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Mixed Rubbles, Pulverized Waste Glass, and Plastic Bottles as Partial Replacements for Aggregates and Binders in a Modified Asphalt Mixture

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***Abstract*: This literature review provides an overview of studies on the use mixed rubbles, pulverized waste glass and plastic bottles as partial replacements for aggregates and binders in a modifies asphalt mixture. Due to the large demand for raw materials in constructing asphalt pavement, many studies about providing different alternative materials for asphalt pavement mixtures have existed. This is to provide a solution for the increasing usage of non-renewable materials in constructing an asphalt pavement. This study determined the strength and compatibility of mixed rubbles, waste glass, and plastic bottles as a partial replacement for aggregates and binders in a modified asphalt mixture. Standard Test Method for Compressive Strength of Bituminous Mixtures (ASTM D1074 – 02) results conducted on the zero day up to the 8th day, shows that it is evident that the specimens' compressive strength values correspond with the quantity of aggregates utilized in the mixture. Standard Test Method for Marshall Stability and Flow of Asphalt Mixtures (ASTM D6927 – 15) results conducted on the zero-day and eight-day, it is evident that the specimens' marshall stability and flow values correspond with the quantity of aggregates utilized in the mixture.**

***Keywords*: Mixed Rubbles, Modified Asphalt Mixture, Waste Glass, Plastic Bottles, Bituminous.**

1. Introduction

Pavements are one of the most demanding assets in the infrastructure department, and they are dependent on natural resources that do not replenish themselves. Pavement is a hard surface made from various materials, used for paths and roadways. Due to the large demand for raw materials in constructing asphalt pavement, many studies about providing different alternative materials for asphalt pavement mixtures have existed. This is to provide a solution for the increasing usage of non-renewable materials in constructing an asphalt pavement. To addressed this issue and to lessen the use of natural aggregates in the construction of asphalt pavement, the researchers conducted this study. By using different alternative materials such as mixed rubbles and waste glass as a partial replacement for aggregates and waste plastic bottles as a partial replacement for binder in modified asphalt mixture.

Recycled rubble from materials such as masonry, concrete, rock, tiles, stones, and terrazzo can all be reused in foundations, road bases, general bulk fill, footpaths, driveways, bank protection, and embankment protection. Using recycled building materials is a cost-effective solution and will have a positive impact on your well-being by contributing to the environment. Waste glass is another waste material that is produced in large quantities and is difficult to eliminate. Waste glass and mixed rubble were used as a partial replacement for aggregates, which can lessen the large demand for natural aggregates in asphalt mixtures.

Plastic bottle waste is a material that pollutes the environment if it is not recycled, thousands of tons of plastic bottle waste is produced from beverage product waste, especially mineral water (Zainuri, Yanti G and Megasari SW 2022). Waste plastic bottles used as asphalt binder are a great way to address the issue of proper disposal and lessen the environmental issues that the world is facing right now.

This study determined the strength and compatibility of mixed rubbles, waste glass, and plastic bottles as a partial replacement for aggregates and binders in a modified asphalt mixture. This study is expected to have a huge impact on the environment and the construction industry. Aside from having cheaper alternative materials, it can also produce easy environmental solutions in terms of waste disposal and preserving non-renewable resources.

2. Scope and Limitation of the Study

The study focused on the compatibility and strength evaluation of a modified asphalt mixture using mixed rubble, pulverized waste glass, and plastic bottles as partial replacements for aggregates and binders in a modified asphalt mixture. Mixed rubble from different construction projects will be gathered randomly. Polyethylene terephthalate (PET) type of plastic used in this study. It is one of the exceptionally asked-for plastics on the planet and among the most well-known plastic waste. Due to increased production in the last decades, the recycling of PET is of major concern. For the recycled waste glass, the researchers used Type III: Bottles made of Soda-Lime or Soda-Lime-Silica Glass. These glass bottles are the most frequently manufactured type. Due to their cost-effectiveness and their resistance to chemicals and water, Type III bottles are widely utilized in the food, beverage, and pharmaceutical industries. This study excludes the actual application of the modified asphalt mixture inroads as a pavement.

