Proceedings of 12th IOE Graduate Conference
Peer Reviewed
ISSN: 2350-8914 (Online), 2350-8906 (Print)
Year: 2022 Month: October Volume: 12

Utilization of Plastic Wastes to Improve the Properties of Bitumen in Road Construction in Nepal

Nabin Poudyal [a], Iswar Man Amatya [b], Anil Marsani [c]

[a, b, c] *Department of Civil Engineering, Pulchowk Campus, IOE, Tribhuvan University, Nepal*
[a]nabin.poudyal51@gmail.com, [b]iswar@ioe.edu.np, [c]anilmarsani@ioe.edu.np

Abstract
Waste plastics are very common in world. Plastics, being easy to carry, are extensively popular in every type of profession. But in the environmental point of view it poses alarming threat to the nature as they are non biodegradable. In the present scenario, waste disposal methods that are adopted have not been able to completely eradicate the plastic wastages which have a negative impact on the environment and health of human. Due to varied application of the plastic, the plastic related waste production cannot be completely eliminated rather it can be reduced and recycled and reused in different sectors through technological innovations. One of promising options to utilize the waste plastic is to mix the waste plastic to modify the bituminous mixes used for paving roads. In this study Low Density Polyethylene (LDPE) plastic waste is used for modification of bitumen. From municipal solid waste, plastic waste is separated. The plastic wastes (LDPE) were cleaned and were cut into 2.36 mm to 4.75 mm conformed from previous research. Bitumen was then heated to 160 to 170℃ and plastic waste in shredded form was slowly added in equal proportion. The comparative properties of bitumen and plastic waste modified bitumen in terms of penetration value, ductility value, softening point value, viscosity value, flash and fire point values tests showed the decrement in penetration and ductility value and increment in softening point and viscosity as the proportion of plastic waste percentage by weight of bitumen is increased. Flash and fire point value observed was almost the same nature even with increase in plastic waste content. The results from this study showed the addition of plastic waste to the normal bitumen improves the characteristic properties and strength as well as stiffness, temperature susceptibility and consistency of bitumen.

Keywords
Bitumen, Low density polyethylene, Plastic waste modified bitumen, Plastic waste

1. Introduction

1.1 Background

Nepal is still struggling with the challenges of management of its Municipal Solid Waste (MSW). The situation is worse in case of plastics as it gets piled up in landfill site, burning and piling up in the river side [1] without any proper mechanism of reuse and recycle. As much as 4900 tons of solid waste generated by urban Nepal every day, 13% contains plastic waste [2]. Plastics are extensively preferred by the user but due to its non-degradable nature, it can remain on earth for years without degradation. The everyday pictures of heaps of garbage dumped everywhere, at the roadside, in open spaces, river and streams challenging the city environment, clogging drains, evading river and streams causing bad smell in dry season and flooding of urban space in rainy season. The best approach for solid waste management is to use 3R's approach i.e. Recycle, Reuse and Reduce waste. Due to varied application of the plastic, the plastic related waste production cannot be completely eliminated hence alternatively be reduced and recycled and reused in different sectors through appropriate technological innovations.

Bitumen is the prime ingredient which is used as binding agent for the flexible pavement construction in Nepal. Difficult topography, geological complexities and unscientific road networking in Nepal results in uneven traffic distribution and traffic loads aggravated by adverse climatic condition. The Normal Bitumen (NB) is now not capable enough to withstand this large number and heavy load of traffic for a considerable time. The eco-friendly solution to the strengthening of bitumen properties and reduction of plastic wastes is modification of bitumen through the addition of plastic polymer in appropriate proportion to obtain the desired bituminous properties. This process is anticipated to have economic benefits in terms of reduced cost for plastic waste management, restoration of natural environment, as well as reduced cost of maintenance of pavement due to reduced exposure to defects and reduced traffic disturbances [3].

1.2 Research Objectives

The overall objective of this study focuses on improvement of property of bitumen by the addition of plastic waste. The particular objectives are:

- To find out the status of different categories of plastic wastes in Kathmandu valley.
- To investigate the properties of normal bitumen and waste plastic modified bitumen.

