Assessment on the Effect of Polyethylene Terephthalate and Low-density Polyethylene Plastic Waste as an Additive in Bituminous Paving Mixes

F D Santos, M A M Taguba and A R Alzona

1 Department of Civil Engineering, National University, Sampaloc, Manila 1008 Philippines
2 Department of Environmental and Sanitary Engineering, National University, Sampaloc, Manila 1008 Philippines

Email: fdsantos@national-u.edu.ph

Abstract. The continuous growth of the population also brings about an increase in traffic that traverse our roads. Due to this increase in the volume of traffic, pavements are subjected to more distress which can lead to its failure. Studies have been performed in order to address these issues on material properties. At present time, waste disposal has been a challenge for various industries. And of the wastes that are abundant in our surroundings, plastic is proving to be a major problem because it poses a major threat to the environment. As a possible solution to the growing problem of the disposal of plastic wastes as well as the constant pursuit to improve the properties of materials, recycling and incorporating plastic to construction materials has been explored in various studies. This study aims to assess the effects of Low-Density Polyethylene (LDPE) and Polyethylene Terephthalate (PET) as an additive to Hot Mix Asphalt (HMA) on the stability, flow and bulk specific gravity of the paving mix. A parametric study was conducted in order to investigate the effect of additive concentration (4%, 7% and 10% by weight of asphalt binder), particle size (2.36 mm, 4.57 mm, and 9.5 mm) and mixing temperature (145°C, 160°C, and 175°C) on the stability, flow and bulk specific gravity of Plastic Waste Bitumen Binder (PWBB). Results show that adding PET and LDPE as additive increases the stability by 36.82%, improves the flow by 22% and it also increases the bulk specific gravity by 2.36% compared to a traditional bituminous mixture.

1. Introduction
The Philippines has been noted through a series of studies for having one of the fastest urbanizations in Southeast Asia [1]. One of the characteristics of urbanization is the continuous increase in the population which incurs an increase also in the traffic volume that travel the streets. The combined effects of the increase in the rate of motorization and private vehicle use intensifies even more the congestion that is present in roads [2]. Due to the high volumes of traffic, pavements experience higher distresses. Some of these serious distresses are rutting, shoving, stripping, and fatigue cracking which may lead to the complete failure of the pavement [3]. Such distresses can also reduce the performance of asphalt pavements under the effect of heavy traffic loading, high temperatures, and water damages. The deformable component properties of bitumen define the good performance of a road pavement [4]. One important property of bitumen mixtures in the wearing course design is its ability to resist shoving and rutting under traffic therefore the stability of the paving mix should be high enough to handle traffic adequately.
Nowadays, disposal of different plastic wastes produced from different industries is a major problem. Plastic wastes, specifically in urban areas, can stay in the environment for a long time that can severely ruin the environment unless it is properly disposed of [5]. Due to the problem brought about by plastic wastes, studies have been conducted in order to find a solution by means of recycling and incorporating them in materials to provide a means of waste diversion. These studies were conducted because of the good mechanical properties of plastic. Molten plastics provide good binding property and increases the value of the compressive and bending strength of flexible pavements when used as a binder [6].

This study aimed to assess the effects of Polyethylene Terephthalate (PET) and Low-Density Polyethylene (LDPE) as additive on the stability and flow together with the bulk specific gravity of the Plastic Waste Blended Bitumen (PWBB) mixture. The method used is the standard mixing method focusing on the significant elements of the study. This paper also aimed to evaluate the effect of varying amount of PET and LDPE (4%, 7% and 10%) by weight of asphalt binder, particle size (2.36 mm, 4.57 mm, and 9.5 mm) and mixing temperature (145°C, 160°C, and 175°C) on the stability, flow and bulk specific gravity of PWBB and compare it to a control mix.

2. Materials
The materials used to produce the samples such as asphalt, cement filler, and aggregate as well the as testing equipment is located at the Department of Public Works and Highways Asphalt Section Laboratory of the Bureau of Research Studies in Quezon City. The PET and LDPE used in the study were collected by the researchers that came from containers of different beverages and junk food that are sold from the local stores and convenient stores in Manila.

3. Experimental methodology

3.1. Synthesis of plastic waste bitumen binder
The researchers fabricated samples of asphalt mixture cylinder infused with PET and LDPE to magnify the effectiveness of the data gathering instruments. The materials used in this research were no less than the materials used in actual practice. The materials consist of asphalt binder, cement filler, coarse and fine aggregates, collected PET and LDPE. The gathered PET and LDPE waste are then washed and dried. The dried materials were then shredded and cut into three different sizes from large (coarse), medium (fine) and smallest (finest), the shredded samples were then sieved through 3/8”, Sieve No. 4 and Sieve No. 8 in order to categorize their particles size diameters.