This study conducted and carried out in Aurora Province, where all of the raw materials are available. The performance evaluation and testing of the asphalt pavement will be evaluated at the NEMATEC Construction Materials Testing Center, located at Brgy. Bantug Norte, Cabanatuan City, Philippines.

3. Conceptual Framework

This section presented an idea that described how mixed rubble can be made into coarse aggregates. The fabrication of the study was accomplished by gathering the needed materials and preparing mixtures based on the standard ratio.

The evaluation of the product and testing were conducted at the DPWH-Aurora District Engineering Office.

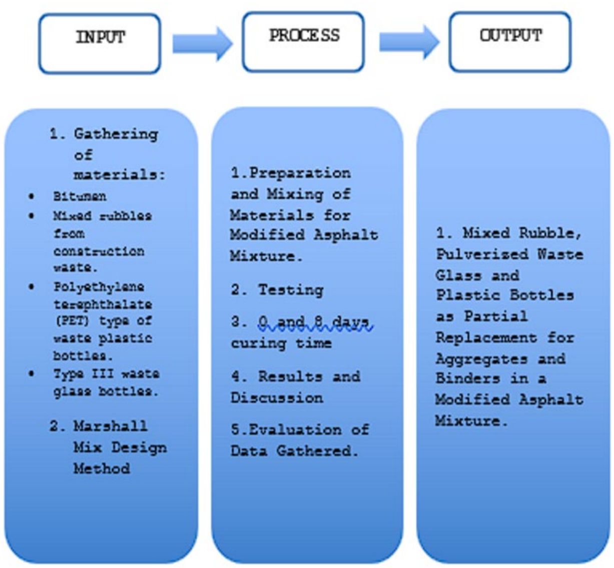

Fig. 1. Conceptual framework of the study

Figure 1 showed the process of generating a modified asphalt mixture using mixed rubble, pulverized waste glass, and plastic bottles as partial replacements for aggregates and binders. By including the input, process, and output, it illustrated the connection between each research technique and the activity. It is necessary to collect pertinent materials and information during the input phase. In order to gather technical data for the study, the researchers conducted a series of experiments to ascertain the physical and mechanical properties of the modified asphalt mixture. The researchers generated a modified asphalt mixture from the aforementioned waste materials as a result.

4. Statement of the Problem

The suitability of plastic bottles, mixed rubbles, and pulverized waste glass as stand-ins for aggregates and binders in a modified asphalt mixture was determined by this investigation.

In order to gather all the necessary data and information, the following questions were addressed in this study:

1. What are the properties of Asphalt mixture in terms of the following:

   Mechanical Properties
   - Flexure
   - Compressive strength
   - Specific gravity
   - Density
   - Moisture content
   - Stability
   - Flow

   Physical Properties
   - Odor
   - Color
   - Absorption
2. What was the optimum mixture ratio for the modified asphalt pavement?
3. How does the modified asphalt pavement differ in terms of material cost, and construction cost compared to the traditional asphalt?

5. Review of Related Literature

A. Waste Glass Bottle as Partial Replacement for Fine Aggregates

Waste glass can be efficiently used as coarse aggregate as a partial replacement for concrete. The study reveals that increasing the amount of waste glass in concrete leads to a decrease in splitting tensile strength and reduced workability (Tamanna, 2020a). Based on other results, the percentage of water absorbed decreases as waste glass content rises. Waste glass concrete becomes lighter as the amount of waste glass increases because the average weight falls as the amount of waste glass increases (Baig et al., 2018).

B. Mixed Rubble as Coarse Aggregates

Numerous researches have looked into the application and effectiveness of recycled concrete aggregate in asphalt concrete. Several studies that used indirect tensile strength, dynamic creep, stiffness modulus, and fatigue testing revealed that the performance of Hot mixed asphalt was lowered when recycled concrete aggregate was added as coarse aggregate (Arabani et al., 2013).

C. Waste Plastic Bottle as Partial Replacement for Binder

The Pulverized plastic bottle was used as a partial replacement for sand. Frigione's research in Italy analyzed the use of recycled PET bottles in replacing fine aggregate in concrete, finding comparable trends with minor strength reduction (Frigione, 2010). In addition to the idea of using plastic waste to modify asphalt binder, many researchers have looked into ways to improve the performance of asphalt concrete mixes.