1.3 Limitations of the Study

The limitations of the research work are:

- The research work was limited to the Low Density Polyethylene (LDPE) Plastic.
- The thickness of LDPE plastic was limited to 60 microns.
- Only Laboratory scale tests were executed.

2. Literature Review

The bitumen binder can be modified with plastic polymer to be used as wearing layer of flexible pavement. The suitable mix proportion of plastic is observed in the range of 5% to 10% by weight of bitumen [4]. According to Prof. C.E.G. Justo, the use of 8.0% plastic by weight of bitumen binder results in a reduced use of bitumen by 0.4% by weight of the bituminous mix. The stability, strength, durability, and other desired properties of bituminous mix are all enhanced by plastic modification of bitumen [5]. The softening point value of plastic is at around 130°C and no gas evolution has been observed at the temperature range of 130 to 180°C as per Thermo gravimetric analysis. The binding property developed by softened plastic can be suited for road construction as a binder material [6]. The bitumen blend modified with plastic resulted in improved properties in terms of binding, density, stability and water resistance [7], as well as increment in softening point value, decrement in penetration value with acceptable ductility [8]. The low density polyethylene and polypropylene in bituminous mixes which are predominant in recycled plastic waste improves the durability and enhanced fatigue life of bituminous or asphalt concrete mix [9].

3. Methodology

Plastic Modified Bitumen was prepared first followed by laboratory tests for modified bitumen. The detailed procedure is explained below.

3.1 Field Studies of Plastic Wastes

Field studies were made at the Teku transfer station and the local municipality offices were visited during this study. During the field studies, the plastic wastes in the MSW were classified and their proportion was identified. The result of Table 1 shows that the amount of plastic waste in Kathmandu valley was found to be 10.79%. The different categories of Plastics like PET 20.70, HDPE 11.00, PVC 1.63, LDPE 63.04, PP 1.46, PS 0.65 and others 1.52% respectively are shown Figure 1.

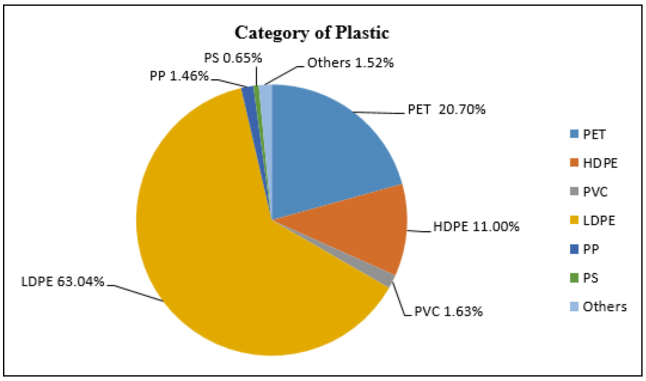

Figure 1: Percentage of different category of plastics

Table 1: Field Study of Plastic Waste

Waste Station	Total Waste Kg	Plastic Waste Kg	Percentage of Plastic Waste
Teku Transfer Station	42.65	4.60	10.79

3.2 Material Collection

The used waste plastics were low density polyethylene (LDPE) of 60 micron or below from household wastes and used bitumen was viscosity grade 10 (VG 10) bitumen from Samanantar Asphalt Plant, Jagati.

3.3 Requirement of Bitumen and Test Methods

As per Standard Specifications for Road and Bridge Works [10], the requirement of bitumen is shown in Table 2 and Table 3.

Table 2: Bitumen Conformation Test Methods (VG10)

Bitumen Test	Specification Limit	Method of Test
Penetration value at 25°C, 100 g, 5 s, 0.1 mm, Min	80	NS: 221:2047 (Part III)/ IS:1203
Absolute viscosity value at 60°C, Poises	800 to 1200	NS: 237:2050 (Part VIII)/ IS: 1206-2
Kinematic viscosity at 135°C. cSt, Min	250	NS: 237:2050 (Part VIII)/ IS: 1206-3
Flash point (Cleveland open cup), °C, Min	220	NS: 237:2049 (Part VII)/ IS:1448-69/ IS:1209
Softening point, (R&B), °C, Min	40	NS / IS: 1205
Ductility at 25°C, cm, Min	75	NS: 221:2046 (Part I)/ IS: 1208

