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RESEARCH ARTICLE

STYROFOAM AS ADDITIVE TO ASPHALT JOINT FILLER IN PORTLAND CEMENT CONCRETE PAVEMENT.

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Abstract

The study aimed to utilize waste Styrofoam as an additive to asphalt joint filler in Portland cement concrete pavement. Specifically, the study aimed to determine the mechanical properties of the asphalt joint filler combined with varying proportions of Styrofoam in terms of Penetration, Water Absorption, Drying time, Flexibility and Flash point. It also determined if there was a significant difference between the mechanical properties of the pure asphalt joint filler and the asphalt joint filler that was mixed with varying proportions of Styrofoam. Finally, the study also determined the acceptable proportion of the asphalt – Styrofoam joint filler mix considering its different properties and its cost vis a vis the pure asphalt joint filler.

All the samples passed the penetration, water absorption and drying time tests. The 40 percent asphalt – 60 percent Styrofoam and the 50 percent asphalt – 50 percent Styrofoam joint fillers cannot be used as joint filler because while it passed the penetration, drying time and water absorption tests, it failed the critical flexibility and flash point tests. The 70 percent asphalt – 30 percent Styrofoam, the 80 percent asphalt – 20 percent Styrofoam, and the 90 percent asphalt and 10 percent Styrofoam joint fillers passed the flexibility, penetration, water absorption and flash point tests. These asphalt – Styrofoam proportioning can therefore be used as alternative to the pure asphalt joint filler in the Portland cement concrete pavement.

The study made use of the Analysis of Variance (ANOVA) one way classifications test and the Duncan's Multiple Range Test (DMRT) to determine if there is a significant difference between the experimental group and the control group in terms of the Penetration, Time of Setting, Flexibility and Flash point test results. For the penetration test, the ANOVA findings showed that there was a significant difference between the different proportions with a P-level of 0.000. However, when this was further tested using Duncan's Multiple (DMRT), the test showed that 90% Asphalt-10% Polystyrene gave a similar result that met the Penetration grade of a pure asphalt joint filler at 11mm. The absorption tests findings were not subjected to any statistical tests because based on the results, all of the samples of the experimental group maintained their original weights at 50 grams after being soaked

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to the water for 24 hours. This test result indicated that all of the samples did not absorb water and are good alternatives for the pure asphalt joint filler.

In terms of the different samples' drying time, the ANOVA test results showed that there was a significant difference between the groups with a P- Level of 0.000. However, this was further tested using Duncan's Multiple Range Test (DMRT) and showed that 40 percent Asphalt -60 percent Polystyrene possesses the fastest drying time at 45 minutes, which was good for a joint filler.

The ANOVA one way classification test was again used to determine if there was a significant difference between the flash point temperatures test results of the different proportions of the experimental group. The laboratory test results showed that there was a significant difference between the two groups with a p-Level of 0.025. However, this was further tested using Duncan's Multiple Range (DMRT) and showed that 60 percent asphalt – 40 percent polystyrene, 70 percent asphalt, 90 percent asphalt – 10 percent Polystyrene gives a similar result that met the standard Flash Point Temperature of 320 ̊C.

It took a laborer 30 minutes to cut a one kilogram of waste polystyrene into pieces. Since the laborer was paid P200/day, the total cost of obtaining a one kilogram of waste Styrofoam was P12.50. Since the cost of one kilogram of pure asphalt is P35.00, the price difference between the pure asphalt and the processed joint filler are P2.25 per kilogram for the 90%-10% proportioning, P4.50 per kilogram for the 80%-20% proportioning and P6.75 per kilogram for the 70%-30% proportioning. By using these proportioning, building contractors will not only be able to save on the cost of joint fillers for the Portland cement concrete pavement, they can also help in reducing the generation of waste discarded Styrofoam.

To conclude, the 70 percent asphalt – 30 percent Styrofoam, the 80 percent asphalt – 20 percent Styrofoam, and the 90 percent asphalt and 10 percent Styrofoam joint fillers passed the flexibility, penetration, water absorption and flash point tests. These asphalt – Styrofoam proportioning can therefore be used as alternative to the pure asphalt joint filler in the Portland cement concrete pavement. The building contractors can also save on cost while using the abovementioned proportioning aside from helping in reducing the generation of waste Styrofoam.