D. Modified Asphalt Mixture

The pavement industry is revolutionized by advanced materials, which guarantee efficiency and sustainability. Research looks into the suitability of waste for building roads plastic and polymers demonstrate better Marshall stability and flow(Rahman et al., 2020).

One of the types of Quantitative Research Design that is used in this study is Experimental Design Research. The Experimental Research Design helps the researcher to test and evaluate the strength and compatibility of mixed rubble as coarse aggregates and waste glass as partial replacement for fine aggregates in asphalt mixture, conducting scientific experiments to investigate the research questions. It helps the researchers to gather the necessary data for making better research decisions and determining the facts of a research study.

6. Research Gaps

Table 1

Materials	Research Gaps	Citation
Mixed Rubble	Investigate the application of current mix design methods for asphalt mixtures containing recycled concrete aggregate.	(Paranavithana & Mohajerani, 2006)
Waste Glass Bottle	Limited usage of waste glass up to 20%.	(Baig et al., 2018)
	Investigate the influence of drying shrinkage on the use of recycled glass in concrete.	(Tamanna, 2020b)
	Waste glass is a poor coarse aggregate replacement due to glasses smooth surface area. This hinders the bond strength developed between the cement paste And the glass aggregate.	(Harrison et al., 2020)
Waste Plastic Bottle	The addition of Recycled Polyethylene Terephthalate to asphalt binder decreased the ductility and the penetration values and increased the softening points and rotational viscosity of the asphalt binder.	(Al-Jumaili, 2018)
	Recycled Polyethylene Terephthalate modifier had a negative effect on the low-temperature performance of asphalt binder. The low-temperature asphalt binder grade was decreased from -22ºC (for control asphalt binder) to -16ºC at 15% and 20% Recycled Polyethylene Terephthalate. It can thus be useful to use the RPET modifier in hot climates that are not highly susceptible to very low temperatures.	(Abuaddous et al., 2021)
	The addition of Recycled Polyethylene Terephthalate had a negative effect on asphalt binder fatigue cracking.	

7. Research Design

This study used a quantitative approach to attain greater knowledge, observe situations, and produce objective data that can be clearly communicated. Quantitative research is the process of collecting and analyzing numerical data.

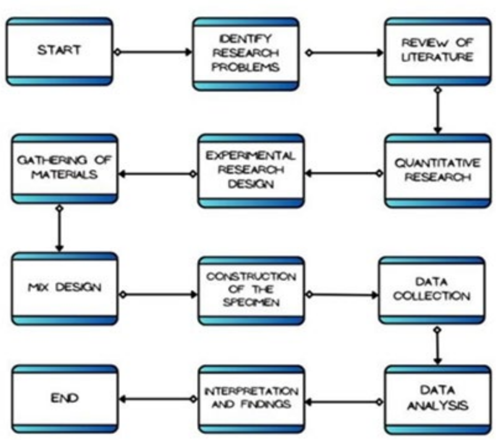

Fig. 2. Flowchart of research design

8. Research Flow

As shown in Figure 2, to evaluate the strength, durability, stability and compatibility of mixed rubble, pulverized waste glass, and plastic bottles as a partial replacement for aggregates in a modified asphalt mixture. The flow of the research started with identifying research problems, the problems and concerns with the selected topic, and why the researchers conduct and select the topic. After identifying research problems, the researchers reviewed all the related literature that would support the topic. A quantitative approach is the research design that would be used. And using an experimental research design to test and evaluate the strength and compatibility of mixed rubble, pulverized waste glass, and plastic bottles as partial replacements of aggregates in a modified asphalt mixture. To perform the experiment, the gathering of materials will be done. After the gathering of Data, mixing and construction of specimen will be done at Nematec Testing Laboratory. Once the testing is done, the result, data, and information on the modified asphalt mixture will be collected to analyze the necessary data for the improvement of the research. The interpretation and findings of the research will be discussed to conclude the result of the test and answer the questions and problems. The indicated objective of the study should be the outcome of the research.