Table 3: Bitumen Conformation Test Methods (VG40)

Bitumen Test	Specification Limit	Method of Test
Penetration value at 25°C, 100 g, 5 s, 0.1 mm, Min	35	NS: 221:2047 (Part III)/ IS:1203
Absolute viscosity value at 60°C, Poises	3200-4800	NS: 237:2050 (Part VIII)/ IS: 1206-2
Kinematic viscosity at 135°C. cSt, Min	400	NS: 237:2050 (Part VIII)/ IS: 1206-3
Flash point (Cleveland open cup), °C, Min	220	NS: 237:2049 (Part VII)/ IS:1448-69/ IS:1209
Softening point, (R&B), °C, Min	50	NS / IS: 1205
Ductility at 25°C, cm, Min	25	NS: 221:2046 (Part I)/ IS: 1208

The specification limit requirements of other types of bitumen- VG20 and VG30 lies between that of requirements of VG10 and VG40 as shown in Table 2 and Table 3 [10].

3.4 Preparation and Testing of Plastic Modified Bitumen

The basic process involved in preparation of plastic modified bitumen are

3.4.1 Cleaning and Shredding of Waste Plastic

- The waste plastics were shredded or cut into small pieces (2.36mm – 4.75 mm).

3.4.2 Mixing of Shredded Waste Plastic with Bitumen[7][4]

- The wet process was employed.
- The bitumen was first heated to 160°C to 170°C.
- The plastic waste in shredded form was then added in equal proportion.
- The mixture was stirred for about 30-60 minutes for homogenous mixtures.
- The percentage plastic wastes of 2, 4, 6, 8 and 10% by weight of the bitumen was used for bitumen modification.

3.4.3 Laboratory Testing of Plastic Modified Bitumen

Plastic-bitumen were mixed in different proportion and laboratory experiments were carried out to find following values: [11]

- Penetration value,
- Ductility value,
- Softening point value,
- Fire and flash point value and
- Viscosity value

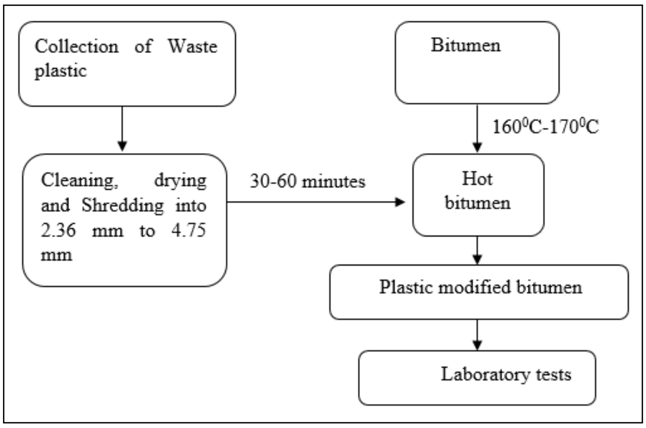

Figure 2: Methodology flow chart for plastic modified bitumen (wet process)[7][4]

4. Results and Discussions

4.1 Penetration Test Result

Penetration test values for normal and plastic modified bitumen is shown in the Table 4.

Table 4: Penetration Value Test Result

Method of Test	Plastic Waste (%)	Penetration, 0.1 mm
NS: 221:2047 (Part III)/ IS: 1203	0 (Pure Bitumen)	92.11
	2	76.22
	4	65.11
	6	52.44
	8	44.44
	10	37.22

A plot of penetration value against percentage of plastic waste content is shown in Figure 3. This shows that penetration (0.1 mm) value decreases on uniform basis with increase of percentage plastic waste content.

