CRUMB RUBBER AS SUBSTITUTE FOR CELLULOSE FIBERS IN ASPHALT CEMENT FOR ROAD CONSTRUCTION

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Abstract

This study aims to develop innovative asphalt material which can be used for road construction. The study investigated the effects of crumb rubber on the binder characteristics of modified materials. The rubber materials were characterized with sieve analyses, Marshall Stability and bulk density determinations. Due to numerous rubber sources and varying methods used to create crumb rubber, this study that characterized the impact of crumb rubber properties in modified binders are important to classify the performance of the modified materials as well as provide guidance for future uses of the materials. The most important aspect of using crumb rubber is the performance evaluation of rubber modified asphalt pavement. The finding from the modified binder testing showed that crumb rubber changes the rheological properties of the binder. The study have shown that using crumb rubber as an additive and binder in asphalt cement of road pavement can give a good results because of the small differences of values compared to the standard mixture.

Keywords: Crumb Rubber, Cellulose Fiber, Asphalt Cement, Marshall Stability, Modified Binders, Sieve Analyses, Bulk Density.

Roads are one of the most essential for transportation in people's daily lives. Going places every day, people tend to experience different problems in road such as, road cracks, uneven surface of the pavement and slippery road that results to hassle and uncomfortable journey, or worst it can lead to accidents.

Life span and strength of the road depends on the fillers and properties of the mixture. However, according to studies, replacing the cellulose fiber by crumb rubber has the same components with adding cellulose fiber as filler.

Crumb rubber was first used as a binder modifier in the United States in 1950's; however, the first application of crumb rubber as a modifier for asphalt pavements construction occurred in 1964. This material was created by Charles McDonald who applied CRM (Charles McDonald) Asphalt as a test patch at the Sky Harbor Airport of Phoenix, Arizona, to seal existing surface cracks from water exposure and to prevent reflective cracking. Upon evaluation, the experimental crumb rubber patch was deemed successful and the product was called "McDonald Technology" (Brown, 1993). This innovative technology led to the development of other liquid asphalt rubber.

The country's solid wastes typically contain more organic components than other materials. According to NSWMC, disposed waste is dominated by biodegradable waste with 52 percent, followed by recyclable waste which accounts for 28 percent of rubber. The Philippines' waste generation continues to rise with the increase in population, improvement of living standards, rapid economic growth, and industrialization especially in the urban areas. The NSWMC calculated that from 37,427.46 tons per day in 2012, the country's waste generation steadily increased to 40,087.45 tons in 2016 with an estimated average per capita waste generation of 0.40 kilograms per day for both urban and rural. There are estimated 4,088,000 tons of waste rubbers in the Philippines in 2016 (Senate.gov, 2017). Hence, proper handling and re-use of used tire cannot affect and harm the environment. In fact, it can be recycled as replacement for the fibers in asphalt cement.

This study focuses on the use of crumb rubber in asphalt pavement. There are four known different methods that produce crumb rubber and identified how each method created uniquely different particles. These methods were listed as a Cracker Mill Process, Granular Process, Micro Mill Process and Cryogenic Process. The report identified the Cracker Mill Process as the most common method for producing crumb rubber. Cracker Milling was conducted by using rotating steel drums that were designed to tear scrap rubber into usable sizes. The second method described was the Granulator Process which uses ambient temperatures along with the revolving steel plates to cut the scrap tire into a usable size. Micro Milling was described as a finishing process that could be used to shred the materials into very fine size. This process requires adding water to the rubber to create slurries that can be passed through an abrasive disc for grinding. The Cryogenic Process was identified as the methods that produce materials with glassy smooth textures. The crumb rubber that was used in this study underwent to Granular Process.

While experience has shown, using recycled rubber in asphalt mixture is feasible; there are varying methods for incorporating the rubber into pavement which affect the overall performance of the mixture. The two main methods of rubber modification are the dry method and wet method. The dry method was developed in 1986 by Tackallou and utilizes coarse rubber particles as a proportion of the aggregate gradation. Dry mixes can incorporate a relatively high amount of rubber with typical mixes consisting of approximately three percent rubber. The wet method stems from a binder modification process developed by Charles McDonald in 1964. This method utilizes finely ground rubber (crumb rubber) particles to modify asphalt binder used in asphalt paving mixtures. The wet method uses rubber content up to

20 % by the weight of the asphalt binder (Brown, 1993).

