International Journal on Engineering Technology (InJET)

www.kec.edu.np/kec-journal/
Volume 2, issue no. 1, Dec 2024, Page 168-175
Received Date: Aug 16, 2024
Accepted Date: Oct 23, 2024
ISSN: 3021-940X (Print)
DOI: https://doi.org/10.3126/injet.v2i1.72568

Performance Comparison of Two Waste Plastics (Low-Density Polyethylene (LDPE) and Polyethylene Terephthalate (PET)) for Asphalt Pavement on the Basis of Marshall Test

Reeta Khadka[1,*], Dipika Poudel[2], Dikshya Timsina[2] , Padam Bahadur Madai[3]

[1]*Kantipur Engineering College, Dhapakhel, Lalitpur, Nepal, ritakhadka@kec.edu.np*
[2]*Kantipur Engineering College, Dhapakhel, Lalitpur , Nepal, kan076bce022@kec.edu.np*
[2]*Kantipur Engineering College, Dhapakhel, Lalitpur, Nepal,kan076bce017@kec.edu.np*
[3]*Department of Road, Dhapakhel, Lalitpur ,Nepal,madaipadam123@gmail.com*

Abstract

Plastic disposal is a significant problem as it is non-biodegradable and causes air pollution if burned. The utilization of waste plastics in road construction has gained attention due to environmental concerns and the need for sustainable development of infrastructure. This research investigates the performance analysis of two different waste plastics, low-density polyethylene (LDPE) and polyethylene terephthalate (PET), for the construction of asphalt pavement based on the Marshall Stability Test. The Optimum bitumen content (OBC) is found to be 5.2% and LDPE and PET (8% and 10% by weight of bitumen) were used. The use of both LDPE and PET on the asphalt pavement has Marshall stability and Marshall flow values in the usable range as specified in the specification criteria of the Standard Specification for Road and Bridge Works (SSRBW). Both 8% and 10% PET perform better than same percentage of LDPE.

Keywords: Marshall Stability, Optimum bitumen content, low-density polyethylene, polyethylene terephthalate, standard specifications for road and bridge work.

1. Introduction

1.1. Hot Mix Asphalt

Hot Mix Technology, which has been used for many years in the construction of pavements, involves heating aggregates and bitumen, mixing, and laying the mixture at a high temperature of around 120°C–165°C. (Kaujageri, P, & N, 2018). It cools and sets quickly, allowing roads and driveways to be opened to traffic shortly after the paving process. (PetroNaft Co. research team., 2024)

1.2. Plastics

Plastics are typically organic polymers of high molecular mass and are usually synthetic. Due to their relatively low cost, manufacture, versatility, and imperviousness to water, plastics are being used in enormous quantities for the packaging, production, and manufacturing of automobile parts, furniture, and toys (Roy, Sinha, & Sarkar, 2015). It is estimated that in Nepal, about 20.7 kilotons of plastic per year leak into the environment, which is about 9% of the total annual plastic consumption. (Ghimire & Bajracharya, 2023).

1.2.1. Types of Plastics

Different types of plastics include low-density polyethylene (LDPE), high-density polyethylene (HDPE), polyvinyl chloride (PVC) and polyethylene terephthalate (PET). The focus of this research paper is polyethylene terephthalate (PET) waste in the form of plastic bottles used for packaging portable water and

*Corresponding Author

low-density polyethylene (LDPE) waste in the form of packaging plastics. The use of PET inroads adds to the increase in the stability value of Marshall, a reduction on the cost of road construction as the materials are low-cost, and an environment-friendliness as non-degradable waste is incorporated in construction (Ahmad et al., 2017). Also, the use of LDPE in roads increases the stability value of Marshall (Dubey & Gupta, 2019).


Figure 1: Portable water Bottle (PET)


Figure 2: Plastic Packaging Bags (LDPE)

Scope

- Asphalt Mix Design with Recycling of Waste Plastics (Low-Density Plastics, Polyethylene Terephthalate.
- Recommending the suitable percentage of plastics by weight of bitumen that are in the usable range as per the specification laid in the Standard Specification for Road and Bridge Works (SSRBW)

Specific objective

The major objective of this research is to compare the performance analysis of two waste plastics Low-Density Polyethylene (LDPE) and Polyethylene Terephthalate (PET) on the basis of Marshall hot mix design.

