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Asphalt Concrete as a Flooring Material

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Abstract

The need for having a good quality flooring has become something very important in order to enhance people's spaces and living lifestyle. Some of the most common tile materials are cork, vinyl, concrete, and ceramic. While these four materials mentioned before are still capable materials, asphalt concrete has a distinct pattern that may be an attractive alternative to the standard tile types. To try and find solutions to these problems and give people another material option, asphalt concrete was evaluated as a flooring material.

The reason why asphalt concrete could have this new application is based on the outstanding properties and its nice appearance that simulates a false granite. This report was focused on evaluating asphalt physical properties, such as flexibility and compressive strength, and aesthetical properties, such as thickness, size, and squareness, using aggregates of different sizes (4.75mm and 12.5mm) and comparing asphalt concrete to standard tile specifications to determine if it adequately fulfills the required tile properties. The early results show that asphalt concrete seems to meet the tile requirements explored for this project. Also, samples with NMAS of 12.5mm had a better performance in tests compared with 4.75mm samples. Thus, this data drives to the conclusion that asphalt concrete is worth pursuing with additional testing and evaluation.

Acknowledgment

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Asphalt Concrete as a Flooring Material

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1. Introduction

Living in a modern world, the need for having good quality flooring has become something very important in order to enhance people's spaces and living lifestyle. Factors considered when choosing flooring covering are not only those based on aesthetics or appearance but also resistance and the durability it can offer. Nowadays, some of the most common tile materials are cork, vinyl, concrete, and ceramic. Cork tiles are made of leftover cork from wine factories. Cork tiles are commonly sold in the standard sizes 12 in. by 12 in. or 12 in. by 24 in. with a thickness of 3/16 in. Although cork material is eco-friendly, when compared to other tiles, cork tiles are less durable. The ASTM F3008 standard method explains the production process of this product and the conditions required to make suitable cork tiles for a factory finish and in situ finish. Next, vinyl tiles are composed of binder and polymers, and the tiles are found as flooring sheet or tiles. Due to the low resistance to heavy load and exposure to sunlight, vinyl flooring is not recommended for outdoor spaces; which could be a disadvantage for consumers. The typical dimensions of vinyl tiles are 12 in. by 12 in. with a thickness of 1/8 in., and any other condition for these tiles are explained in detail in ASTM F170. Another common tile is concrete tiles. Concrete tiles are made of cement, aggregates, water, and other components. Concrete tiles are very popular in the flooring industry due to their versatility and durability. These tiles are found typically in 6 in. by 6 in. size and 3/8 in. thick, but sizes and thicknesses can vary as long as ASTM C1731 standard is applied correctly. Ceramic tiles, however, have clay as a principal component. Most ceramic tiles are about ¼ in. thick and 12 in. by 12 in. size, and the ASTM C126 explains in detail the process for making this tile. This product is durable and easy to maintain; nonetheless, the material does not hold the heat well so it might become cold and uncomfortable for consumers to walk on.

Nowadays, it is very common to find any type of material being researched as a component for flooring material. For example, leonardite and coal bottom ash have been researched to find if they can be used for the production of ceramic floor tiles. The physical, mechanical, and chemical properties of these new materials were examined and compared to the ceramic tiles requirements. The results reported that it is possible to produce ceramic tiles using those raw materials (Namkane et al., 2016).

While these four material mentioned before are good solutions, asphalt concrete has a distinct pattern that may be an attractive alternative to the standard tile types. Trying to find a solution to those problems mentioned before and to give people another material option, asphalt concrete was evaluated as a flooring material.

Asphalt concrete is composed of two main components, aggregate, and asphalt. Asphalt is a constituent of petroleum and is composed of a performance-graded binder. Asphalt concrete is commonly used as surface layers for roads, sidewalks, or parking lots.

The use of asphalt concrete as a flooring material has not been well explored. One of the few times that asphalt was used as a popular flooring material choice was during the 1980's. The asphalt tiles were mixed with Asbestos, a thermoplastic binder, resinous type, pigments and inert material as filler, formed under while hot and cut to size (Canadian Standard Association, 1947). The standard sizes of asphalt asbestos tiles could be 9 in. by 9 in. and 12 in. by 12 in., and the thicknesses of the tile might be either 1/8 in. or 3/16 in. (Canadian Standards Association, 1947). Later on, asbestos was found to be detrimental for health; therefore, asphalt asbestos tiles were slowly replaced by flexible vinyl tile and other types that did not include asbestos. During the time it existed, the tiles proved to be durable and economical to produce. An example of asbestos tiles can be seen in Figure 1.