One disadvantage of the dry method is mixture uniformity. Differences in rubber and aggregate densities cause the rubber and aggregate to separate during the mixing and hauling processes (Marvin Myhre, 2002). The separation can cause large pockets of rubber to exist in the pavement which led to construction and long term performance problems. Additionally, when rubber is exposed to the asphalt binder, the rubber absorbs some light ends and oils of the binder. When these occur, the rubber modified mixture is weakened (Marvin Myhre, 2002).

While the quantity of rubber used in the wet process is not as great as that in the dry process, the wet method of directly modifying the asphalt binder has numerous benefits by directly modifying the binder with crumb rubber, there is less rubber separation in the final mixture generating a more homogenous material when compared to dry method mixtures. The smaller particles allow for better dispersion of the rubber and increase the influence of the rubber modification on the total mix lending itself to be highly durable quieter and smoother (Marvin Myhre, 2002).

Asphalt is the composition of bituminous binder with aggregates; a mix of crushed stones, gravel and sand, and approximately 4-7% of bitumen. The use of the rubber additives in asphalt mixture may differ the ratio and pavement construction cost. Even so, replacing the cellulose fiber by crumb rubber is eco-friendly and practical. Rubber asphalt is produced either by wet process: rubber is melted in the liquid asphalt binder before mixing, or by dry process: rubber replaced a portion of fine aggregate during mixing (Huang et al. 2007). Rubber pavement association found that using tire rubber in open-graded mixture binder could decrease tire noise by approximately 50% (Zhu and Carlson, 2001). It can also be used to minimize the damage of pavement such as resistance to rutting and fatigue cracking (Ali, 2013).

Background of the Study

The researchers aim to validate the improvement of asphalt that may be used in road construction by adding a content of crumb rubber. The researchers are also interested to determine the effect of the added waste tire to the feature of the asphalt. The study corroborated the findings from the standard mixtures compare to the crumb rubber mixture. The researchers prepared sample mix following the standard percentage of the mixture. Cellulose fiber in pellets form is to be added in wet mixed aggregates in the amount of 0.3% to 0.45% by weight (3.0 to 4.5 kg per metric tons).

Statement of the Problem

Smooth riding experience for users is the main goal of modern highway. Damaged road is one of the problems in the field of transportation that needs immediate attention. Hence, the researchers conceptualize the study to provide new ideas on how to improve the durability and strength of the roads through generation of a material suitable for the construction of roads which replaces the cellulose fibers by crumb rubber in the mixture. The study sought to answer the following questions:

1. What are the physical properties of the asphalt mixtures?

2. What is the mechanical property of the asphalt mixtures?

Objective of the Study

1. To determine the physical properties used for road construction in terms of voids, flow and specific gravity.

2. To determine the mechanical property used for road construction in terms of Marshall Stability.

Scope and Delimitations

The scope of the study is limited to the following:

1. The use of crumb rubber as a binder.
2. The study will consider Marshall Stability for mechanical property.
3. The study will consider voids, flow and specific gravity for physical properties.
4. Crumb rubber will be supplied by Vermillion Incorporation company.
5. Asphalt bitumen will be supplied by L.R Tiqui Builders.

Significance of the Study

The study is going to be significant to the following groups for the possible benefits the product may be useful for them.

Students. The study may provide a ready reference for studies/research which is similar to the topic presented.

Construction Industry. The study may help asphalt production industries and construction firms as result of the study may provide an additional design mixture that can be used for road construction.

Society. The study aims to provide information about the advantages of using crumb rubber as substitute for cellulose fiber. It also aims to introduce to the society the properties of the new mixed design of asphalt pavement.

Researchers. The study may help the researchers to discover the improvement of using crumb rubber in asphalt cement mixture for road construction and to develop new mixture design that can be improved by other researchers.

Environment. The study may help the environment to lessen the number of used tires and making it as a useful material in road construction (by processing and as substitute in cellulose fiber).

