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Asphalt modification using thermoplastic polymer components

Roy O. Anabo
Head Teacher I, Dolores National High School, Dolores, Eastern Samar, Philippines
ORCID ID: 0000-0002-4656-726X
roy.anabo@deped.gov.ph

ABSTRACT

Asphalt modification using thermoplastic polymer components a plastic waste turned into an innovative product, environmentally friendly, and cost-effective. Plastics, specifically thermoplastics have many uses but with the increasing population, consumption of plastic is rampant. To come up with innovative solutions that can be used to minimize plastic and create usage in construction highways, buildings, and houses is the main concern in this study. Therefore, the study aimed to find innovative solutions using plastic waste that can use thermoplastics as an asphalt modification. An experimental research method was used to determine the acceptability and predict what may occur. Based on the findings of the actual observations made from two set-ups (Modified Asphalt and Unmodified Asphalt) it was found the results of acceptability data in the utilization of thermoplastic polymer components under set-up a got a final mean score of 3.9. However, set-up b provided the best result with the highest acceptability mean score of 4.8. Therefore, using thermoplastic polymer components in terms of texture, strength/durability, and soundness is highly acceptable. The cost of modified asphalt amounted to Php 10.00; it shows positively that the use of thermoplastics for modifying asphalt pavement is not costly but rather cheap. Utilization of recycled thermoplastic polymers as an asphalt modification will contribute strength of the pavements, help to attain sustainability in reducing plastic waste, and friendly environment innovation techniques. A highly recommended follow-up marshall-stability testing was conducted to have more reliable results regarding the strength/durability, modulus of elasticity, and rupture of the asphalt.

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INTRODUCTION

In many developing countries the amount of plastics in the household is increasing and become a major problem in urban areas that can cause blocking of drainage, health problems, and other diseases.

Plastic pollution arises from day-to-day life, with the proper waste disposal, recycling, reusable, and reconstruction of new things for them to make alternative solutions minimizing plastic.

Plastics take more than a decade to decompose, so the use of plastic is not advisable in every municipality. Create an ordinance not to use single plastic, and minimize the production of plastic waste. To prevent blocking the drainage area, and pollution in the river or ocean. However, the manufacturing of plastics has increased due to higher consumption of products but waste management provides some measures to mitigate, and decrease the single-use plastics.

The materials used suitably in road construction highways might be reduced when the application of plastic waste has been considered in road making based on technical, economic, and ecological innovative ways (Bilema, et.al., 2021).

Urban routes with increased high traffic volumes are the major concern of the interstate highway system there is a need for rehabilitation and reconstruction. More demands are placed on road pavements to improve functional and structural performance. In addition, the modification of bitumen with polymers can improve the quality of flexible pavements in asphalt mixtures (Costa, et.al., 2013).

However, asphalt mixture of plastic waste in the modification of bitumen polymers can improve the performance of roads, increase deformation, higher stiffness at high temperatures, and reduction of temperature susceptibility (Yildirim, 2027).

The main reason why the researcher looked for viable alternative solutions in the reduction of plastic waste and determining the acceptability of thermoplastic polymer components in asphalt modification.

OBJECTIVES OF THE STUDY

This study aspired to determine the acceptability of thermoplastic polymer components in asphalt modification. Specifically, this study aims to answer the following:

1. Do thermoplastic polymer components contribute to the strength of the asphalt?
2. How does the following factor affect the acceptability of thermoplastic polymer components in asphalt modification?
    a. Strength/Durability
    b. Soundness
    c. Texture
    d. Modulus of Elasticity
    e. Modulus of Rupture
3. Is there a significant difference between the asphalt-modified using thermoplastic and unmodified asphalt in terms of?
    a. Strength/Durability;
    b. Soundness
    c. Texture
    d. Modulus of Elasticity
    e. Modulus of Rupture