9. Research Process

In this study, the process of modified asphalt mixture is being made with the use of raw materials such as mixed rubble as coarse aggregates, crushed waste glass as partial replacement for fine aggregates and waste plastic bottle as partial replacement for binders.

A. Step 1: Preparation of Mixed Rubble

Fig. 3. Preparation of Mixed Rubble

B. Step 2: Preparation of Waste Glass Bottle

Fig. 4. Preparation of Waste Glass Bottle

C. Step 3: Preparation of Waste Plastic Bottle

Fig. 5. Preparation of Waste Plastic Bottle

D. Step 4: Preparation of Paving Asphalt/Mixing of Materials

Fig. 6. Preparation of Paving Asphalt/Mixing of Materials

Fig. 7. Preparation of Paving Asphalt/Mixing of Materials

E. Step 5: Preparation of Specimen for Testing

Fig. 8. Preparation of Specimen for Testing

Fig. 9. Preparation of Specimen for Testing

Fig. 10. Final Specimen

10. Results and Discussion

A. Compressive Strength Test Result

The researchers conducted a compressive strength test at the NEMATEC BRS-DPWH Accredited Construction Materials Laboratory. The test was important to ascertain the amount of compression that the asphalt can withstand and to understand how they could be used in construction projects for specific purposes. The finding from zero day to eighth-day compressive strength test were displayed in Figure 11.

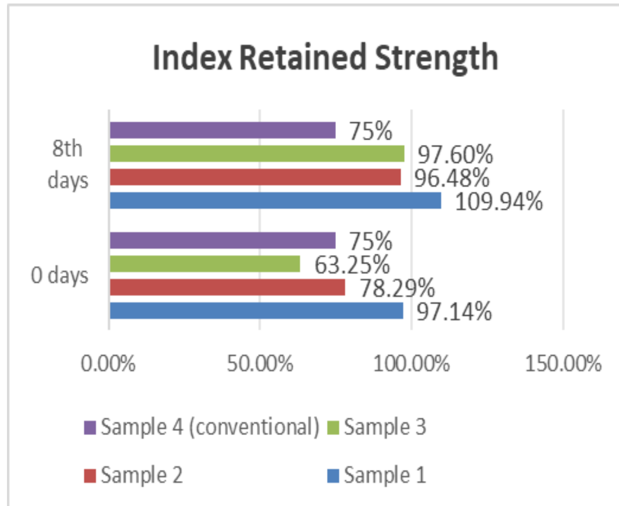

Fig. 11. Compressive strength of asphalt through the 0th days, 8th days curing process

The values of compressive strength within zero and after eight days of curing are shown in Figure 3. Within zero day and eighth days, Sample 1 index retained strengths are 97.14% and 109.94%. On the zero and eighth days, Sample 2's index retained strengths were 78.29% and 96.48%, respectively, whereas Sample 3's index retained strengths were 63.25% and 97.60% respectively. The standard sample of asphalt has a minimum index retained strength of 75%. On the zero day, the Sample 1 and Sample 2 have met the standard index retained strength while Sample 3 failed to achieve the minimum strength. Sample 1, Sample 2, and Sample 3 on the 8th day had an increase in their index retained strength and attained the minimum requirement for its compressive strength.

B. Marshall Stability & Flow Test

The researchers conducted a marshal stability and flow test at the NEMATEC BRS-DPWH Accredited Construction Materials Laboratory. The test was important to evaluate the strength and deformation characteristics of the asphalt mixture. To determine the suitability of asphalt mixture for road construction and maintenance. The findings from the zero-day to eighth-day marshal stability and flow test were displayed in Figure 12.