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Introduction:-

Plastic waste is a major global problem. According to Agence France – Presse, 9.1 billion tons of waste plastics have been produced by mankind as of 2015. These plastics are filling up the sanitary landfills and are polluting the oceans at an alarming rate. In urban areas, waste plastics are also one of the major causes of flooding as they clog up the sewers and drainage systems.

According to Greenpeace, an environmental group, the Philippines ranked as the third worst plastic polluter of oceans in 2017, next only to China and Indonesia. This does not come as a surprise considering that in a Manila Times Online press release on May 12, 2016, Metro Manila alone dumps an average of 861, 967 tons of waste plastics a year.

There are basically two types of plastics, namely, thermosetting or thermoplastic. Thermosetting plastics become soft when heated but they remain soft only for a short time. When they are heat continuously, they set or become hard. In contrast, a thermoplastic material also become soft when it is heated but it remains soft if the heat continues.

They also harden or set when they are cooled but they can be softened several times by heating them over and over again.

One of the Thermoplastic materials is Styrofoam. In the Philippines, Styrofoam is widely used in popular fast food chains to serve their meals or as food pack lunch. Since most of the Filipinos have the habit of eating out at lunch and dinner, a lot of these Styrofoam waste is generated.

Asphalt is a dark solid or somewhat plastic substance that is general used to pave roads and highways. In concrete roads, asphalt is also used as joint fillers or sealants. The asphalt joint filler is primarily used to protect the Portland cement concrete pavement from the penetration of moisture and unwanted materials as the concrete pavement expands and contracts with the changes in temperature. Since asphalt is a residue of petroleum, it is expensive. The Philippines imports asphalt from other countries.

The study aimed to utilize waste Styrofoam as an additive to asphalt joint filler in Portland cement concrete pavement.

General Objective:-

The primary objective of the study was to utilize the discarded Styrofoam material as an additive to asphalt joint filler in Portland Cement Concrete Pavement or PCCP.

Specific Objectives:-

The following were the specific objectives of the study: To add varying amounts of Styrofoam to the asphalt joint filler using the following proportions: 90% asphalt: 10% Styrofoam by weight, 80% asphalt: 20% Styrofoam; 70% asphalt; 30% Styrofoam; 60% asphalt: 40% Styrofoam; 50% asphalt; 50% Styrofoam; and 40% asphalt: 60% Styrofoam by weight proportioning; To determine the mechanical properties of the asphalt joint filler combined with varying proportions of Styrofoam in terms of Penetration, Absorption, Drying time, Flexibility and Flash point; To determine if there was a significant difference between the mechanical properties of the typical asphalt joint filler and the asphalt joint filler that was mixed with varying proportions of Styrofoam; and, to determine the acceptable proportion of the asphalt – Styrofoam joint filler mix considering its different properties and its cost vis a vis the standard asphalt joint filler.

Theoretical and Conceptual Framework:-

The research used the Conservation of Mass theory as well as the Reduce – Reuse – Recycle concept. By aiming to reuse Styrofoam pack lunch container, a waste product of many fast-food restaurants in the Philippines, as additive to the asphalt joint filler in the Portland cement concrete pavement (PCCP), the researchers will be able to develop an alternative building material that will also lessen the generation of Styrofoam waste in the country. Figure 1 presents the schematic diagram of the development of the joint filler using Styrofoam as an additive.