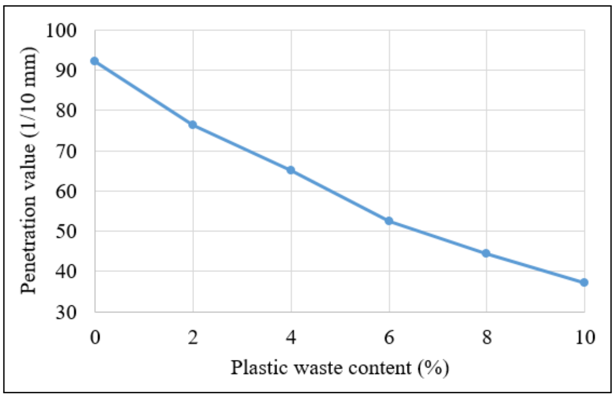

Figure 3: Plotting of plastic waste content percentage against penetration value

From this result it can be said that plastic waste increases the consistency of bitumen. This reduces the susceptibility of bitumen to degradation and helps it withstand rutting type deformation.

4.2 Result of Ductility Value Test

Ductility test values for normal and plastic modified bitumen is shown in the Table 5. A plot of ductility value against percentage of plastic waste content is shown in Figure 4. This shows that sharp decrease in ductility value as the plastic waste content percentage increases in the bitumen. This suggests that the ductility value of normal bitumen is significantly impacted by the addition of plastic waste for modification.

Table 5: Ductility Value Test Result

Method of Test	Plastic Waste (%)	Ductility at 25°C, cm
NS: 221:2046 (Part I)/ IS: 1208	0 (Pure Bitumen)	100
	2	93
	4	69
	6	45.67
	8	30.33
	10	19.67

Huge reduction in ductility of bitumen is disagreeable for use as paving material. Hence the optimal plastic content in bitumen shall have to be traded between decreased ductility. Table 2 and Table 3 suggests that ductility should remain between 75 and 25. Figure 4 shows that more than 8% of plastic waste in bitumen decreases the ductility value below 25. This indicates that 8% of plastic waste is the optimum percentage for bitumen modification by plastic waste..

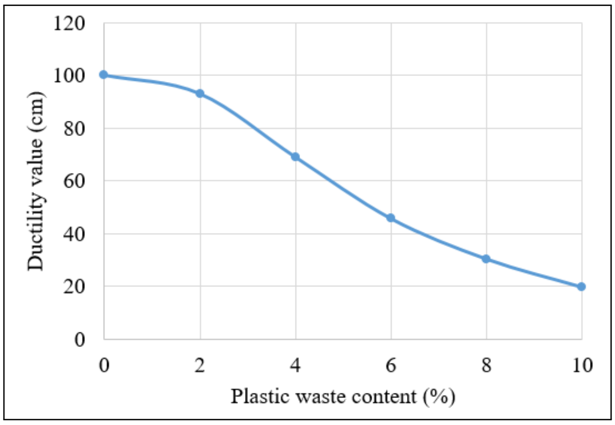

Figure 4: Plotting of plastic waste content percentage against ductility value

4.3 Softening Point Test Result

Softening point variation for normal bitumen and bitumen modified by plastic waste is listed in the Table 6.

Table 6: Softening Point Value Test Result

Method of Test	Plastic Waste (%)	Softening point, (R&B), °C
NS/IS: 1205	0 (Pure Bitumen)	45.50
	2	49.50
	4	55.25
	6	61.50
	8	68.25
	10	70.00

A plot of softening point value against percentage of plastic waste content is shown in Figure 5. This shows that the increase of softening point value occurs due to the increase in plastic waste percentage. The increment in softening point with the increased percentage of plastic waste in bitumen illustrate decrease in temperature susceptibility in case of bitumen modified by plastic waste. Thus bitumen modified by plastic waste can help lessen the problem of segregation and bleeding in high temperature areas and resistant to rutting in road pavements.