Figure 1. Asphalt Asbestos Floor Tiles. Asbesto Global, 6 Dec. 2017.
www.asbestosglobal.org/asbestos-asphalt-floor-tiles/

The reason why asphalt concrete could have this new application is based on the outstanding properties it has shown in the construction area that also fulfill many of the requirements for the architecture area. According to Neale in the “Tribology Book”, some of the architectural requirements for flooring include resistance to abrasion, resistance to impact, and resistance to chemicals and solvents (Neale, 1995). In addition, from an architecture perspective, it is important to highlight that the visual appearance of asphalt when cut is visually appealing because of its black background mixed with the aggregates which simulate the idea of false granite (Figure 2). This nice appearance results in attractive tiles not only for architects but for people in general.

Figure 2. Visual Appearance of Asphalt

This research aims to use several floor specifications for concrete tiles, cork tiles, vinyl tiles, and ceramic tiles as a reference to evaluate asphalt concrete as a flooring material. In addition, the previous research on asphalt asbestos tiles guided initial dimensions for the asphalt concrete tiles. Using all this information will help to create a new specification for asphalt concrete as a flooring material.

2. Objectives

Asphalt concrete is a versatile and visually aesthetic material that can be used for different applications. This research was focused on evaluating asphalt concrete as a possible flooring material. First, its physical properties, such as flexibility and compressive strength, were tested using specified aggregates of different sizes, as well as different material thickness and binder content, and I was compared to standard tile specifications to determine if it adequately fulfills the required properties. Second, its aesthetical properties were analyzed to determine if it is viable flooring material from an architectural perspective.

Finally, having determined its adequacy as a flooring material, potential logistical issues were identified and briefly discussed. These issues include production methods, production time, production yield, production costs, shipping survival, and application complexity.

3. Significance of Research

This research was focused on broadening the asphalt concrete application and extending present specifications to include asphalt concrete as a flooring material. During this process, asphalt concrete was sampled and tested rigorously in order to obtain enough data to determine its physical properties, including those as a flooring material. Due to the limited knowledge of the properties of asphalt concrete as a flooring material, this research has a particular interest on filling this void, with the potential for becoming a reference paper to those interested in continuing developing asphalt concrete applications. As developers become interested in this novel application for this readily available material, it could represent a business opportunity for manufacturers that will give customers a new option for flooring.

4. Materials and Methods

Two asphalt concrete mixture from the Department of Transportation (ArDOT) and Sem Materials, L.P were used for this research. The first mixture had a PG 64-22 binder with a nominal maximum aggregate size (NMAS) of 12.5 mm. The samples were compacted at a temperature of 290°F with an air void of 4.5 % and bulk specific gravity (G_{mb}) of 2.306. The aggregate gradation for 12.5mm could be seen in table 1.

Table 1. 12.5 mm Aggregate Gradation

Sieve Size	1	2	3	4	5		Job Mix	Control Points
50	100	100	100	100	100		100	100%
37.5	100	100	100	100	100		100	100%
25	100	100	100	100	100		100	100%
19	100	100	100	100	100		100	100%
12.5	68	100	100	100	100		96	90-100%
9.5	42	89	100	100	96		90	90% Max
4.75	6	29	97	93	75		63	
2.36	2	5	65	48	56		35	28-58%
1.18	2	5	41	19	43		22	
0.6	2	5	26	35	35		15	
0.3	2	5	16	6	27		11	
0.15	1	4	9	5	18		7	
0.075	1.3	3.6	4.1	4.5	12.4		4.9	2-10%
Cold Feed %	11	30	25	20	14			
Gsb	2.57	2.52	2.56	2.58	2.565			

The second mixture design had a PG 64-22 binder with a NMAS of 4.5 mm. The following characteristics are present in the mixture: compaction temperature 310°F, an air void of 0.8%, G_{mb} of 2.362, and asphalt content of 9.0%. The aggregate gradation for 4.75mm could be seen in table 2.