CONCEPTUAL FRAMEWORK

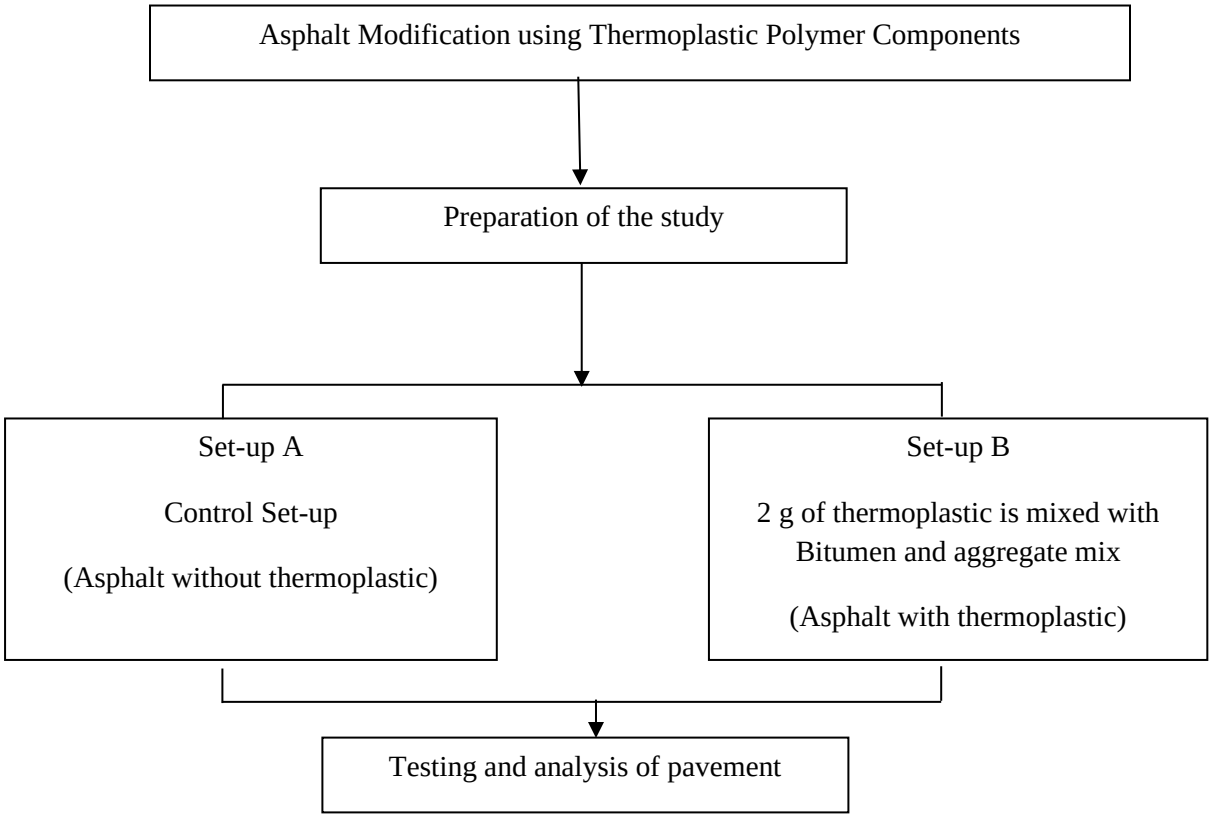


Figure 1. *Conceptual framework of the study "Asphalt Modification using Thermoplastic Polymer Components"*

SIGNIFICANCE OF THE STUDY

The study aimed to determine thermoplastic polymer components asphalt modification because of the alarming amount of waste plastic in the environment and the increasing demands placed on pavements.
Therefore, this study would be beneficial to the following:

To the Society. This study would be beneficial to society in a way that promotes the reuse and reduction of waste plastics.
To Engineers and Constructors. The results of this study would be a great help to the improvement of thermoplastic polymer components in asphalt modification.
To Future Researchers. This research will help as a guide for future researchers in their future investigations of the other uses of waste thermoplastics.
To the Researcher. This study would widen the knowledge of the researcher in modifying asphalt using thermoplastic polymer components and other ideas related to this study.

SCOPE AND LIMITATION

This study concentrates on the acceptability of thermoplastic polymer components in asphalt modification. The researcher conducted this study from June 2022 to October 2022 in Dolores, Eastern Samar. For the testing of materials, the researcher went to the Regional Office in Palo, Leyte. This study is only limited to producing a modified asphalt mixture applicable to road construction.