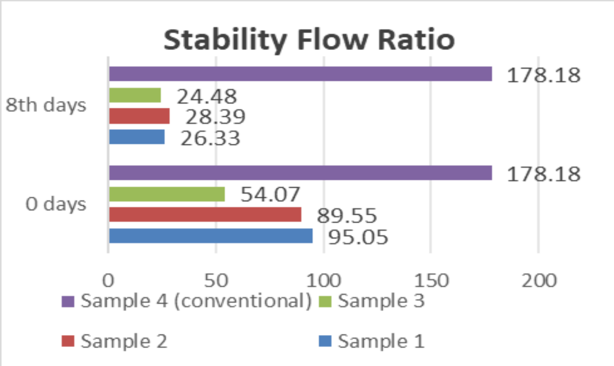

Fig. 12. Marshall stability and flow test of asphalt through the 0th days, 8th days curing process

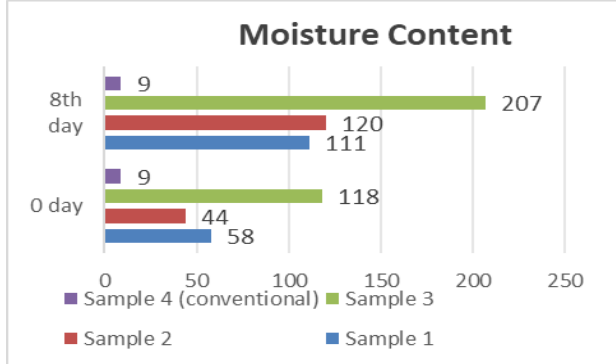

Fig. 13. Moisture content result on the 0 day and after 8th days of curing time

Figure 12, display the marshall stability - flow ratio of each specimen after an asphalt production was created. The samples were composed of the same materials with different proportion.The values of marshall stability and flow test of asphalt within zero and after eight days of curing are shown. Within zero day and eighth days, Sample 1 was composed of 30% partial replacement for coarse aggregates, 15% partial replacement for fine aggregates, 8% partial replacement for asphalt cement (bitumen); the result of its (stability to flow ratio) within 0 days was 95.05 lbs/in then after 8th days was 26.33 lbs/in, while sample 2 was composed of 50% partial replacement for coarse aggregates, 15% partial replacement for fine aggregates, and 8% partial replacement for asphalt cement (bitumen), 0 days has 89.55 lbs/in and after 8th days of curing the stability to flow ratio was 28.39 lbs/in. Sample 3 was composed of 70% partial replacement for coarse aggregates, 15% partial replacement for fine aggregates, 8% partial replacement for asphalt cement (bitumen) has a lower value of stability to flow ratio than the two samples with 54.07 lbs/in on 0 day and 24.48 lbs/in after 8th days of curing. Conventional samples were created in a manner similar to the commercially available asphalt. Only the conventional asphalt, with a stability-to-flow ratio of 178.18 lbs/in. Referring to figure 4. considering the results of the marshall stability and flow tests conducted on the zero-day to eighth-day, it is evident that the specimens' marshall stability and flow values correspond with the quantity of aggregates utilized in the mixture. As the quantity of conventional aggregates decreases, the specimens' marshal stability also decreases.

C. Moisture Content

Moisture content calculation is used to determine the amount of moisture present in the asphalt sample. It was obtained using the formula: Moisture Content (%) = ((Ww - Wd) / Wd) x 100. The figure below shows the result of the moisture content calculation and the effect of mixed rubbles, pulverized waste glass, and plastic bottles as partial replacements for aggregates and binders in a modified asphalt mixture on 0-day to 8-days curing process.

The graph above shows the moisture content values on 0-day and after 8-days of curing process. Sample 1 is having 58% on 0 day and 111% after 8th days of curing, while on sample 2 the result of 0 day is 44% and 120% after 8 days of curing. Sample 3 shows that 0day has 118% of moisture content and 207% after 8th days of curing. The result of moisture content on the 0days and after 8th days shows that the longer curing time, the values are also increasing, but still all sample are passed on the requirement of conventional asphalt mixture moisture content.

D. Density Test

Determination of the density of the asphalt was important since it helped projects where weight was an issue and with certain construction components that had weight restriction. The table shows the tabular representation of data from the asphalt's density test after oven drying on the 0 days and 8th days cured samples.