Table 2. 4.75 mm Aggregate Gradation

Stockpile ID	**AGG 1**	**AGG 2**	**AGG 3**			
Producer	2007.0532	2007.0533	2007.0534			
Type	Man. Sand	Natural Sand	Mineral Filler			
% in Blend	63	32	5	100	Production	
SIEVE				BLEND	Tolerance	Specs
25.0 mm	100	100	100	100		100
19.0 mm	100	100	100	100		100
12.5 mm	100	100	100	100		100
9.5 mm	100	100	100	100		100
4.75 mm	98	97.2	100	97.8		80-100
2.36 mm	70.2	88	100	77.4	+/-5.0%	60-85
1.18 mm	42.6	78.4	100	56.9		40-70
0.600 mm	22.6	60.2	100	38.5		25-55
0.300 mm	14	24	100	21.5		15-35
0.150 mm	9.6	3	98	11.9		8-20
0.075 mm	7.4	1.6	95	9.9	+/-1.0%	6-14
Aggregate gSB	2.625	2.558	2.800	2.611		
Sand equivalency						45 min

Four tests were performed in order to determine the physical properties of asphalt as a flooring material. First, compressive strength using the ASTM D1074-17 specification. The compressive strength test is used to observe what amount of load can be applied to a sample before failing. The compressive strength helps to determine if asphalt is suitable for certain environments and loading conditions that is an important characteristic when determining a material for flooring. During the process of selection of materials for batching, the aggregate samples were obtained following the practice ASTM D75 and reduced to an appropriate size according to the practice ASTM C702 (ASTM D1074, 2019). The asphalt binder was heated at a temperature of 310°F and mixed with the preheated aggregates to a temperature no hotter than 50°F above the mixing temperature. The mix should be completed within 90 to 120 s. The obtained specimen were cylinders with the dimension of 4.0 in. diameter and 4.0 ± 0.1 in. height as the ones shown in Figure 3.

Figure 3.Equipment of compressive strength test

The test was performed on three different samples for each mixture design to verify the accuracy of the result.

The second test run on the asphalt concrete was the flexibility test. A flexibility test was performed in order to determine asphalt concrete capability to bend before cracking. The benefit of the flexibility test in flooring studies is that it allows one to know the ease of handling in rolling, cutting, and fitting flooring material. The Canadian standard A100 was used in order to study the flexibility of asphalt as a flooring material. Instead of producing an asphalt tile for this test, a cylinder with a diameter of 6 in. was cut in samples with a thickness of 7/16 in. (Figure 4), and then those new samples were cut with the following dimensions: 4 in. wide and 4 in. long (Figure 5). It is important to mention that this process was made for both mixture designs. For the specimen preparation, five samples of each mixture were needed, and they were brought to a temperature of 73.4°±1.8°F. Following the Canadian standard for asphalt asbestos tile, the pieces were submerged in a water bath at the indicated temperature for no less than 15 minutes and no more than 30 minutes to achieve the needed moisture saturation for the test (Canadian Standard Association, 10). A MTS machine was adapted in order to perform this test. The rods had a separation of 2.5 in., and a load rod measuring 6 in. long by 4 in. wide by 0.6 in. deep was used. The uniform rate value chosen for this test was 0.002 in/min and took 5 to 7 seconds to complete the bend. The test was repeated five times for each mixture design.

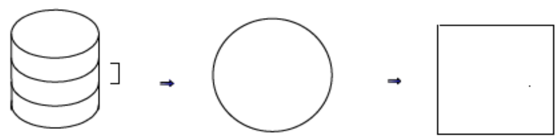

Figure 4. Specimen Preparation from Asphalt Concrete Cylinder

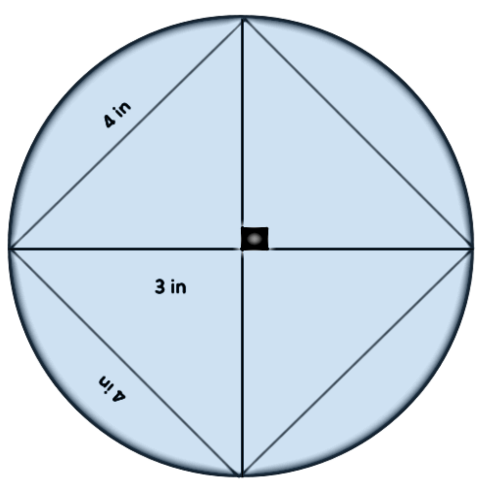

Figure 5. Specimen Dimension

The third test evaluated was the ASTM F386 Standard Test Method for Thickness of Resilient Flooring Material. The thickness test was performed to verify that a material keeps a constant surface. In flooring products, this test helps to ensure compliance with a certain specification so the quality of products can be preserved. The specimens had the following dimensions: 4 in. wide by 4 in. long with a thickness of 7/16 in (Figure 6). Following the ASTM F386 minimum size for the sample. Five specimens were prepared, and they were left at least 24 hours at a temperature of 73°± 3°F and 50±10 % relative humidity in the same space (ASTM F386, 2017). The test was performed five times, and five measurements in different parts of samples for each specimen were taken.