Though road construction using asphalt modification has so many other brands apart from the ones that have been presented in this study, this research study is limited only to the acceptability of thermoplastic polymer using plastic waste in road construction. The research work covers only experimental research at Dolores National High School Science Laboratory.

REVIEW OF LITERATURE AND STUDIES

A large number of plastic waste products or materials are increasing in quantity due to higher demands for the rehabilitation and construction of highways. The use of rubber and tires develops each year estimated an amount of 15 million tons, these will be a large number of waste materials that gradually intensive pollution a catastrophic result of environmental issues and concerns (Wang, et.al., 2015).

Plastic Name	Products		Properties
Polyamide (Nylon)		Bearings, gear wheels, casings for power tools, hinges for small cupboards, curtain rail fittings and clothing	Creamy colour, *tough*, fairly *hard*, resists wear, self-*lubricating*, good resistance to chemicals and machines
Polymethyl methacrylate (Acrylic)		Signs, covers of storage boxes, aircraft canopies and windows, covers for car lights, wash basins and baths	Stiff, hard but scratches easily, durable, *brittle* in small sections, good electrical insulator, machines and polishes well
Polypropylene		Medical equipment, laboratory equipment, containers with built-in hinges, 'plastic' seats, string, rope, kitchen equipment	Light, hard but scratches easily, tough, good resistance to chemicals, resists *work fatigue*
Polystyrene		Toys, especially model kits, packaging, 'plastic' boxes and containers	Light, hard, stiff, transparent, brittle, with good water resistance
Low density polythene (LDPE)		Packaging, especially bottles, toys, packaging film and bags	Tough, good resistance to chemicals, flexible, fairly soft, good electrical insulator
High density polythene (HDPE)		Plastic bottles, tubing, household equipment	Hard, stiff, able to be sterilised

Source: *www.stephensinjectionmoulding.co.uk*

Figure 2. The Different Types of Thermoplastics

The formulation of TPE-modified asphalt had a better result in high temperatures than SBS-modified asphalt in low temperatures. But then, by adding rubber and plastic at a higher temperature the composite-modified asphalt was found to be more stable, very prominent, and improve the performance of the asphalt (Fathy, 2019).

In addition, thermoplastic components can improve aging resistance on the base of asphalt, evidently found the increase the penetration ratio and decrease softening on the asphalt. The dispersion of modified asphalt can improve thermal properties, and storage stability in higher temperatures (Yu, et.al.,2018).

However, the study of Ibañez, et.al., (2023) revealed that familiarity with environmental laws was not a substantial understanding and knowledge, despite the limited awareness demonstrated a positive attitude towards waste management.

From the data showing the quantity and composition of waste disposed from all sources in Dolores, Eastern Samar, 9,886.385 kg of waste is generated per day. Most of the waste disposed is from residential areas (MENRO, 2017).

Table 1. Q*uantity and composition of waste disposed from all sources in Dolores, Eastern Samar*

	Total Waste Generation	
Major Sources	Kg. /Day	Percentage
Residential	9,456.918	95.85%
Commercial	303.285	3.07%
Institutions	106.183	1.08%
Total Waste Disposed	9,866.385	66.84%

Using polystyrene in modified asphalt can provide stability and strength of material. Furthermore, the decrease in resistance when the situation of construction was in hot climate conditions (Asmael & Waheed, 2018).

The use of plastic waste in coating aggregates of bitumen mixture was found efficient characteristics by minimizing cracks formation and reducing infiltration of rainwater. It was found that the bituminous base and wearing courses were effectively used to flex the pavement roads and highways (Shaikh, 2017).

However, according to the report of Chandramouli, et.al., (2016) cited by Jatap, et.al., (2017) to improve the stripping characteristics of crumb rubber-modified mixture it must be used plastic-modified binders to elevate temperature and reduce cracks rather than unmodified asphalt mixture.

In their investigations, Jan, H., et.al, (2017), it was found the modification of asphalt using polymers contributed to increasing the pavement length of service and reducing the thickness of the base. However, modification of asphalt using polymers provides a vital rule to become flexible in its inclined.