Review of Related Literature

In the study of Pasalkar, Atul A. and Bajaj, Yogesh M. as cited in the article "Waste Rubber Tires in Construction of Bituminous Road by Prof. Justo et al (2002), at the Centre for Transportation Engineering of Bangalore University, they compared the properties of the modified bitumen with ordinary bitumen. It was observed that the penetration and ductility values of the modified bitumen decreased with the increase in proportion of the plastic additive up to 12 percent by weight. Therefore the life of the pavement surfacing using the modified bitumen is also expected to increase substantially in comparison to the use of ordinary bitumen. Shankar et al (2009), stated that crumb rubber modified bitumen (CRMB 55) was blended at specified temperatures. Marshall's mix design was carried out by changing the modified bitumen content at constant optimum rubber content and subsequent tests have been performed to determine the different mix design characteristics and for conventional bitumen (60/70) also. This has resulted in much improved characteristics when compared with straight run bitumen and that too at reduced optimum modified binder content (5.67 %). Mohd, Imtiyaz (2002) concluded that the mix prepared with modifiers shows: - Higher resistance to permanence.

Waste rubber tires were collected from roads sides, dumpsites and waste-buyers. The collected waste tires were sorted as per the required sizes for the aggregate. The waste tires were cut in the form of aggregate of sizes ranging from 22.4mm to 6.00 mm (as per IRC-SP20) in the tire cutting machine. The waste rubber tires can be managed as a whole tire, as slit tire, as shredded or chopped tire, as ground rubber or as a crumb rubber product. The rubber of tire

usually employed in bituminous mix, in the form of rubber particles are subjected to a dual cycle of magnetic separation, then screened and recovered in various sizes and can be called as Rubber aggregate. It was cleaned by de-dusting or washing if required. The rubber pieces (rubber aggregate) were sieved through 22.4 mm sieve and retained at 5.6 mm sieve as per the specification of mix design and these were added in bituminous mix, 10 to 20 percent by weight of the stone aggregate. These rubber aggregate were mixed with stone aggregate and bitumen at temperature between 1600c to 1700c for proper mixing of bituminous mix. As the waste rubber tires are thermodynamically set, they are not supposed to melt in the bitumen, at the time of mixing of rubber aggregate, stone aggregate and bitumen in hot mix plant (Irjet, 2018).

This study states that ordinary bitumen was compared with the modified bitumen by performing such test as penetration and ductility test which shows a remarkable result as they increase the percentage of the additive. However, the present study done by the researchers did not add but replaced the fillers by crumb rubber and also increased its quantity.

Furthermore, according to the study of Abusharar, Sari W and Al-Tayeb, Mustafa (2016), they stated that "The primary reason for using waste rubber in asphalt pavements is that it provides significantly improved engineering properties over conventional asphalt pavements. As demonstrated by various researchers, waste rubber have reduced fatigue and reflection cracking, greater resistance to rutting, improved aging and oxidation resistance and better chip retention due to thicker binder films. Also asphalt rubber pavements have been demonstrated to have lower maintenance costs, lower noise generations, higher skid resistance and better night-time visibility due to contrast in the pavement and stripping"

Abusharar's study highlights the advantages of using used tire in asphalt pavement than conventional asphalt pavements in road construction. It is required to study the effectiveness of used tires which is the purpose of conducting this study. The researchers also aim to study and verify the proficiency of using used tires in asphalt pavement as rubber is one of the main constituents in this study. The study have shown rubber modification of asphalt pavement could enhance the performance of low temperature flexibility, higher strength when wet and more resistance to oxidative hardening (Myhre, 2002). Other reports show addition of rubber can modify thermal cracking, rutting, reflective cracking and aging (Amirkhanian, 2006).

"Rubberized asphalt concrete is basically used for road construction, and is obtained from recycled tires. It is normally called RAC. It essentially includes ground tire rubber that is obtained from the granulated rubber particles. During recycling, the rubber is separated from the tire fabric and steel elements. The materials are grinded to form crumb rubber. These materials are basically derived from tires of light trucks or other resources where the content of rubber is high. RAC is produced by the wet process that involves mixing of binder and the rubber. The binder normally consists of 70%-80% of asphalt cement and 15%-25% of crumb rubber that are mixed thoroughly before delivery to the hot mix plant. Studies have established that four inch of the normal asphalt can be conveniently substituted with two inches of rubberized asphalt, to attain similar fatigue characteristics. This construction material has been proved to deliver satisfactory performance. It is environmentally friendly and economical, compared to the usual road paving materials. Normally, 2,000 used tires may be consumed for each lane mile that is paved. In some countries, asphalt rubber is one of the greatest single sources for ground rubber."https://www.brighthubengineering.com/structural-engineering/62920-rubberized-asphalt-concrete-materials/

Conceptual Framework

The study used the IPO model as the study framework.

