S. (2014). A review literature on the use of waste plastics and waste rubber tyres in pavement. Int J Core Eng Manag, 1(1), 1–5.

Gawande, A., Zamare, G., Renge, V. C., Tayde, S., & Bharsakale, G. (2012). An overview on waste plastic utilization in asphalting of roads. Journal of Engineering Research and Studies, 3(2), 1–5.

Kalantar, Z. N., Karim, M. R., & Mahrez, A. (2012). A review of using waste and virgin polymer in pavement. Construction and Building Materials, 33, 55–62.

Kulkarni, S. (2017). Paper Waste Recycle and Its Sludge Reduction - Towards Waste and Cost Minimization. International Journal of Research & Review (www.gkpublication.in), [online] 4(10), p.19. Available at: https://www.ijrrjournal.com/IJRR_Vol.4_Issue.10_Oct2017/IJRR004.pdf.

Manju, R., Sathya, S., & Sheema, K. (2017). Use of plastic waste in bituminous pavement. Int J ChemTech Res, 10(08), 804–811.

Poudyal, N., Amatya, I. M., & Marsani, A. (2022). Utilization of Plastic Wastes to Improve the Properties of Bitumen in Road Construction in Nepal.

Rajasekaran, S., Vasudevan, R., & Paulraj, S. (2013). Reuse of waste plastics coated aggregates-bitumen mix composite for road application—green method. American Journal of Engineering and Research, 2(11), 1–13.