Lastly, the modified bitumen mixture that aggregates waste plastic-coated roads shows better binding properties in road construction. The presence of water in modified asphalt can increase the durability and resistance to wear and not easily tear off the road (Gawande, 2013).

Based on the related literature and studies above, the acceptability of thermoplastic polymer in a modified asphalt mixture can be used in the construction of roads.

MATERIALS AND METHODS

Research Design

The experimental research was used in this study. It enables the researcher to test their hypothesis of theory by reaching valid conclusions about the relationship between independent and dependent variables.

According to Johnson (2009), this method provides strong evidence for casual interpretation which is conducted to observe the consequences and predict the phenomenon. Since this research study is to ascertain the acceptability of asphalt modification using thermoplastic polymer components, the experiment method accommodates the necessary outcome as the researchers gather data for further inquiry on the research.

Locale of the Study

This study was conducted at Dolores, Eastern Samar. It was the most accessible and needed materials used for this study were gathered from the Provincial office, Borongan, City.

Samples of the Study

The samples used, studied, and manipulated in the study were comprised of thermoplastic polymer materials Bitumen, Fine aggregates, and Course Aggregate. The thermoplastic polymer components were gathered by the researcher from the DNHS (Dolores National High School) and it was randomly selected regardless of its kind, to gather the exact ratio that would yield a minimum of two asphalt samples with 7x8 inches measurement.

Sampling design

The sampling design used was purposive sampling. The sampling designs are selected based on the knowledge and purpose. This sampling only needed to find samples by observing them based on their purpose and availability (Babbie, 2001).

Research Procedure

The Materials in the study were the following:

Bitumen Charcoal

Pan
Stirrer
Trowels Kiln (*Pugon*)
Weighing Scale
Fine Aggregates, Coarse Aggregates
Thermoplastic Wastes Alternative Compactor
7x8 in. Plyboard Molder

Preparation for the Set-ups

The needed materials were gathered and prepared. The thermoplastic wastes were collected for cleaning and drying, these plastic wastes were then scraped into the required size (2 to 3 mm). The researcher made two 7x8 ins Ply board Molders. Samples were prepared out of which one will have 2 g of thermoplastic waste and one sample without plastic waste, this will serve as the control set-up.

For Set-up A: In a large pan, bitumen is heated to around 120°c to 150°c. While the bitumen is heated, a mixture of Fine aggregates and Coarse Aggregates is also heated in another pan. After reaching the desired temperature of the bitumen, it was then added to the Fine aggregates and Coarse Aggregates mixture. The heated bitumen Fine aggregates and Coarse Aggregates mixtures were thoroughly mixed. After mixing, the mixture was poured into the molder, and then it was compressed using an alternative compactor for it to be compact.

For Set-up B: In a large pan, bitumen is heated to around 120°c to 150°c. While the bitumen is heated, a mixture of Fine aggregates and Coarse Aggregates is also heated in another pan. The pan which contained a Fine aggregates and Coarse Aggregates mixture was removed from the kiln. The 2 g of scraped/cut thermoplastic waste was added to the fine and coarse aggregate mix.

After reaching the desired temperature of the bitumen, the heated bitumen was thoroughly mixed. After mixing, the mixture was poured into the second molder, and then it was compressed using an alternative compactor for it to be compact.