The first frame is the input of the study. It includes the data and information gathering, identification of materials, mechanical properties of cellulose fiber and rubber, determination of mix proportion and process to be used.

The second frame shows the methods and techniques. It includes preparation of materials and equipment, testing and also the analysis of formulation for acceptability and cost

The third frame deals with the output of the study which is assessing the performance of the ideal design mixture for asphalt pavement.

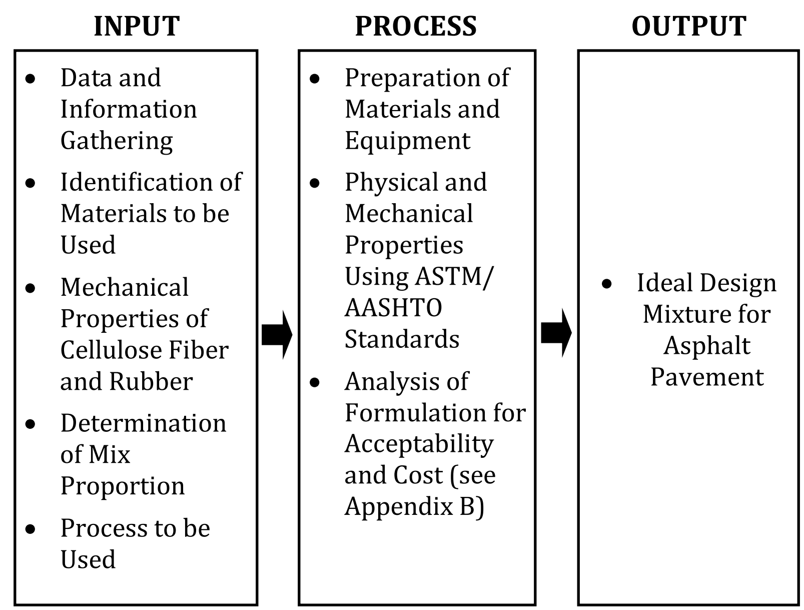

Figure 1. The Input – Process – Output Model

Method

The study is to be conducted in order to come up with a new design of asphalt mixture for road construction. It is also to be conducted as an experimental method for stronger road compared to standard design of asphalt mixture. The researchers will use crumb rubber tires as substitute for cellulose fibers as filler in order to achieve a less brittle road.

According to Mitchell (2015), the design of research is fraught with complicated and crucial decisions. Researchers must decide which research questions to address, which theoretical perspective will guide the research, how to measure key constructs reliably and accurately, who or what to sample and observe, how many people/places/things need to be sampled in order to achieve adequate statistical power, and which data analytic techniques will be employed.

The study is related in experimental design of new asphalt mixture, the experimental method of research is the proper method to use. The researchers used a comparative method analysis to the sample given by the asphalt manufacturer and the asphalt made by the researchers using Marshall Stability Test. To give proof to the study, the researchers will conduct experimental study to answer the how/why/what questions relating to the research.

The increased demand on highway roads might reduce its strength properties and make roads more susceptible to permanent distresses and failure. In general, pavement performance properties are affected by the bitumen binder properties. It is known that the conventional bitumen has a limited range of rheological properties and durability that are not sufficient enough to resist pavement distresses. Therefore, bitumen researchers and engineers are looking for different types of bitumen modifiers. There are many modification processes and additives that are currently being used in bitumen modifications such as styrene butadiene styrene (SBS), styrene-butadiene rubber (SBR),

ethylene vinyl acetate (EVA), and crumb rubber modifier (CRM). The use of commercial polymers such as SBS and SBR in road and pavement construction increase the construction cost as they are highly expensive materials. However, with the use of alternative materials such as crumb rubber modifier (CRM), it will definitely be environmentally beneficial, and not only it can improve the bitumen binder properties and durability but it has also a potential to be cost effective (Mashaan et al., 2014).

The researchers aim to improve the strength of the asphalt pavement using crumb rubber as substitute to cellulose fibers as filler in asphalt mixture used for road construction. It will be conducted and experimented to lessen the brittleness and crankiness of the road for better and comfortable transportation.