General objective

- To find the OBC of the mix.
- To recommended best plastic mix design for the construction of new Asphalt Pavement.

Limitations

1. Plastics used for the research have not been tested before their use, like aggregates and bitumen.
2. The research recommendation is fully based on the Marshall hot mix design only.
3. Aggregates are taken from a single quarry.
4. The test is limited to two types of waste plastics only.

2. Literature Review

(Ahmad, et al., 2017) Utilization of PET helps to improve the properties of flexible pavement such as increasing its stability, stiffness, and viscosity and hence it can improve stripping, thermal cracking, temperature susceptibility, fatigue damage, and rutting resistance. Considering the economic and environmental point of view, the utilization of PET as an additive to asphalt mixture is suitable to be used for road pavement. (Sasidharan, Torbaghan, & Burrow, 2019) Laboratory tests have shown that the use of plastics in small amounts (5-10% by weight) results in positive scenarios in improving pavement stability, strength, and durability. (R.Manju, S, & K, 2017)When plastic is placed on the heated aggregate, it develops an oily coat on the surface of the aggregates which helps to bind the bitumen and aggregates which results in the increased performance from the

field observation showcase that the plastic fillers can bear stress and extend the life of the roads reducing environmental problems. (Ahmad, et al., 2017) A.F Ahmad in this research article using 30 samples to find the impact of using PET at various percentages (2%, 5%, 10%, 15% & 20%) concluded that 10% of PET by the weight of binder content was the best amount. (Sabina, Khan, Sharma, Sangita, & Sharma, 2009) This paper concluded that the use of plastics (8% and 15 %) results in the improvement in the Marshall stability, and rutting. (Genet, Sendekie, & Jembere, 2021) This paper investigated the use of three different waste plastics (LDPE) at different percentages 4,6,8 and 10 % and found that asphalt mix modified by using 6.5% plastics had 33.67% higher stability value compared to non-modified asphalt. (Moses, 2019) In this study, the optimum bitumen content of asphalt concrete was replaced by 4% to 16% of PET and found that the maximum stability for PET waste-modified asphalt concrete was recorded at 12 % content of PET waste. (Ahmad & Ahmad, 2019) The PET proportioned by different percentages as 8%,10%, and 12 % by the weight of bitumen content when compared using Marshall values found that the PET-modified mixtures were more resistant to deformation to the conventional sample and also the rate of deformation was less compared to the conventional sample. (Saleh, 2023) LDPE from 6% to 18 % was tested based on the Marshall flow and stability. It was found that the modified mixture was more stable than the conventional mixture; also the addition of 14.8 % of LDPE to the asphalt mixture gave the best improvement in the pavement performance.

3. Materials Collection and Testing

3.1. Bitumen

The bitumen used for this research study is VG-30 grade, generally used in Kathmandu Valley. The bitumen is selected based on the table specified by the Standard Specification for Road and Bridge Works (SSRBW).

Table 1. Selection Criteria for Viscosity-Graded (VG) Paving Bitumen Based on Climatic Conditions (SSRBW, 2073)

Lowest Daily Mean Air Temperature, °C	Highest Daily Mean Air Temperature, °C		
	Less than 20°C	**20 to 30°C**	**More than 30°C**
More than 10 °C	VG-10	VG-20	VG-30
	VG-10	VG-10	VG-20

Table 2. Test Result of Bitumen on the basis of SSRBW 2073

S. N	Name of test	Unit	Bitumen VG:30(HP)	Specification limit (SSRBW 2073)
1	Penetration 25 degrees Celsius, 100 g, 5 s, 0.1 mm, min	1/10mm	45	45(Min)
2	Absolute viscosity at 60 °C, Poises	Poises	2852.27	2400-3600
3	Flashpoint (Cleveland open cup), degree Celsius, min	Degree Celsius	285/312	220(min)
4	Solubility in trichloroethylene, % by weight (min)	%	99.7	99(min)
5	Softening point (Rand B), degree Celsius min	Degree Celsius	49.5	47(min)
6	Specific gravity		1.04	1.00-1.50
7	Loss on heating (5 hrs. at 163 degrees Celsius)		0.18	0.5
8	Ductility at 25 degrees Celsius, min.	Cm	100	40 (min)
9	Water content, by weight		nil	0.2