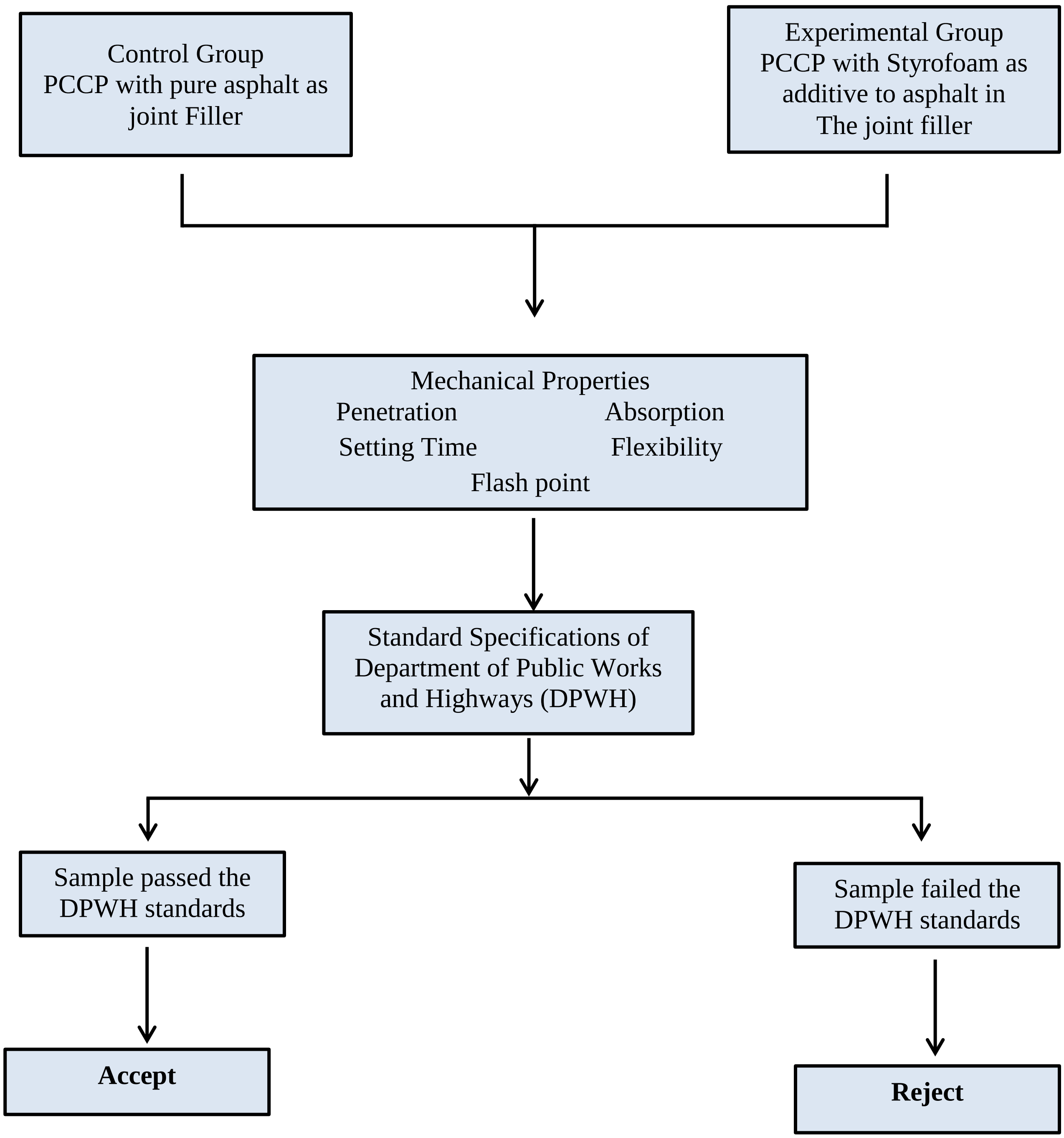

Figure 1:-Conceptual Framework of the study

Methods:-

The study used the Experimental-Correlational method of research. The experimental research attempts to maintain control over all factors that may affect the result of an experiment. The correlational method of research seeks to establish relationships between two or more variables.

The Styrofoam materials that were used in this study were obtained from among the waste materials of the fast food chains along the downtown area at Tacloban City, Leyte, Philippines. They were washed with water and detergent soap to eliminate the oil and dirt that were present in the samples. After washing the samples, they were wiped dry with cloth. They were cut into small pieces to facilitate weighing and placed into different containers. Apparatus, instruments and other facilities for all laboratory tests were limited to those available at the Department of Public Works and Highways, Region 8, Government Center, Candahug, Palo, Leyte, Philippines.