This study determines the effectiveness of crumb rubber as a modifier on asphalt mixture. On the other hand, the study that will be done by the researchers may possibly attained the characteristics which is also said on the study above, the presence of crumb rubber on the asphalt mixture may result on its improved characteristics of anti-rutting, anti -cracking, and anti-fatigue.

Figure 2. Crumb Rubber

Figure 3. Aggregates

Figure 4. Bitumen

Figure 5. Cement

Material Testing Procedure

1. Prepare the materials to be used (Crumb Rubber, Cement, Bitumen and Aggregates (3/8 and S1)).
2. Heating of bitumen with the temperature of 150 – 160 degrees Celsius.
3. Batching of materials per mixture (3/8 Aggregates, S1, Cement and Crumb Rubber).
4. Heating of 3/8 Aggregates, S1 and Cement to 150 – 160 degrees Celsius using stove with sand bath.
5. Adding of crumb rubber.
6. Adding of bitumen.
7. Preparing of moulds.
8. Mix all the materials in a container.
9. Pouring of mixture into the moulds. (140 – 145 Degree Celsius).
10. Tamping using spatula (15 times at the side and 10 times at the center).
11. Compacting using rammer (75 blows each side).
12. Cure the mixture for 24 hours.
13. De - moulding of the sample.
14. Measuring the dimensions of the sample using ASTM D – 3549.
15. Testing the density and specific gravity using ASTM D – 2726.
16. The mixtures are heated in a water bath for 35 minutes at 60 degree Celsius.
17. After being heated, the mixture is removed from the water bath, damp dried, and quickly placed in the Marshall apparatus.
18. The testing load is applied to the specimen at a constant rate of 2 in. per minute until failure occurs.
19. The failure recorded as the Marshall Stability value.
20. Computation of the Density, Specific Gravity, Voids and Marshall Stability Test.

The Marshall Stability Test, Density and Specific Gravity will be performed by the researchers at Reynaldo Guevarra Enterprise (RGE) at Tibag, Pulilan, Bulacan.

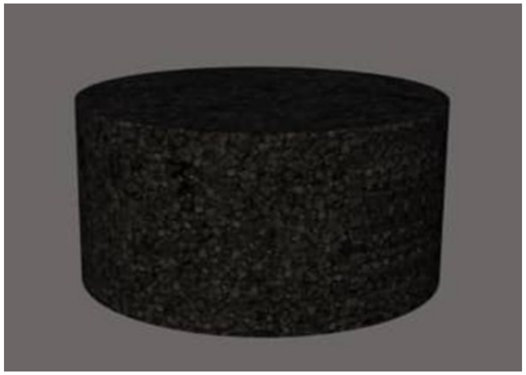

Figure 6. Proposed Asphalt Pavement

Samples to be Used

The main objective of this study is to determine the stability of asphalt by replacing cellulose fiber by crumb rubber. In this section, testing the samples, analysis of results and finding of observation and conclusion are indicated.

The nine (9) samples composing of three (3) different mixtures were made using cylindrical mold with the dimension of 2.5 inches in height and 4 inches in diameter were tested for Marshall Stability Test at Reynaldo Guevarra Enterprises (RGE). The samples took 24 hours to cure.

For the testing of Mixture 1 (Standard Mixture), Mixture 2 (50% cellulose fiber and 50% crumb rubber) and Mixture 3 (100% crumb rubber):

Sample Preparation (Mixture 3)

Prepare a 49.5% (594g) of 3/8 and 42.5% (510g) of S1 size aggregates with 1% (12g) of cement, 6.8% (72g) of bitumen and replacing the 1% (12g) cellulose fibers of 1% (12g) crumb rubber. After complete mixing pour the mixture in the moulds.

Table 1. Table of Mixtures

MIXTURE 1 (1200 g)	MIXTURE 2 (1200 g)	MIXTURE 3 (1200 g)
1% CEMENT = 12 GRAMS	1% CEMENT = 12 GRAMS	1%xx CEMENT = 12 GRAMS
42.5% SAND = 510 GRAMS	42.5% SAND = 510 GRAMS	42.5% SAND = 510 GRAMS
49.5% GRAVEL = 594 GRAMS	49.5% GRAVEL = 594 GRAMS	49.5% GRAVEL = 594 GRAMS
6% BITUMEN = 72 GRAMS	6% BITUMEN = 72 GRAMS	6% BITUMEN = 72 GRAMS
1% CELLULOSE FIBER = 12 GRAMS	0.5% CELLULOSE FIBER = 6 GRAMS	1% CRUMB RUBBER = 12 GRAMS
	0.5% CRUMB RUBBER = 6 GRAMS	

Additionally, after the aggregates, sand and bitumen were heated on the stove with sand bath (150 - 160 degrees celsius) with designated ratio, each mixture is mixed as indicated:

While performing the Marshall Stability Test, the researchers noticed that all the samples failed by deforming.