3.2. Aggregates

Aggregates of size 20mm down, 10 mm down, and stone dust are used for study. This entire material was collected from the quarry at Kathmandu, which supplied the material from Dukuchhap. The aggregate tests and evaluations carried out based on the specifications provided in the table below

Table 3. Physical Requirements for Coarse Aggregate for Bituminous Concrete (SSRBW, 2073)

Name of test	Specification	Test standards

Aggregate impact value	Max 24 %	Is 2386 (part 4)
Water absorption test	Max 2%	Is 2386 (part 3)
Los Angeles abrasion test	Max 30 %	Is 2386 (part 4)
Specific gravity test		AASHTO T166
Combined EI +FI	Max 35%	Is 2386 (part 1)

Table 4. Test Result of Aggregate on the basis of SSRBW, 2073

Name of test	**Observation**	**Standard value (SSRBW 2073)**	**Remarks**
Combined elongation index (EI)+flakiness index (FI)	31.88%	Max 35 %	Ok
LAA (LOS Angeles Abrasion Test)	15.82%	Max 30%	Ok
Aggregate impact test (AIV)	12.86%	Max 24 %	Ok
Water absorption 20 mm down aggregate	0.32%	Max 2%	Ok
Water absorption 10 mm down aggregate	0.60%	Max 2%	Ok
Specific gravity 20 mm down aggregate	2.71		Ok
Specific gravity 10 mm down aggregate	2.64		Ok
Specific gravity stone dust	2.68		Ok

3.3. Waste Plastics

The study involves the use of two different waste plastics. Low-density polyethylene (LDPE) and polyethylene terephthalate (PET). LDPE is collected from waste packing plastics, and PET is collected from waste mineral water bottles.

3.4. Gradation of Aggregates

To find the job mix proportion of aggregate, sieve analysis is performed based on the specification in SSRBW (Standard Specification for Road and Bridge Works).

Table 5. Gradation ofAggregates on the basis of SSRBW, 2073

Grading	1	
Nominal aggregate size	19 mm	
Layer thickness	50 mm	
Is sieve (mm)	Cumulative % by weight of total aggregate passing (SSRBW 2073)	Cumulative % by weight of total aggregate passing of sample
45		
37.5		
26.5	100	100

19	90-100	99.7
13.2	59-79	78.84
9.5	52-72	60.6
4.75	35-55	39.97
2.36	28-44	32.57
1.18	20-34	24.61
0.6	15-27	19.52
0.3	10-20	14.03
0.15	5-13	5.08
0.075	2-8	2.04
Bitumen content % by mass of total mix	Min * 5.2	

3.5. Mix design

Table 6. Mix Design of Aggregate

Name of aggregate	% Used
20 mm down aggregate	42%
10 mm down aggregate	8%
Stone dust	50%
Total	100%

4. Results and Discussions

The selected bitumen (VG 30) satisfied the all the test of butimen as per SSRBW 2073.

Aggregates of size 20mm down, 10 mm down, and stone dust from Dukuchhap quarry satisfied all the test of aggregates as per SSRBW 2073.

The Marshall test is performed in the Marshall cake and the Optimum Binder Content (OBC) was found as 5.2%. At OBC the Marshall Stability, Specific Gravity, 4% Air Void of mix without plastic was found as 18.30KN, 5.50 and 5.20 respectively.

The Marshall test containing the 8% and 10% of both LDPE and PET are performed on the basis of OBC.

The test result of Marshall properties of 8% and 10% (both LDPE and PET) are compared and analysis with the Marshall properties of OBC.

Table 7. Marshall Test Results of different percentage of LDPE and PET plastics.