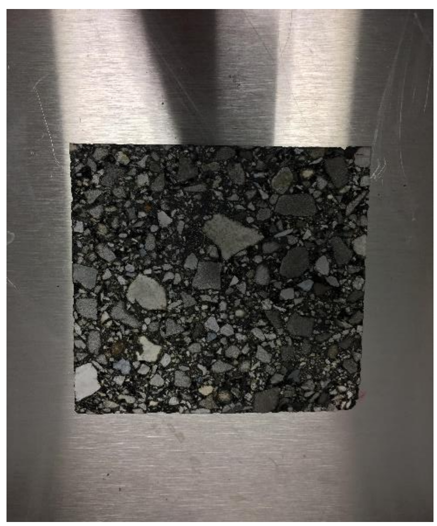

Figure 6. Specimen for Thickness and Squareness Tests

Finally, the fourth test was the ASTM F2055 Standard Test Method for Size and Squareness of Resilient Floor Tile. This test was performed in order to determine the dimensions and size conditions of asphalt as a flooring material. The importance of this test is reflected when installing flooring materials because it is significant that a flooring material meets the specified conditions to save time and money, as well as to keep a good appearance. For the specimen preparation, five specimens were used for this test, and they will consist of 4 in wide and 4 in long (Figure 7). According to the ASTM F2055, the specimen condition should be at a temperature of 73°± 1.8°F and 50±10 % relative humidity, and also they should be put on a flat surface such as the surface of the floor or a table to ensure the workability of the test. The test did not use the four dial gages specified by the ASTM 2055; instead, a ruler was used. The test was performed five times for each mixture design.

Figure 7. Squareness Test Performance

5. Results and Discussion

5.1 Compressive strength

Table 3 shows a summary of the mixture properties for both design mixtures calculated during the compression test.

Table 3. Summary of Mixture Properties for 4.75mm and 12.5mm mix design

Mixture Properties	4.75mm	12.5mm
Bulk density, kg/m^3	2.273	2.375
Max density, kg/m^3	2.294	2.482
Void content , %	3.9	4.0

Following the ASTM D1074-17 specification for Compressive Strength of Asphalt Mixture, the peak compressive strength was calculated by dividing the maximum vertical load by the total cross-sectional area of the cylinder. Then, the average peak compressive strength for the 4.75 mm mixture design was 298.63 psi while the average peak compression strength for 12.5mm mixture design was 362.15 psi. The results are shown in Table 4. As it is seen, all 12.5mm samples showed higher compression strength values than the 4.75mm asphalt mixtures.

Table 4. Peak Compressive Strength Values per Sample

No. Samples	4.75mm	12.5mm
1	298.85 psi	362.05 psi
2	299.92 psi	361.71 psi
3	297.12 psi	362.68 psi
Total Average	298.63 psi	362.15 psi
Standard Deviation	1.1413	0.4922

Figures 8 and 9 show samples of the behavior of each mixture depending on the type of nominal maximum aggregate size. 4.75mm samples indicated a clear peak with a drop afterward, while 12.5mm samples had a peak and then maintained the load. This could have happened because asphalt mixtures with 12.5mm NMAs seem to form a strong aggregate skeleton with more resistance to deformation when applying monotonic compressive loads. Both samples' mixtures failed when the displacement reached approximately 4 in.