Results of Density Test for Mixtures using ASTM D2726

Note:
The tables show the weight of the samples: Air (A) weight while exposed to atmosphere, Water (B) weight while submerged to water and Saturated Surface Dry (SSD) weight after being removed from the water and wiping the surface of the sample.

Subtracting the Water from Saturated Surface Dry (SSD) is the formula to get the Volume. In computing the Density, the Air is divided by Volume.

Having a lower density means higher air voids.

Table 2. Mixture 1 (Standard Mixture)

ASTM D2726					
Mixture 1	Mass, g			Volume, ml, D = C– B	Density @ 25°C, kg/m3, E =A/D
	Air, A	Water, B	SSD, C		
A	1183.56	663.81	1186.38	522.57	2.265
B	1191.92	663.87	1195.75	531.88	2.241
C	1180.46	656.86	1185.58	528.72	2.233

*This table is the basis of the further test results

The results in Mixture 1 C got the lowest value of density that indicates a good result compared to Mixture 1 A and Mixture 1 B.

Table 3. Mixture 2 (0.5% Cellulose Fiber and 0.5% Crumb Rubber)

ASTM D2726					
Mixture 2	Mass, g			Volume, ml, D = C– B	Density @ 25°C, kg/m3, E =A/D
	Air, A	Water, B	SSD, C		
A	1188.29	662.2	1195.03	532.83	2.23
B	1195.29	658.83	1206.14	547.31	2.185
C	1181.84	655.5	1186.14	530.64	2.227

The result in Mixture 2 B got the lowest value of density that indicates a good result compared to Mixture 2 A and Mixture 2 C.

Table 4. Mixture 3 (1% Crumb Rubber)

ASTM D2726					
Mixture 2	Mass, g			Volume, ml, D = C– B	Density @ 25°C, kg/m3, E =A/D
	Air, A	Water, B	SSD, C		
A	1182.28	657.31	1187.65	530.34	2.229
B	1196.77	670.54	1197.74	527.2	2.27
C	1186.06	655.88	1193.01	537.13	2.208

The result in Mixture 3 C got the lowest value of density that indicates a good result compared to Mixture 3 A and Mixture 3 B.

Results of Specimen Height (mm) for Mixtures Using ASTM D3549

Note:

The table shows the measurement of the samples by measuring four different angles of the specimen.

To get the average, add the specimen height 1, 2, 3 and 4 and divide it by 4.

Table 5. Mixture 1 (Standard Mixture)

Mixture 1	ASTM D3549 Specimen Height (mm)				
	1	2	3	4	Average
A	65.46	62.22	65.97	65.54	65.8
B	66.95	67.06	66.84	66.8	66.91
C	66.48	66.65	67.45	67.84	67.08

Table 6. Mixture 2 (0.5% Cellulose Fiber and 0.5% Crumb Rubber)

Mixture 2	ASTM D3549 Specimen Height (mm)				
	1	2	3	4	Average
A	68.42	68.3	68.43	68.81	68.49
B	69.37	69.06	69.4	69.71	69.385
C	66.95	66.87	66.7	66.43	66.7375

Table 7. Mixture 3 (1% Crumb Rubber)

Mixture 3	ASTM D3549 Specimen Height (mm)				
	1	2	3	4	Average
A	67.19	67.22	67.54	67.5	67.3625
B	66.48	66.85	66.65	66.87	66.7125
C	67.87	66.48	66.48	66.23	66.765

Results of Stability for Mixtures using ASTM D6927

Note:

- The value of Stability Reading and Flow came from the Marshall Test apparatus.
- The value of Correlation Ratio depends on the corresponding coefficient of the volume of the sample (See Table 8).