The researchers used the following varying amounts of Styrofoam in coming up with the experimental groups: 90% asphalt: 10% Styrofoam by weight, 80% asphalt: 20% Styrofoam; 70% asphalt; 30% Styrofoam; 60% asphalt: 40% Styrofoam; 50% asphalt; 50% Styrofoam; and 40% asphalt: 60% Styrofoam by weight proportioning. After coming up with the experimental groups, the mechanical properties of the asphalt joint filler combined with varying proportions of Styrofoam were tested in terms of Penetration, Absorption, drying time, Flexibility and Flash point were determined. Appropriate statistical tools such as Analysis of Variance (ANOVA) one-way classification test and the Duncan's Multiple Range Test (DMRT) were then used to determine if there was a significant difference between the mechanical properties of the typical asphalt joint filler and the asphalt joint filler that was mixed with varying proportions of Styrofoam. Finally, the researchers determined the acceptable proportion of the asphalt – Styrofoam joint filler mix considering its different properties and its cost vis a vis the standard asphalt joint filler.

Results and Discussions:-

The results of the laboratory test conducted for the engineering property determination of the 90 percent asphalt-10 percent Styrofoam, 80 percent Asphalt-20 percent Styrofoam, 70 percent Asphalt-30 percent Styrofoam, 60 percent Asphalt-40 percent Styrofoam, 50 percent Asphalt-50 percent Styrofoam, and 40 percent Asphalt-60 percent Styrofoam samples are presented in the succeeding tables. The tests conducted on the experimental group were the Penetration test, Water-absorption test, Drying Time and Flexibility determination and the Flash Point Test.

The results of the penetration test are shown in Table I. This test is used to determine the consistency of the samples.

Table 1:-Penetration Test Result On The Experimental Group

Proportion Asphalt/Styrofoam	Sample No.	Penetration Grade	Specification on Penetration Grade	Remarks
90%-10%	1	8	90max	Passed
	2	8	90max	Passed
	3	9	90max	Passed
80%-20%	1	7	90max	Passed
	2	7	90max	Passed
	3	7	90max	Passed
70%-30%	1	6	90max	Passed
	2	6	90max	Passed
	3	6	90max	Passed
60%-40%	1	5	90max	Passed
	2	5	90max	Passed
	3	5	90max	Passed
50%-50%	1	2	90max	Passed
	2	2	90max	Passed
	3	3	90max	Passed
40%-60%	1	-	90max	Passed
	2	-	90max	Passed
	3	-	90max	Passed

As manifested in Table I, all of the samples of the experimental group passed as far as consistency is concerned. And even if the 40 percent Asphalt-60 percent Styrofoam sample had no penetration grade, it was considered is as having passed the penetration test because the maximum allowable penetration grade is 90. With this result, all of the samples had met the specification needed on an asphalt joint filler on a penetration test.

Table 2 presents the results of the water absorption test on the Experimental Group.

Table 2:-Water-Absorption Determination Of The Experimental Group

Proportion Asphalt/Styrofoam	Sample No.	Dry Weight	Weight after soaking the sample to water	Weight Absorb
90%-10%	1 2 3	50g 50g 50g	50g 50g 50g	0g 0g 0g
80%-20%	1 2 3	50g 50g 50g	50g 50g 50g	0g 0g 0g
70%-30%	1 2 3	50g 50g 50g	50g 50g 50g	0g 0g 0g
60%-40%	1 2 3	50g 50g 50g	50g 50g 50g	0g 0g 0g
50%-50%	1 2 3	50g 50g 50g	50g 50g 50g	0g 0g 0g
40%-60%	1 2 3	50g 50g 50g	50g 50g 50g	0g 0g 0g

Based on the result of Table 2, all of the samples of the experimental group maintained their original weights after being soaked to the water for 24 hours. This test result indicated that all of the samples did not absorbed water and are good alternatives for the pure asphalt joint filler.

The Drying time of the Experimental Group was measured by simply allowing all the samples of the Experimental Group to dry. The results for the Drying time are displayed in Table 3.