3.2. Methodology on parametric samples
The concentration of PET and LDPE additive was varied from 4%, 7% and 10% by weight of asphalt binder with the ratio of distribution of 50% for both plastic types (PET and LDPE). Also, the mixing temperature was varied from 145°C, 165°C and 175°C in determining the properties of the bituminous pavement. Moreover, aside from the concentration and the mixing temperature, the varying particle diameter size (2.36 mm, 4.57 mm, and 9.5 mm) was also examined on its possible effect on the mechanical properties of the bitumen.

3.3. Preparation of test specimen
The aggregates and asphalt were heated in the oven, mixed in a bowl using a metal spatula. The mixing temperature of the PWBB was varied from 145°C, 165°C, to 175°C. The mixed samples were then placed into the moulding cylinders where bitumen is added compacted on each circular face. Each side received 75 blows by the compaction machine in accordance with the standard. The researchers tested the cylinders consisting of various proportions and additive mixtures as determined in the aim of this paper.

Aside from the bulk specific gravity of the specimen, the bituminous pavement also underwent the Marshall Stability test to examine the stability and flow of the mixture. One by one the specimens were loaded perpendicularly into the Marshall testing apparatus. A certain force in now applied by the
The data was obtained from the machine and was recorded for analysis.

3.4. Testing of specimens
The standards adopted are those mandated by the American Society for Testing and Materials. ASTM D 6927 (Standard Test Method for Marshall Stability and Flow of Bituminous Mixtures) was the principal standard used as a basis for evaluating the strength and density of the modified specimens.

4. Results and discussion

4.1. Parametric study of PWBB.
The results of the stability test of PWBB with varying temperature, plastic concentration and particle size are shown in Figure 1.

Based on the results, the effect of increasing mixing temperature and plastic particle size showed decreasing stability in PWBB, however, the while increasing the plastic percentage infused in the PWBB, the stability also increases up to a value of 90.3 kN. In comparison to the normal asphalt mix which recorded a stability of 66 kN, the stability of the PWBB increased by 36.82%. Figure 2 presents the effect of the varying parameters on the flow.
Figure 2. The effect of varying temperature, plastic concentration and particle size on flow

Results of the flow test show that increasing mixing temperature and plastic particle size again showed decreasing flow in PWBB, however, increasing the plastic percentage in the PWBB also increases the flow to a maximum of 42.7 mm. Comparing it to the flow of the control sample, the flow of PWBB is greater by 22%. A summary of the results of the Bulk Specific Gravity is depicted in Figure 3.
In the three tests, results that the PWBB showed significant results even in Bulk Specific Gravity. Comparing the maximum bulk specific gravity obtained to the control sample, it can be said that it has increased by 2.36%.

5. Conclusion

This paper meant to evaluate the effect of using PET and LDPE as an additive in Hot Asphalt Mix on the mechanical properties such as stability, flow and bulk specific gravity and results were also compared to a traditional bituminous mixture. Considering the varying factors of temperature, plastic percentage and plastic particle size and results of the tests, the following conclusions were made:

- Due to the addition of PET and LDPE as additive in the bituminous mixture, there is an evident increase in the stability, flow and bulk specific gravity of HMA compared to normal (conventional) pavement mixtures.
- With respect to the concentration of plastic, increasing the amount of plastic in the mixture decreases the stability, flow and bulk specific gravity of the mixture. And Assessment on the effect of polyethylene terephthalate and low-density polyethylene plastic waste as an additive in bituminous paving mixes.
- Based on the parameter of particle size of plastic waste in the mixture, the increase in particle size is directly related to the increase in the stability, flow and bulk specific gravity of the paving mixture.

The findings also signify that plastic wastes can be used in the production of an innovative and low-cost construction material while serving as a waste diversion for plastic wastes in order to address the waste disposal problem of the community.

6. References

[1] Roberts B and Kanaley T 2006 Urbanization and Stability in Asia: Good Practice Approaches in Urban Region Development, ADB, Cities Alliance.
[2] Regidor J R F (2013) Traffic Congestion in Metro Manila: Is the UVVRP Still Effective? Philippine Engineering Journal 34(1), 66-75.
[3] Kurikulum, D. (2012). Abstract, 14(1), 47–64. https://doi.org/10.1061/(ASCE)0733-9410(1991)117.
[4] Kalantar, Z., Mahrez, A., & Karim, M. R. (2009). Properties of bituminous binder modified with waste polyethylene terephthalate (PET).
[5] Rajkumar, P. (2015). A Study of the Plastic Waste and Environmental Degradation. ABC Journal of Advanced Research, 4(1), 9–16.
[6] Gawande, A., Zamarea, G., Rengea, V.C., Saurabh Taydea, G. B. (2012). An overview of waste plastic utilization in asphaltling of roads. Journal of Engineering Research and Studies, 3(2), 1–5.