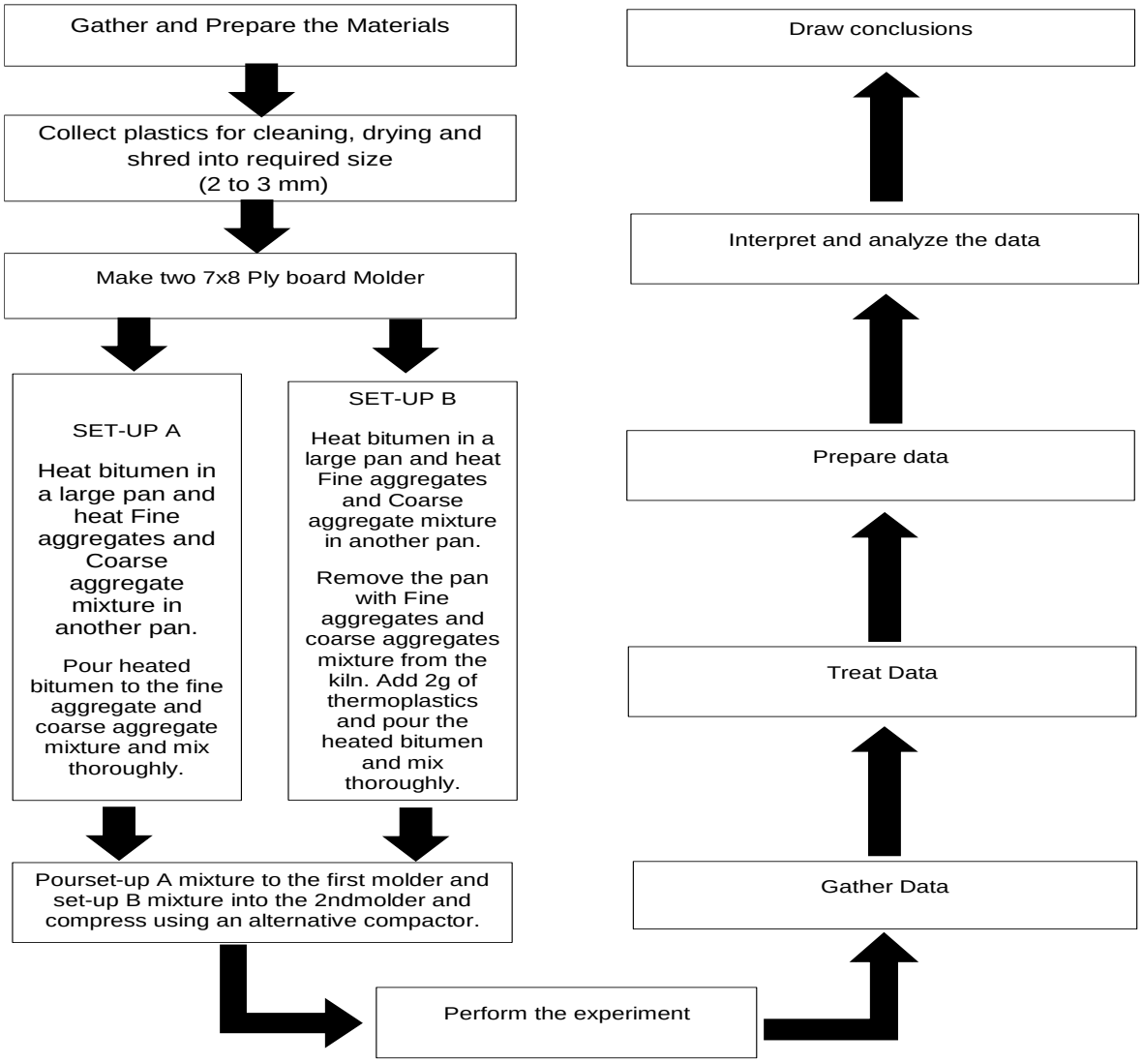
Validation of instrument

The researcher experimented at Dolores, Eastern Samar. The researcher was able to come up with a solution or a product from the use of materials that were found in the same place or gathered from the DPWH Provincial Office, Borongan City. To further validate the experiment, a Likert 5-point scale was used to record observations and explanations taken from knowledgeable. From a range of 1 to 5 the highest scale is 5 strongly agree with an explanation of Very good texture, in highly good condition, and the strength/durability is highly acceptable. Scale of 4 Moderately Agree with an explanation of Moderately good texture, in moderately good condition, and the strength/durability is moderately acceptable. Scale 3 Agree with an explanation of Good texture, in good condition, and the strength/durability is acceptable. While Scale 2 Slightly Disagree with an explanation of a Texture is slightly not good, the condition is slightly not good, and the strength/durability is slightly not acceptable. And lastly, the lowest Scale is 1 Disagree with an explanation of Texture is not good, condition is not good, and the strength/durability is not acceptable.