Table 3:-Drying Time Of The Experimental Group

Proportion Asphalt/Styrofoam	Sample No.	Drying Time
90%-10%	1 2 3	65min 64 min 66 min
80%-20%	1 2 3	57 min 57 min 57 min
70%-30%	1 2 3	49min 47 min 51 min
60%-40%	1 2 3	43 min 44 min 42 min
50%-50%	1 2 3	36 min 38 min 34 min
40%-60%	1 2 3	28 min 30 min 32 min

Based on the result of Table 3, the 40 percent Asphalt and 60 percent Styrofoam had the fastest drying time while the 90 percent Asphalt and 10 percent Styrofoam had the longest drying time among the proportions tabulated. Since asphalt joint fillers should have fast drying times, the 50 percent Asphalt- 50 percent Styrofoam and the 40 percent Asphalt-60 percent Styrofoam are good joint fillers as far as drying time is concerned.

In an Asphalt application, the drying time of asphalt influences the workability of the material. Hot asphalt use in joint fillers to the pavement should have a short drying time so that concrete pavement can be used right away after the joint filler has dried.

Table 4 illustrates the Flexibility of the Experimental Group. The results of this Flexibility Determination were based on the expert observations of the Senior Material Engineer of the Department of Public Works and Highways Region VIII.

Table 4:-Flexibility Of The Experimental Group

Proportion Asphalt/Styrofoam	Sample No.	Remarks
90%-10%	1	More flexible
	2	More flexible
	3	More flexible
80%-20%	1	Flexible
	2	Flexible
	3	Flexible
70%-30%	1	Flexible
	2	Flexible
	3	Flexible
60%-40%	1	Less brittle
	2	Less brittle
	3	Less brittle
50%-50%	1	Brittle
	2	Brittle
	3	Brittle
40%-60%	1	Brittle
	2	Brittle
	3	Brittle

Based on the result on Table 4, the 40 percent Asphalt-60 percent Styrofoam ratio and the 50/ 50 percent ratio were the most brittle and failed to meet the qualification of an asphalt joint filler. Joint filler must be flexible in order to cope with the varying temperatures. However, the 90% Asphalt-10 percent Styrofoam was the most flexible sample whereas the 80 percent Asphalt-20 percent Styrofoam and 70 percent Asphalt-30 percent Styrofoam also passed the Flexibility test.

The results of the Flash Point Test of the Experimental group are revealed in Table 5.

Table 5:-Flash Point Temperature Of The Experimental Group

Proportion	Flash Point Temperature
90%-10%	310°C
80%-20%	302°C
70%-30%	294°C
60%-40%	288°C
50%-50%	274°C
40%-60-%	260°C

Based on the results on Table 5, the 40 percent Asphalt-60 percent Styrofoam had the lowest igniting temperature, while the 90% perce
Point Temperature of asphalt because asphalt is flammable.

Table 6 demonstrates the summary of findings of all the laboratory tests results.

Table 6:-Summary Of Test Results

Proportion	Penetration	Absorption	Time of Setting	Flexibility	Flash Point	Cost Cu. Ft	Recommendation
90%-10%	**8**	**0**	**65**	**More Flexible**	310°C	204.74	Suitable
80%-20%	**7**	**0**	**57**	**Flexible**	302°C	169.26	Suitable
70%-30%	**6**	**0**	**49**	**Flexible**	294°C	132.07	Suitable
60%-40%	**5**	**0**	**43**	**Less Brittle**	288°C	144.13	Not Suitable
50%-50%	**2**	**0**	**36**	**Brittle**	274°C	**-**	Not Suitable
40%-60%	**-**	**0**	**30**	**Brittle**	260°C	**-**	Not Suitable

As presented in Table 6, only the 90 percent asphalt 10 percent Styrofoam, 80 percent asphalt 20 percent Styrofoam and 70 percent asphalt 30 percent Styrofoam proportioning by weight are suitable alternatives to the pure asphalt joint filler because they all passed the critical flexibility and flash point tests.

With regards to the statistical treatment of the data, the study made use of the Analysis of Variance (ANOVA) one – way classification test to determine if there is a significant difference between the Penetration test results. Table 7 elucidates the ANOVA test on penetration. The test results showed that there was a significant difference between the proportions with a P-level of 0.000.