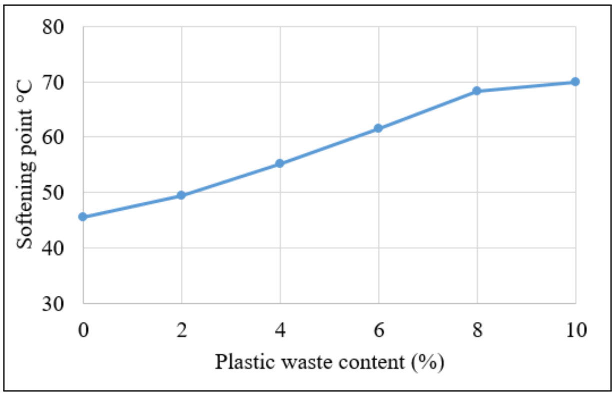

Figure 5: Plotting of plastic waste content percentage against softening point value

4.4 Fire and Flash Point Test Result

Fire and Flash point test values for normal and plastic modified bitumen is shown in the Table 7.

A plot of fire and flash point values against percentage of plastic waste content is shown in Figure 6. It is seen the initial increment in fire as well as flash point up to 6% of plastic waste content by weight of bitumen and then it is seen decrease in the fire or flash point value. It is found justifiable in safety considerations.

Table 7: Fire and Flash Point Value Test Result

Method of Test	Plastic Waste (%)	Flash Point Value (°C)	Fire Point Value (°C)
NS: 237:2049 (Part VII)/ IS:1448 69	0 (Pure Bitumen)	323	337
	2	326	340
	4	330	346
	6	335	350
	8	319	331
	10	303	314

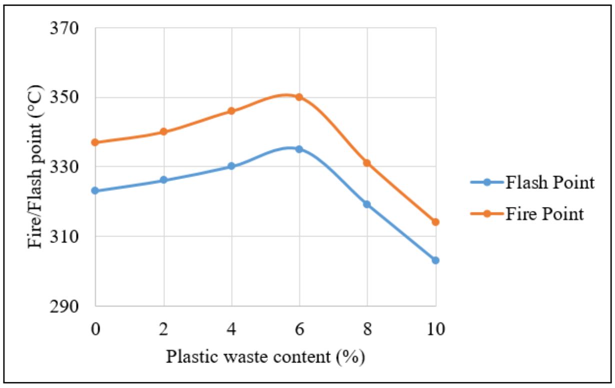

Figure 6: Plotting of plastic waste content percentage against fire and flash point value

4.5 Kinematic Viscosity Test Result

Kinematic Viscosity Test values for normal and plastic modified bitumen is shown in the Table 8.

A plot of kinematic viscosity value against percentage of plastic waste content is shown in Figure 7. This shows that as the plastic waste percentage rises, the kinematic viscosity value increases which means that the positive effect on viscosity with increased plastic waste content occurs. With the increased viscosity property of bitumen modified by plastic waste shall counterbalance recurring distress of rutting type permanent deformations, observed in existing conventional road pavements.

Table 8: Kinematic Viscosity Value Test Result

Method of Test	Plastic Waste (%)	Kinematic viscosity at 135°C. cSt
NS: 237:2050 (Part VIII)/ IS: 1206-3	0 (Pure Bitumen)	272
	2	336
	4	414
	6	511
	8	602
	10	653

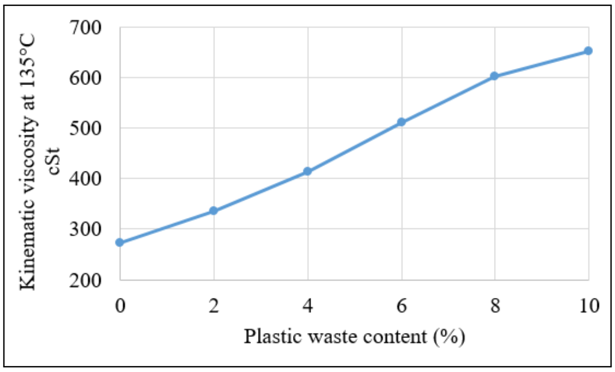

Figure 7: Plotting of plastic waste content percentage against kinematic viscosity value