Table 2. Likert 5-point scale

Scale	Interpretation	Explanation
5	Strongly Agree	Very good texture, in highly good condition, and the strength/durability is highly acceptable.
4	Moderately Agree	Moderately good texture, in moderately good condition, and the strength/durability is moderately acceptable.
3	Agree	Good texture, in good condition, and the strength/durability is acceptable.
2	Slightly Disagree	Texture is slightly not good, condition is slightly not good, and the strength/durability is slightly not acceptable.
1	Disagree	Texture is not good, condition is not good, and the strength/durability is not acceptable.

Methodology Chart



Ethical consideration

This study followed the appropriate research ethics guidelines. The researcher asks permission from the coordinator of school waste management for safety and environmental concerns

Parental consent from participants through their adviser, to use their given data. The participants were assured that the data collected were kept confidential and could not be used in any legal actions against them.

RESULTS AND DISCUSSION

In the study of Asphalt modification using thermoplastic polymer components, the whole study was divided into its focal parts according to the specific questions:

1. Do thermoplastic polymer components contribute to the strength of the asphalt?
2. How does the following factor affect the acceptability of thermoplastic polymer components in asphalt modification?
    a. Strength/Durability
    b. Soundness
    c. Texture
    d. Modulus of Elasticity
    e. Modulus of Rupture
3. Is there a significant difference between the asphalt-modified using thermoplastic and unmodified asphalt in terms of?
    a. Strength/Durability;
    b. Soundness
    c. Texture
    d. Modulus of Elasticity
    e. Modulus of Rupture

The data gathered in the study are presented through a tabular presentation.

Table 3. Summary Result of the acceptability of asphalt in terms of Texture

	TEXTURE	
	SET-UP A	SET-UP B
Sum	39	48
Mean	3.9	4.8
Alpha	0.05	
P-value	0.000110582	
F-crit	4.413873419	

As shown in Table 3, Summary Result of the acceptability of asphalt in terms of Texture. Based on the results the Sum of the score in Set-up A is 39 and Set-up B is 48. However, Set-up A with a Mean score of 3.9, while an increase in Set-up B has a Mean score of 4.8. Therefore, accept the alternative hypothesis in asphalt-modified using thermoplastic in terms of texture.

Table 4. Summary Result of the acceptability of asphalt in terms of Soundness

	SOUNDNESS	
	SET-UP A	SET-UP B
Sum	38	49
Mean	3.8	4.9
Alpha	0.05	
P-value	0.065169488	
F-crit	4.413873419	

As shown in Table 4, Summary Result of the acceptability of asphalt in terms of Soundness. Based on the results the Sum of the score in Set-up A is 38 and Set-up B is 49. However, Set-up A with a Mean score of 3.8, while an increase in Set-up B has a Mean score of 4.9. Therefore, accept the null hypothesis in asphalt-modified using thermoplastic terms of soundness.

Table 5. Summary Result of the acceptability of asphalt in terms of Strength/Durability

	STRENGTH / DURABILITY	
	SET-UP A	SET-UP B
Sum	40	46
Mean	4.0	4.6
Alpha	0.05	
P-value	0.000794488	
F-crit	4.413873419	

As shown in Table 5, Summary Result of the acceptability of asphalt in terms of Strength/Durability. Based on the results the Sum of the score of Set-up A is 40 and Set-up B is 46. However, Set-up A with a Mean score of 4, while an increase in Set-up B has a mean score of 4.6. Therefore, accept the alternative hypothesis in asphalt-modified using thermoplastic in terms of Strength/Durability.

To find which set-up is most acceptable to the respondents, the researcher made a table showing the data for every set-up with the rating for each factor.

Table 6. Summary Mean Rating for Set-up A in terms of texture, soundness, and strength/durability.

Set-up A		
Factors	Mean	Mean of the Mean for each factor
Texture	3.9	
Soundness	3.8	3.9
Strength / Durability	4.0	

As shown in Table 6, Summary Result of the Mean rating for Set-up A in terms of texture, soundness, and strength/durability. Based on the results the three factors' mean score in Set-up A was strength/durability is the highest mean with a total of 4, however, soundness had the lowest Mean of 3.8. Therefore, the mean of the mean for each factor was 3.9 in Set-up A.