Table 7:-One Way Classification For The Penetration Test

SU	SS	df	MS	F	P-Level	
Proportions	143.78	5	28.76	0.000		Significant
Error	1.33	12	0.11			
Total	145.11	17				

Conversely, when the data was further tested using Duncan's Multiple Range Test (DMRT), the 90% Asphalt-10% Polystyrene still gave a similar result that met the Penetration grade of a pure asphalt joint filler as disclosed in Table 8 below.

Table 8:-Dmrt For The Penetration Test

Proportion						
90%-10%	8.33					
80%-20%		7				
70%-30%			6			
60%-40%				5		
50%-50%					2.33	
40%-60%						0.000

The study made use if the Analysis of Variance(ANOVA) one way classification test to determine if there was a significant difference between the Drying Time Determination results of the different proportions of the experimental group. As shown in Table 9, the laboratory test result showed that there was a significant difference between the groups with a P- Level of 0.000.

Table 9:-One Way Classification For The Time Setting

SU	SS	df	MS	F	P-Level	
Proportions	2560	5	5127	219.43	0.000	Significant
Error	28.00	12	2.33			
Total	8213	17				

Nevertheless, this was further tested using Duncan's Multiple Range (See Table 10) and showed that 40 percent Asphalt -60 percent Polystyrene possessed the fastest drying time, which was good for a joint filler at 45 min.

Table 10:-Dmrt For Time Of Setting Of Asphalt

Proportion						
90%-10%	65					
80%-20%		57				
70%-30%			49			
60%-40%				43		
50%-50%					36	
40%-60%						30

To determine if there was a significant difference between the Flash point temperatures test result of the different proportions of the experimental groups, the study made use of analysis of Variance (ANOVA) one way classifications test (See Table 11). As exemplified by the test results, there was a significant difference between the groups with a p-Level of 0.025. On the other hand, when the data was further tested using Duncan's Multiple Range test, the results showed that 60 percent asphalt – 40 percent polystyrene, 70 percent asphalt, 90 percent asphalt – 10 percent Polystyrene conformed to the standard Flash Point Temperature of 320 °C.

Table 11:-One Way Classification For Flash Point Test

SU	SS	df	MS	F	P-Level	
Proportions	5088	5	1017.6	3.9013	0.025	Significant
Error	3130	12	260.83			

With respect to the cost comparison between the experimental group and the control group, it took the laborer 30 minutes to cut a one kilogram of waste Styrofoam into small pieces. Since the laborer was paid P200.00 per day, the total cost of obtaining a one kilogram of waste polystyrene was P12.50 per one kilogram. On the other hand, the cost of one kilogram of pure asphalt is P35.00 per kilo.

Table 12 elucidates the summary of the cost analysis of the different proportions of the processed Joint Filler.

Table 12:-Cost Analysis Of The Processed Joint Filler

Proportion filler	Cost of Experimental Group	Cost of Control Group	Price Difference
90%-10%	P 32.75	P 35.00	P 2.25
80%-20%	P 30.50	P 35.00	P 4.50
70%-30%	P 28.25	P 35.00	P 6.75

***The price of the pure asphalt is P35.00 per kilo**

Based on Table 12, it revealed that the difference of price between the pure asphalt and the processed joint filler are P2.25 per kilogram for the 90%-10% proportioning, P4.50 per kilogram for the 80%-20% proportioning and P6.75 per kilogram for the 70%-30% proportioning. By using these proportioning, building contractors will not only be able to save on the cost of joint fillers for the Portland cement concrete pavement, they can also help in reducing the generation of waste Styrofoam.

To conclude, the 70 percent asphalt – 30 percent Styrofoam, the 80 percent asphalt – 20 percent Styrofoam, and the 90 percent asphalt and 10 percent Styrofoam joint fillers passed the flexibility, penetration, water absorption and flash point tests. These asphalt – Styrofoam proportioning can therefore be used as alternative to the pure asphalt joint filler in the Portland cement concrete pavement. The building contractors can also save on cost while using the abovementioned proportioning aside from helping in reducing the generation of waste Styrofoam.

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