Table 8. Table of Correlation Ratio

Volume of Specimen	Correlation Ratio
354-367	1.92
368-379	1.79
380-392	1.67
393-405	1.56
406-420	1.47
421-431	1.39
432-443	1.32
444-456	1.25
457-470	1.19
471-482	1.14
483-495	1.09
496-508	1.04

Table 8. Continuation

Volume of Specimen	Correlation Ratio
509-522	1
523-535	0.96
539-546	0.93
547-585	0.83
586-598	0.81
599-610	0.78
611-625	0.76

- The value of Corrected is the product of Reading and Correlation Ratio.
- The formula to get the Voids in Mineral Aggregates (VMA) is:

$$100 - \textit{Average Density}\left(\frac{100}{\textit{Bulk Specific Gravity of Aggregates}}\right)$$

Table 9. Mixture 1 (Standard Mixture)

Mixture 1	ASTM D6927 Stability, (kN) Reading	Correla-tion Ratio	Corrected	Flow, (mm)	Void in Mineral Aggregates (VMA)
A	7.93	0.96	7.61	3.18	
B	6.21	0.96	5.96	2.97	
C	5.77	0.96	5.54	3.57	
Average			6.37	3.24	16

Table 10. Mixture 2 (0.5% Cellulose Fiber and 0.5% Crumb Rubber**)**

Mixture 1	ASTM D6927 Stability, (kN) Reading	Correla-tion Ratio	Corrected	Flow, (mm)	Void in Mineral Aggregates (VMA)
A	5.02	0.96	4.82	3.81	
B	4.12	0.89	3.67	4.16	
C	6.74	0.96	6.47	3.6	
Average			4.99	3.86	17.2

Table 11. Mixture 3 (1% Crumb Rubber**)**

Mixture 1	ASTM D6927 Stability, (kN) Reading	Correla-tion Ratio	Corrected	Flow, (mm)	Void in Mineral Aggregates (VMA)
A	7.94	0.96	7.62	3.81	
B	8.72	0.96	8.37	3.7	
C	6.05	0.93	5.63	3.11	
Average			7.21	3.54	16.4