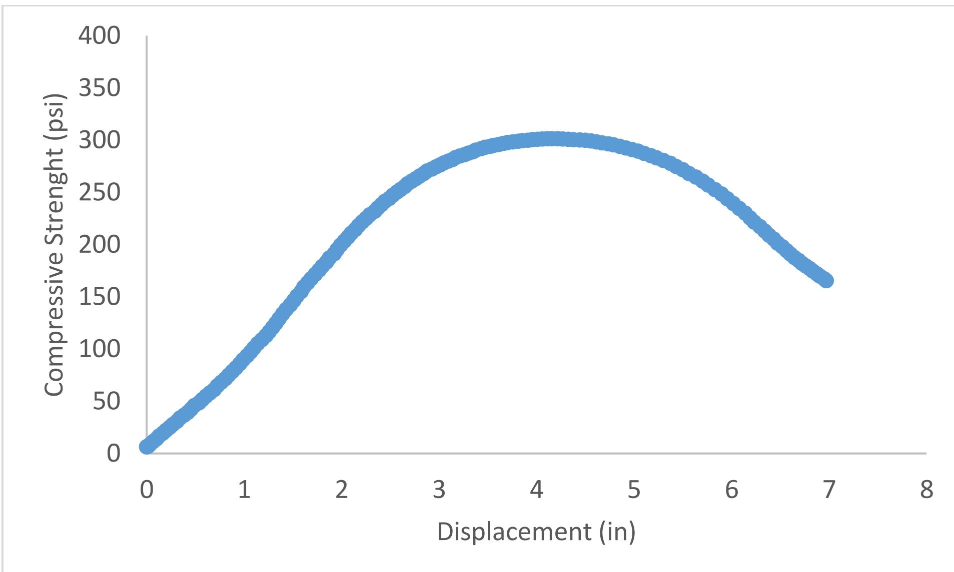

Figure 8. Compressive Strength Test Behavior in 4.75mm Mixture

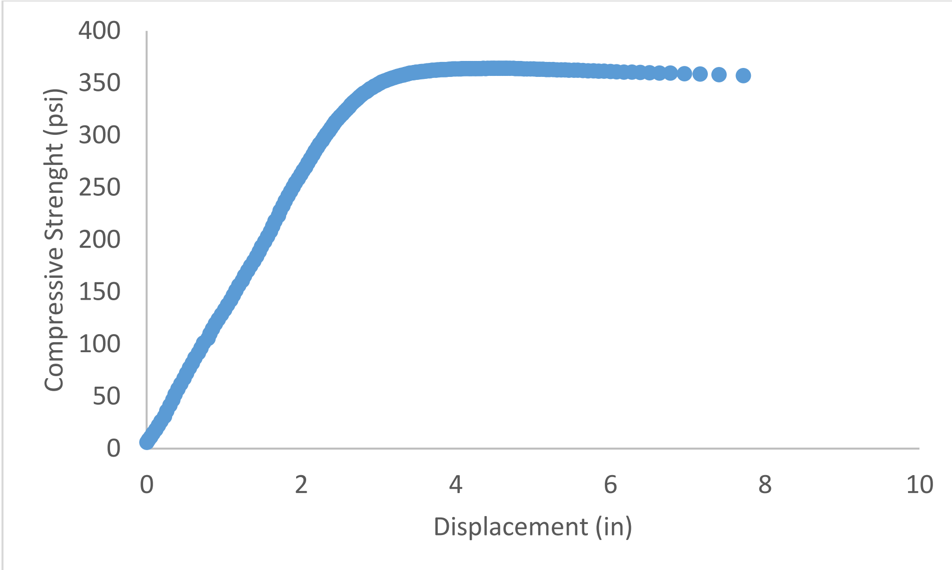

Figure 9. Compressive Strength Test Behavior in 12.5mm mixture

For concrete floor tiles, clay load-bearing facing tile and facing brick, average compressive strength values required are equal or exceed 4000 psi and minimum 3000 psi respectively. Comparing these results with the asphalt concrete samples used on this test, it is seen that asphalt concrete compressive strength in both mixtures is lower. However, this result was expected because it is known that asphalt concrete mixtures have a lower compressive strength compared with concrete and clay.

5.2 Flexibility Test

According to the ASTM F137, the passing criteria is that neither the face nor the back showed cracks, breaks, or permanent damages as it is shown in Figure 10 (ASTM F137). It is important to highlight that due to the dimension of the load rod, the test was performed only for the top and not for the back as it is specified in the ASTM F137. Table 5 summarizes the results founded in this test for both mixtures. 12.5mm mixture showed the majority of samples passing compared with 4.75mm samples.