Plastics %	Flow	Stability	Density	Air voids	VMA	VFB	Marshall quotient	Remark
0%	4.00	18.30	2.384	4.00	15.95	74.80	4.58	OBC
8%	3.8	16.59	2.375	4.27	15.21	71.93	4.37	LDPE
10%	3.9	16.4	2.372	4.4	15.16	70.98	4.21	LDPE
8%	3.72	17.58	2.377	4.53	15.48	70.74	4.73	PET

10%	3.77	17.62	2.38	4.48	15.28	70.68	4.67	PET

5. CONCLUSION AND RECOMMENDATION

Plastics which are non-biodegradable waste have a serious impact on the environment. Using the waste plastics in the construction of the asphalt pavement could bring a better solution for the plastics waste management problem.

This test result shows that both the waste plastics LDPE (8% and 10) and PET (8% and 10%) satisfied the all the Marshall test criterion such as Marshall Stability, Flow Value, VMA,VFB and Marshall Quotient.

Since Both the waste plastics satisfied Marshall Mix Design Condition, on the basis of test result as all the properties are nearly equal and within the range, so we can compare the performance of two waste plastics on the basis of Marshall Stability as the stability value is slightly different.

Although both the plastics mix satisfied Marshall Suitability, the Marshall Stability of PET both for 8% and 10 % are greater than the Marshall Stability of LDPE. Hence, PET will be the best option to be used for the construction of new Asphalt pavement.

Recommendation based on Standard specification for roads and works (SSRBW)

- The use of 8% and 10% of both LDPE and PET were found to fulfill all the criteria as per SSRBW that is stability, flow, density, air voids, VMA, and VFB. So, the use of both 8% and 10% of LDPE and PET can be recommended by this study.
- On the basis of performance analysis, as all the Marshall properties are nearly equal for both the waste plastics (8% and 10%) except Marshall Stability and the Marshall Stability values for PET is greater than LDPE, so this study recommend the that the use of PET will be best for the construction of new Asphalt Pavement as per SSRBW.
- Among the 8% and 10% of PET, the Marshall Stability value of 10% PET is greater than 8%, so as per SSRBW this study will recommend the use of 10% PET is best suited for the construction of new Asphalt Pavement.

References

Ahmad, A. F., A. R., Razelan, I. S., Jalil, S. A., Noh, M. M., & Idris, A. A. (2017). U*tilization of polyethylene terephthalate (PET) in bituminous mixture for improved performance of roads. Mechanical Engineering, Science and Technology International Conference. IOP Publishing.*

Ahmad, M. S., & Ahmad, S. A. (2019). T*he impact of polyethylene terephthalate waste on different bituminous designs. journal of Engineering and Applied Science volume.*

Dubey, P., & Gupta, N. (2019). *Utilization of Low-Density Plastic Waste in Construction of Flexible Pavement with a Partial Replacement of Bitumen.*

Genet, M. B., Sendekie, Z. B., & Jembere, A. L. (2021). *Investigation and optimization of waste LDPE plastic as a modifier of asphalt mix for highway asphalt: Case of Ethiopian roads*.

Ghimire, Y., & Bajracharya, P. (2023, September 11). *Circular Economy of Plastics*.

Kaujageri, M. S., P, D. P., & N, M. S. (2018). *Comparative study on Hot Mix Asphalt and Cold Mix Asphalt for BC layer*.

Moses, O. O. (2019). T*he use of polyethylene terephthalate waste for modifying asphalt concrete using the Marshall test.*

PetroNaft Co. research team. (2024, February 5). *Understanding Hot Mix vs Cold Mix Asphalt: A Comprehensive Introduction.*

R.Manju, S, s., & K, s. (2017). *Use of Plastic Waste in Bituminous Pavement.* ROY, P. M., Sinha, D. A., & Sarkar, K. S. (2015). *Plastic: Its Sources, Applications, Side Effects & Controlling Managements".*

Sabina, Khan, T. A., Sharma, D. K., Sangita, & Sharma, B. M. (2009). *Performance evaluation of waste plastic/polymer modified bituminous concrete mixe.*

Saleh, M. S. (2023). *Investigating Performance of Asphalt Concrete Using Waste Material as Bitumen Modifier.*

Sasidharan, M., Torbaghan, D. M., & Burrow, D. M. (2019). *Using waste plastics in road construction.* Shrestha, S., & Niraula, S. (2022). *Analysis Of Plastic Composite Roads with LDPE As BinderModifier.*