Table 7. Summary Mean Rating for Set-up B in terms of texture, soundness, and strength/durability.

Set-up B		
Factors	Mean	Mean of the Mean for each factor
Texture	4.8	
Soundness	4.9	4.8
Strength / Durability	4.6	

As shown in Table 7, Summary Result of the Mean Rating for Set-up A in terms of texture, soundness, and strength/durability. Based on the results the three factors' mean score in Set-up B was soundness is the highest mean with a total of 4.9, however, strength/durability had the lowest mean of 4.6. Therefore, the mean of the mean for each factor was 4.8 in Set-up B.

Legend:
4.01-5 – Highly Acceptable
3.01-4 – Acceptable
2.01-3 – Slightly Unacceptable
1.01-2 – Unacceptable
0.01-1 – Highly Unacceptable

As shown in Tables 6 and 7, acceptability data of set-ups a and b in all three (3) factors are gathered in a table. Set-up a got a final mean score of 3.9 and set-up b got a final mean score of 4.8.

Since Set-up A got a final mean of 3.9, therefore it is Acceptable. Since Set-up B got a final mean of 4.8, therefore it is Highly Acceptable.

Cost Analysis

The cost-benefit was determined by comparing the total expenses of the materials needed in preparing the samples and the total expenses for the materials needed in preparing standard asphalt roads.

Cost analysis for a 17.78 cm by 20.32 cm unmodified asphalt sample

Materials	*Amount*
Fine aggregates	60
Coarse aggregates	90
Bitumen	200
	Total expenses = Php 350.00

Cost analysis for a 17.78 cm by 20.32 cm modified asphalt sample

Materials	*Amount*
Fine aggregates	60
Coarse aggregates	90
Bitumen	200
Waste Thermoplastic	10
	Total expenses = Php 360.00

Although the cost difference between the unmodified asphalt sample and the modified asphalt sample amounted to Php 10.00; it shows positively that the use of thermoplastics for modifying asphalt pavement is not costly but rather cheap.

Summary

The study of Asphalt modification using thermoplastic polymer components is experimental research that promotes environmental and economic status. Plastics, specifically thermoplastics have many uses, but the increase of use and production of plastics is a particular concern. Therefore, the researcher aimed to find innovative solutions using waste thermoplastics as asphalt modification. Based on the gathered data, the acceptability data of Set-ups A and B in all factors such as textures, soundness, and strength/durability. With all this taken into consideration the result of the ratings of each Set–up: Set-up A got a final mean score of 3.9 and Set-up B got a final mean of 4.8. The use of thermoplastic components contributes to the texture, soundness, strength/and durability of the asphalt. The researcher, therefore concludes that Set-up B the asphalt-modified sample using thermoplastic is the most highly acceptable set-up in this study.

CONCLUSION

In order to test the acceptability of thermoplastic polymer components in asphalt modification the actual observations made from the two set-ups: Modified Asphalt and Unmodified Asphalt are used together and specifically, the following conclusions were drawn that the use of thermoplastic polymer components in asphalt modification is highly acceptable and polymer components can be utilized in asphalt modification. Meanwhile, the utilization of thermoplastic polymer components under set-up b provided the best result with the highest acceptability mean score of 4.8. Therefore, using thermoplastic polymer components in terms of texture, strength/durability, and soundness is acceptable. The cost of modified asphalt amounted to Php 10.00; it shows positively that the use of thermoplastics for modifying asphalt pavement is not costly but rather cheap. Utilization of recycled thermoplastic polymers will help in attaining sustainability, and environmentally friendly innovation techniques.

RECOMMENDATION

The following recommendations were given after the findings of the study. Further analysis should be conducted to determine the specific active component of thermoplastics that contributes to the strength of the asphalt; It is recommended that a follow-up experiment be conducted with different factors from this study. The researcher recommends that future studies be on road constructions and DPWH to consider the use of thermoplastic polymer

components in Asphalt modification. It is highly recommended that a follow-up Marshall-stability testing be conducted to have more reliable results regarding the strength/durability, modulus of elasticity, and rupture of the asphalt samples, and future research should be conducted with similar topics to verify and nullify for improvement.

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