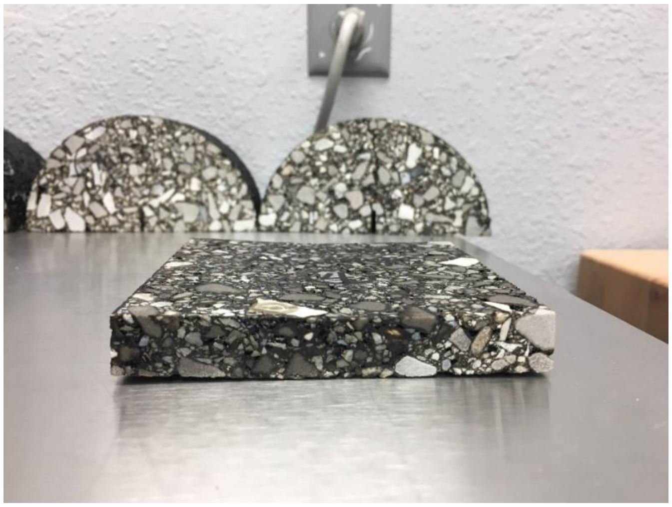

Figure 10. Passing Criteria Sample

Table 5. Summary of the Data obtained during Flexibility Test

4.75mm Thickness Samples	**Results**	**12.5mm Thickness Samples**	**Results**
0.4889	Failing	0.4870	Passing
0.5004	Failing	0.4685	Passing
0.5287	Passing	0.5209	Passing
0.4437	Failing	0.4846	Failing
0.5587	Passing	0.4964	Failing

As an extension of the data, the maximum forces applied to the samples are summarized in Table 6. For 4.75mm samples, there is a connection between the thickness and the maximum applied load; thicker samples are able to hold higher levels of forces before cracking. Contrary to this, 12.5mm samples did not necessarily show a connection between thickness and the load applied.

Table 6. Maximum Force applied to Both Mixture Samples

4.75mm Thickness Samples	Maximum Applied Load (kN)	12.5mm Thickness Samples	Maximum Applied Load (kN)
0.4889	0.2511	0.4870	0.2586
0.5004	0.2139	0.4685	0.2668
0.5287	0.3622	0.5209	0.2802
0.4437	0.2482	0.4846	0.2839
0.5587	0.2519	0.4964	0.3093

Taking a look into other tiles, it is seen that for solid vinyl floor tiles and cork tiles, the mandrel sizes specified for this test are 1 in. and 2 in. respectively, and samples should not show cracks or fractures. It is important to highlight that some changes were made to the ASTM F137 and comparing those tiles with the asphalt concrete samples is not possible in this case. However, it could be possible to create a correlation coefficient factor by testing the other types of tile materials under the same test condition. The development of such a correlation coefficient should be pursued in future research.

5.3 Thickness Test

The thickness value assigned for all the samples was 7/16 in. (0.4375 in). This value was chosen considering that tiles can usually be between 0.118 in. to 0.433 in. in thickness, and also the fact that generally thin tiles are more vulnerable to impact damage and decreased functional usage. The total average thickness for 12.5mm samples is 0.5081 in. which exceeds the thickness tolerance by 0.07 in. The total average thickness for 4.75mm samples is 0.4888 in. which also exceeds the thickness tolerance by 0.05 in. Tables 7, 8, 9, and 10 summarize the results obtained for 4.75mm samples and 12.5mm samples. As it is seen, samples for both mixture do not fall within the established value; however, when looking at Figure 11, it is noted that 4.75mm samples had a better approach to this assigned thickness value compared with 12.5mm samples. This data was expected considering the 4.75mm mixture exhibits less aggregate interlocking and lower shear resistance; therefore, cutting these samples might be easier. Specimen fabrication is a big part of tile production, so considering NMAs size if the field moves toward actual production should be studied in more detail.

Table 7. Summary of Findings for 12.5mm Thickness Test for Samples

Thickness of 12.5mm Samples (in)

	sample 1	Sample 2	Sample 3	Sample 4	Sample 5
	0.4810	0.5361	0.5050	0.5070	0.5180
	0.4850	0.4832	0.4995	0.4920	0.5550
	0.4960	0.4710	0.5235	0.4825	0.5380
	0.4940	0.5225	0.5110	0.5335	0.5325
	0.4810	0.5310	0.4910	0.5020	0.5315
Average Thickness	0.4873	0.5088	0.5060	0.5034	0.5350
Standard Deviation	0.0064	0.0296	0.0122	0.0193	0.0120
Coefficient of Variant	0.0131	0.0582	0.0242	0.0383	0.0224
Minimum Thickness	0.4873				
Maximum Thickness	0.5764				

Table 8. General Average Values for thickness, Standard Deviation, and Coefficient of Variant of 12.5mm Samples

Average Thickness	**Standard Deviation**	**Coefficient of Variant**
0.5081	0.0159	0.0312

Table 9. Summary of Finding for 4.75 mm Thickness Test

Thickness of 4.75mm Samples (in)