The graph above shows the density values of sample 1 having 2.16 g/cm3, 2.18 g/cm3, and 2.17 g/cm3 on 0-day and having 2.20 g/cm3, 2.14 g/cm3, and 2.17 g/cm3 after 8-days of curing; the sample 2 have values of 2.20 g/cm3, 2.17 g/cm3, and 2.13 g/cm3 on 0-day and 2.16 g/cm3, 2.20 g/cm3, and 2.16 g/cm3 after 8th days of curing; while the sample 3 have 2.11 g/cm3, 2.03 g/cm3, and 2.01 g/cm3 on 0 day of curing and values of 2.12 g/cm3, 2.04 g/cm3, and 2.04 g/cm3. On the other hand, the conventional samples have density values of 2.457 g/cm3, 2.474 g/cm3, and 2.470 g/cm3.

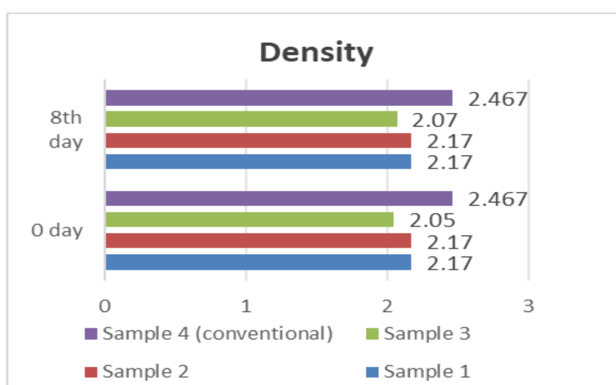

Fig. 14. Density test result on the 0 day and after 8th days of curing time

E. Bulk Specific Gravity Test

Determination of the bulk specific gravity was important since it gives vital information about the material's volumetric properties. Engineers use this information to design asphalt mixtures, calculating vital parameters like air voids and mineral aggregate voids, to ensure pavement durability and performance. The table shows the tabular representation of data from the asphalt's bulk density test.

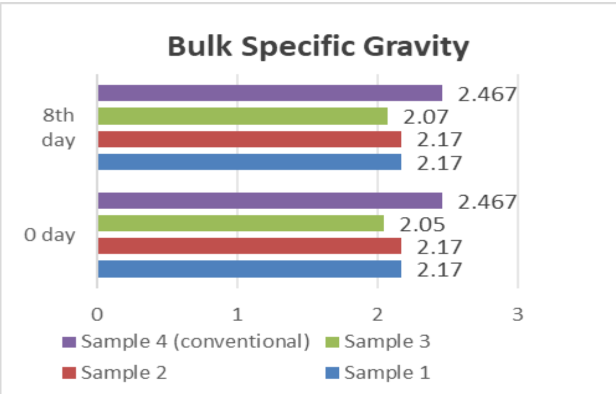

Fig. 15. Bulk specific gravity result on the 0days and after 8th days of curing time

The figure above shows the density values of sample 1 having 2.16, 2.18, and 2.17 on 0-days and 2.20, 2.14, and 2.17 after 8th days of curing, sample 2 have values on 0-days of 2.20, 2.17, 2.13 and 2.16, 2.20, and 2.16 after 8th days of curing; while the sample 3 have 0days values of 2.11, 2.03, 2.01 and after 8th days value of 2.12, 2.04, and 2.04 . On the other hand, the conventional samples have density values of 2.457, 2.474, and 2.70.

F. Physical Properties (Odor, Color)

Determining the physical qualities of an asphalt mixture, including odor, color, and absorption is critical to guaranteeing the end product's quality, performance, safety, and cost-effectiveness. By assessing these features, asphalt mixture designers and producers may make high-quality mixtures that satisfy specifications, perform well, and reduce environmental and safety risks.

a. Sample 1

Fig. 16. Sample 1

Fig. 17. Sample 1

Fig. 18. Sample 1

b. Sample 2

Fig. 19. Sample 2

Fig. 20. Sample 2

c. Sample 3

Fig. 21. Sample 3

Sample 1, Sample 2, and Sample 3 odor was a strong chemical odor, especially during its creation, and it smells like gasoline. Sample 1 appeared to be black in color while Sample 2 was also black in color but darker than Sample 1 and Sample 3 appeared to be black but lighter in color than the two samples.