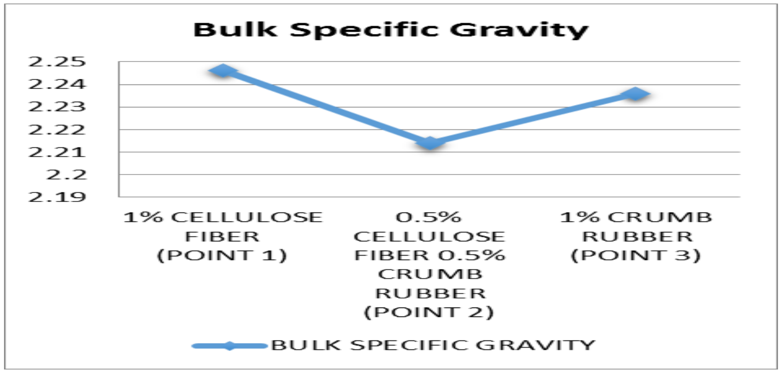

Figure 7. Bulk Specific Gravity

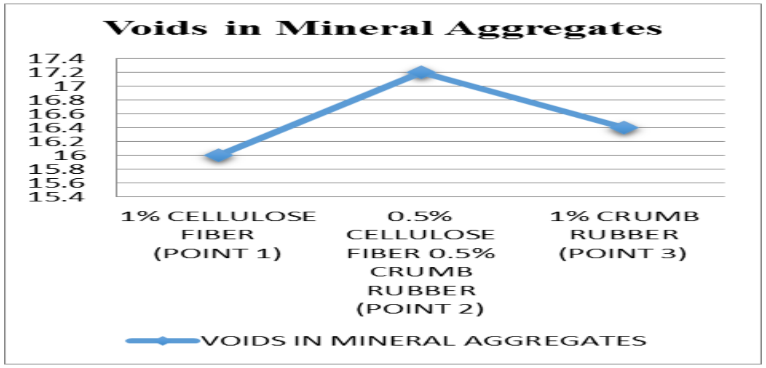

Figure 8. Voids in Mineral Aggregates

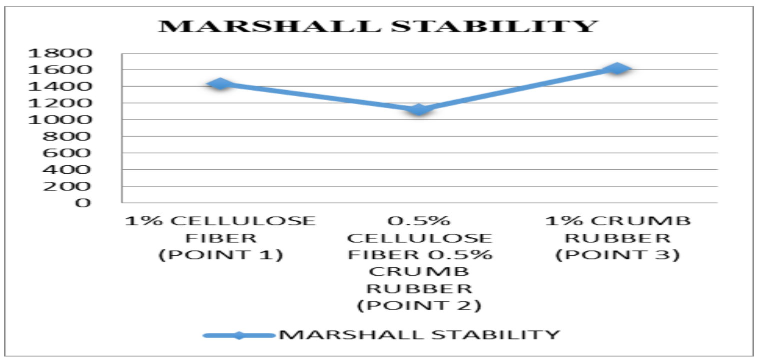

Figure 9. Marshall Stability

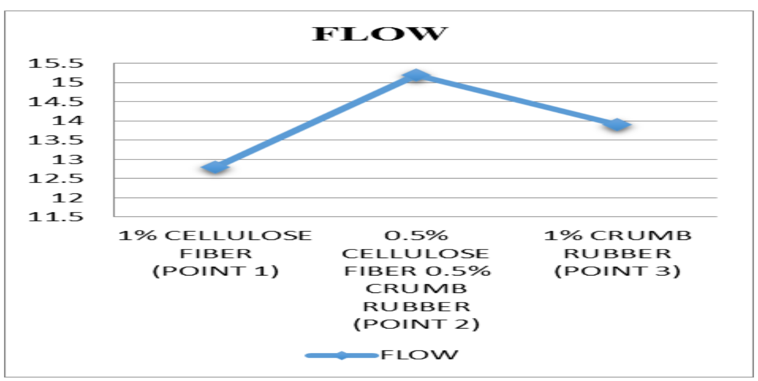

Figure 10. Flow

The graph indicates the results of the Marshall Stability Tests performed at Reynaldo Guevarra Enterprise (RGE) located at Tibag, Pulilan, Bulacan.

Note:

Point 1 indicates Mixture 1 (1 % Cellulose Fiber)
Point 2 indicates Mixture 2 (0.5 % Cellulose Fiber and 0.5 % Crumb Rubber)
Point 3 indicates Mixture 3 (1 % Crumb Rubber)

In Figures 7, 8, and 10 the results are good because of the small difference between the Proposed Mixture (Mixture 3) to the Standard Mixture (Mixture 1).

In Figure 9 shows outstanding result of the stability of Mixture 3 which went higher than the existing mixture despite the small changes on the other properties.

Summary

This thesis entitled "Crumb Rubber from tire as substitute for Cellulose fibers in Asphalt Cement for Road Construction" is devoted to study the characteristics of rubber tire that may be used as substitute for cellulose fiber in making asphalt cement mixture. This study was performed in the period from January 2019 till December 2019, and the researchers are fifth year Civil Engineering students of Baliuag University.

The researchers of this study evaluated the comparison of the cellulose fiber modified binder versus crumb rubber modified binder illustrated that the value of the test results does not deviate the measurable effect on performance characteristics of the materials. Each mixture composed of three specimens, a total of 9 specimens; Mixture 1 (Cellulose fiber), Mixture 2 (Cellulose Fiber and Crumb Rubber) and Mixture 3 (Crumb Rubber). These samples underwent Marshall Stability Test.

Ultimately, analysis of the Mixture 3 (Crumb Rubber as substitute for Cellulose Fiber) showed improvement in terms of Stability likewise in voids, flow, and specific gravity.

Conclusions

This study shows that waste rubbers are not just to be thrown and be just waste for a very long time. It can also be used for possible component as substitute to fibers for a useful and valuable material known as asphalt cement. Through the results of tests and analysis, the following conclusions were presented:

- Asphalt cement with crumb rubber almost has the same results with asphalt cement that used the current cellulose fiber as its binder based on the tests that the researchers conducted.

- Based on the tests results, it showed that the current cellulose fibers that is being used and the crumb rubber are not compatible to be used in a mixture combined as revealed in the result shown in the test conducted. The mixture showed the lowest strength in all the mixtures presented.

Recommendations

Based upon the results and findings of the study, the researchers would like to recommend the following:

1. Using of crumb rubber as substitute for cellulose fiber is more practical and economical because of the price difference between the two; the cellulose fiber costs Php 200 per kg. While the crumb rubber cost Php 20 per kg.

2. Using crumb rubber as substitute for cellulose fiber because it will be more eco-friendly considering that you will be recycling waste rubbers instead, the waste staying in the environment for a very long time.

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