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
	0.4920	0.4960	0.4681	0.4926	0.4910
	0.4810	0.4865	0.4621	0.4730	0.5280
	0.4865	0.4860	0.4550	0.4655	0.5215
	0.5290	0.4716	0.4661	0.4650	0.5095
	0.4985	0.4830	0.5471	0.4835	0.4835
Average Thickness	0.4974	0.4846	0.4796	0.4759	0.5067
Standard Deviation	0.0188	0.0087	0.0380	0.0117	0.0191
Coefficient of Variant	0.0378	0.0180	0.0792	0.0247	0.0378
Minimum Thickness	0.4757				
Maximum Thickness	0.5067				

Table 10. General Average Values for thickness, Standard Deviation, and Coefficient of Variant for 4.75mm Samples

Average Thickness	**Standard Deviation**	**Coefficient of Variant**
0.4888	0.0192	0.0395

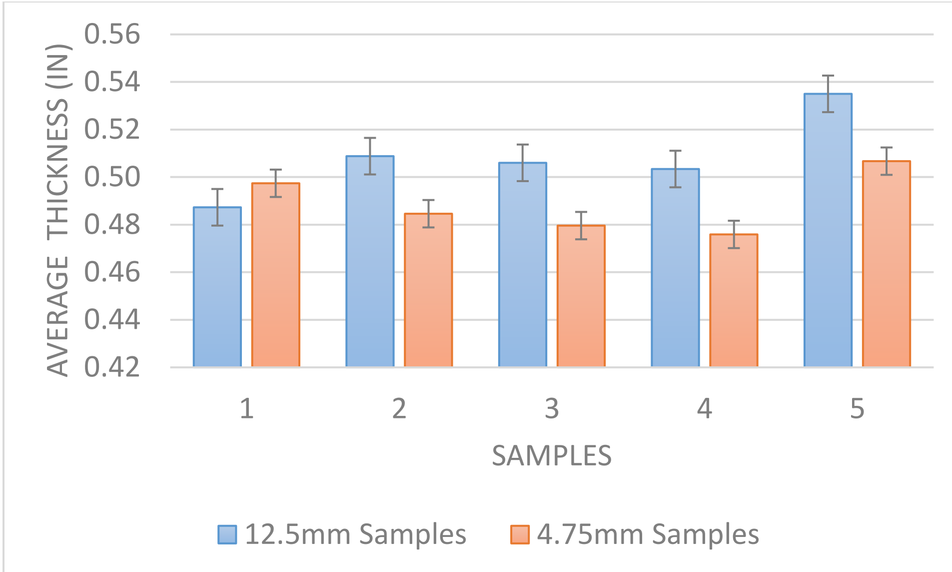

Figure 11. Comparison in Thickness Averages between 12.5mm and 4.75mm Samples

When comparing these asphalt samples with cork tiles, asphalt asbestos tiles, and solid vinyl tiles which are tested in accordance of ASTM F386, it is seen that the thickness variation should not exceed ±0.01, ±0.005, and ±0.005 in samples respectively; therefore, the results found in this test suggest that the variation in thickness in asphalt samples can be improved, and also this difference in the thickness tolerance could have occurred due to errors while making the samples. However, it is important to mention that doing these processes through specialized machines could lead to a better thickness tolerance margin among samples.

5.4 Size and Squareness Test

Appendix A and Appendix B show the measurements taken for each sample. The findings of this test show that the average length deviation and the average width deviation for 4.75mm samples are 0.003 in. and 0.004 in. respectively. For 12.5mm samples, the average length and width deviation are 0.005 in. and 0.003 in. respectively. Tables 11 and 12 summarize the calculation data. Those values match some of the tolerance ranges found in other tiles when performing the same test for size. For example, a tolerance range of ±0.008 in. for asphalt asbestos tiles is required when having a nominal linear dimension of 9 in. or less. The results founded in both mixtures fit in the range perfectly. Likewise, cork floor tiles and solid vinyl floor tiles having a dimension of 12 in. by 12 in. have a tolerance range of ±0.016. The data from both mixtures also fits in this range; however, the dimensions specified are larger than the one used for this test.