11. Cost Estimation of Traditional Asphalt Mixture Vs. Modified Asphalt Mixture

Table 1, shows the cost estimation difference between Traditional Asphalt Mixture and Modified Asphalt Mixture with 30%, 50% and 70%. It shows that the total cost estimation of Traditional Asphalt Mixture (14, 144,013.5) is higher than the cost estimation when the Coarse Aggregate is being replace by 30% costing 12,793,814.77 , 50% costing 12,602,313.58 and 70% costing 12,410,812.35.

12. Conclusion and Recommendation

This section presents the conclusion drawn from the results and the recommendations made from the conclusion of this research.

13. Conclusion

This paper has presented some of the experimental results obtained in an investigation of the effect of Mixed Rubbles, Pulverized Waste Glass, And Plastic Bottles As Partial Replacements For Aggregates And Binders In a Modified Asphalt Mixture. Based on the laboratory testing results of the gathered data, the researchers came to the following conclusions:

- The Properties of Asphalt Mixture in terms of Physical Properties and Mechanical Properties are being investigate by using Standard Test Method for Compressive Strength of Bituminous Mixtures (ASTM D1074 – 02) and Standard Test Method for Marshall Stability and Flow of Asphalt Mixtures (ASTM D6927 – 15).
- Standard Test Method for Compressive Strength of Bituminous Mixtures (ASTM D1074 – 02) results conducted on the zero day up to the 8th day, shows that it is evident that the specimens’ compressive strength values correspond with the quantity of aggregates utilized in the mixture. As the quantity of conventional aggregates decreases, the specimens’ compressive strength also decreases. On the zero day, the Sample 1 and Sample 2 have met the standard index retained strength while Sample 3 failed to achieve the minimum strength. Sample 1, Sample 2, and Sample 3 on the 8th day had an increase in their index retained strength and attained the minimum requirement for its compressive strength.
- Standard Test Method for Marshall Stability and Flow of Asphalt Mixtures (ASTM D6927 – 15) results conducted on the zero-day and eight-day, it is evident that the specimens’ marshall stability and flow values correspond with the quantity of aggregates utilized in the mixture. As the quantity of conventional aggregates decreases, the specimens’ marshal stability also decreases.
- The Moisture Content results shows that all the sample’s passed the required value for moisture content while the result on Density test, no sample passed and all of them are failed to pass the required Sample 1, Sample 2, and Sample 3 odor was a strong chemical odor, especially during its creation, and it smells like gasoline. Sample 1 appeared to be black in color while Sample 2 was also black in color but darker than Sample 1 and Sample 3 appeared to be black but lighter in color than the two samples.
- In terms of its cost estimation, the Modified Asphalt Mixture is having low cost rather that the Traditional Asphalt Mixture because the materials that are used for partial replacement are all waste material that are being recycled.

Table 2
Cost estimation of traditional asphalt mixture and modified asphalt mixture

	Traditional Asphalt Mixture	Modified Asphalt Mixture		
		30%	50%	70%
Asphalt Cement	13,071,859.2	-	-	-
Asphalt Cement w/ 8% Partial Replacement	-	12,026,109.49	12,026,109.49	12,026,109.49
3/4" Coarse Aggregates	390,871.57	273,610.12	195,435.81	117,261.47
3/8" Coarse Aggregates	566,634.43	396,644.10	283,317.22	169,990.33
Fine Aggregates	114,648.30	-	-	-
Fine Aggregates w/ 15% Partial Replacement	-	97,451.06	97,451.06	97,451.06
TOTAL COST	14,144,013.5	12,793,814.77	12,602,313.58	12,410,812.35

14. Recommendation

Future Researchers can further improve this research by:

- Aside from Laboratory Testing, try investigate Field Trials and Real-Life Application for better result on the effect of waste materials for being Partial Replacement on certain materials.
- Explore a broader or higher percentage of replacement for each waste materials to determine the optimal balance between performance and sustainability.
- Investigate the effect if the waste material became additives on the mixture instead of being a Partial Replacement only.
- Conduct a more longer curing time process if these can affect the Physical and Mechanical Properties of the Sample.
- Try other waste material that can be use as an additive or partial replacement on a modified asphalt mixture and make it a waterproof mixture.

15. Acknowledgment

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