5. Conclusions

- No objectionable gases are detected coming from the heated plastic waste throughout the laboratory process of making plastic waste modified bitumen.
- It was found from the field demonstration that there was a plenty of low density polyethylene (LDPE) plastic waste available. Because of this, there is no shortage of plastic waste on the market.
- As the amount of plastic waste in bitumen increases, the penetration value of the bitumen modified by plastic waste decreases. When 8% plastic waste is added to the bitumen, it has been found that penetration value is reduced by more than 50% as compared to normal bitumen. This reduces the binder's susceptibility to degradation and helps it withstand rutting type deformation.
- As more plastic waste is added to bitumen, the ductility value of the bitumen modified by plastic waste rapidly declines. According to results of an experimental examination, bitumen with an 8% plastic waste component loses more than 69% of its ductility when compared to bitumen that is normal.
- As the amount of plastic waste in bitumen rises, so does the softening point. In the case of 8% plastic waste component compared to normal bitumen, the softening point rises by around 33%. The bitumen modified by plastic waste will be less sensitive to temperature variations with the inclusion of plastic waste.
- Fire and flash point of bitumen modified by plastic waste are almost equal to normal bitumen.
- Viscosity increases as the percentage of plastic waste in the bitumen increases. High viscosity means less chances of rutting.
- From these findings it is concluded that adding plastic waste to the normal bitumen improves the design life, characteristic properties and strength of the mix. Stiffness, temperature susceptibility, consistency and other fundamental properties of bitumen are improved also.
- The use of 8% plastic waste to the bitumen is considered the optimum plastic content for bitumen modification by plastic waste. This plastic waste percentage can make the road pavement able to withstand heavy traffics and high temperatures.
- Economic and environmental point of view indicates that uses of plastic waste for bitumen modification can help reduce problems of waste disposal and improve road pavement quality.
- As the plastic waste modification of bitumen has the potential on making road pavement durable, reducing costs of construction and frequency of maintenance, it has great potential and prospect in terms of conditions of weather and construction practices of road in Nepal.

6. Recommendations

The development of a comprehensive project for the plastic waste processing and the use of bitumen modified by plastic waste to build roads is recommended for government agencies.

Acknowledgments

The authors acknowledge Everest Laboratory Private Limited, Kathmandu for providing space for the laboratory. The authors are also grateful for the support from the Civil Engineering Department of Pulchowk Campus, Lalitpur.

References

[1] CBS. *Waste Management Baseline Survey of Nepal 2020*. Central Bureau of Statistics, 2021.

[2] WB. *Assessment of SWM Services and Systems in Nepal*. World Bank Group, 2020.

[3] B Aforla, A Woode, DK Amoah, and SY Baako. Assessment of suitability of plastic waste in bituminous pavement construction. *Civil and Environmental Research*, 7(11):1–6, 2015.

[4] Vidula Swami, Abhijeet Jirge, Karan Patil, Suhas Patil, Sushil Patil, and Karan Salokhe. Use of waste plastic in construction of bituminous road. *International Journal of Engineering Science and Technology*, 4(5):2351–2355, 2012.

[5] CEG Justo and A Veeraragavan. Utilization of waste plastic bags in bituminous mix for improved performance of roads. *Centre for Transportation Engineering, Bangalore University, Bangalore, India*, 2002.

[6] VS Punith. Effect of plastic modifiers on bituminous mix properties. In *Seminar Report, II Semester in ME Highway Engineering, Department of Civil Engineering, Bangalore University, Bangalore, India*, 2001.

[7] Amit Gawande, G Zamare, VC Renge, Saurabh Tayde, and G Bharsakale. An overview on waste plastic utilization in asphalting of roads. *Journal of Engineering Research and Studies*, 3(2):1–5, 2012.

[8] R Vasudevan. Utilization of waste plastics for flexible pavement. *Indian Highways (Indian Road Congress)*, 34(7):105–111, 2006.

[9] SE Zoorob and LB Suparma. Laboratory design and investigation of the properties of continuously graded asphaltic concrete containing recycled plastics aggregate replacement (plastiphalt). *Cement and concrete composites*, 22(4):233–242, 2000.

[10] DOR. *Standard Specifications for Road and Bridge Works*. Department of Roads, Ministry of Physical Infrastructure and Transport, Government of Nepal, 2017.

[11] BIS. *Indian Standard Methods for Testing Tar and Bituminous Materials (IS 1201 to 1220-1978)*. Bureau of Indian Standards, 2007.