Table 11. Length and Width Deviation for 4.75mm Samples in inches

	Sample 1	**Sample 2**	**Sample 3**	**Sample 4**	**Sample 5**	**Average**
Length deviation, left side = (1A+3C)/2	0.002	0.006	0.006	0.002	0.003	0.004
Length deviation, center = (1B+3B)/2	0.003	0.002	0.006	0.002	0.002	0.003
Length deviation, right side = (1C+3A)/2	0.005	0.002	0.004	0.002	0.004	0.003
Width deviation, left side = (2A+4C)/2	0.003	0.002	0.005	0.002	0.002	0.003
Width deviation, center = (2B+4B)/2	0.003	0.002	0.003	0.010	0.010	0.005
Width deviation, right side= (2C+4A)/2	0.003	0.003	0.003	0.003	0.010	0.004

Table 12. Length and Width Deviation for 12.5mm Samples in inches

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Average
Length deviation, left side = (1A+3C)/2	0.003	0.004	0.008	0.004	0.009	0.006
Length deviation, center = (1B+3B)/2	0.003	0.004	0.003	0.009	0.002	0.004
Length deviation, right side = (1C+3A)/2	0.002	0.004	0.008	0.004	0.009	0.005
Width deviation, left side = (2A+4C)/2	0.003	0.006	0.004	0.003	0.003	0.004
Width deviation, center = (2B+4B)/2	0.002	0.004	0.003	0.004	0.009	0.004
Width deviation, right side= (2C+4A)/2	0.003	0.002	0.002	0.002	0.002	0.002

Table 13.Squareness Deviation Values for 4.75mm Samples in inches

Corner	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
1	0.012	0.004	0.012	0.004	0
2	0.002	0.004	0.002	0.004	0
3	0.002	0.002	0.002	0.002	0.008
4	0.002	0.002	0.002	0.008	0.002
Average	0.004	0.003	0.001	0.004	0.002

Table 14. Squareness Deviation Values for 12.5mm Samples in inches

Corner	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
1	0.002	0.004	0.000	0.002	0.004
2	0.004	0.004	0.004	0.004	0.004
3	0.004	0.008	0.008	0.004	0.002
4	0.004	0.002	0.004	0.004	0.002
Average	0.003	0.004	0.016	0.003	0.003

The squareness deviation values for 4.75mm and 12.5mm samples are 0.003 in. and 0.006 in. respectively. Tables 13 and 14 summarize this data. Comparing other tiles' materials, it is seen that asphalt concrete samples can meet some of the requirements for tiles. For example, for solid vinyl tiles, the out of squareness should not exceed 0.010 in. On the other hand, when comparing cork floor tiles, they are required not to exceed 0.002 in. The asphalt samples exceed this value but not in a significant range.

It is important to remember that this test is to ensure quality of tile products. A perfectly square tile can make the installation process quick and easy, and at the same time improve the visual appearance of the entire floor. The data collected from our samples drives to the conclusion that size and squareness of asphalt tiles can be improved and be more accurate by using much better specialized equipment.

6. Conclusion

The target of this project was to explore asphalt properties and compare them to actual tiles in the market. In this project, specimens of PG 64-22 binder with a NMAS of 4.75mm and 12.5mm were tested for compressive strength, flexibility, thickness, size, and squareness. According to the data collected from the four tests, early results show that asphalt concrete seems to meet the tile requirements tested in this project. Also, samples with NMAS of 12.5mm had a better performance in the tests compared with 4.75mm samples. However, more investigation into the asphalt properties, such as resistance to abrasion and impact, is worthwhile. It is also recommended to do a cost analysis because this is an important factor when considering flooring material.

7. References

ASTM International. *D1074-17 Standard Test Method for Compressive Strength of Asphalt Mixtures*. West Conshohocken, PA, 2017. Web. 25 Mar 2019.

ASTM International. F137-08(2013) *Standard Test Method for Flexibility of Resilient Flooring Materials with Cylindrical Mandrel Apparatus*. West Conshohocken, PA, 2013. Web. 15 Nov 2017.

ASTM International. *F2055-17 Standard Test Method for Size and Squareness of Resilient Floor Tile by Dial Gage Method*. West Conshohocken, PA, 2017. Web. 12 Nov 2017.

ASTM International. *F386-17 Standard Test Method for Thickness of Resilient Flooring Materials Having Flat Surfaces*. West Conshohocken, PA, 2017. Web. 12 Nov 2017.

Canadian Standard association. Specification for Asphalt Floor Tile. CSA standard, no. n A100, 1949, pp. 3-9.

Namkane, Kasree et al. "Utilization of coal bottom ash as raw material for production of ceramic floor tiles". *Environ Earth Sci*, 75, 386, 2016, pp. 1. Web. 12 Nov 2017.

Neale, Michael J. "D21 Industrial Flooring". T*ribology Handbook*. Butterworth-Heinemann, Oxford, England; Boston;,1995, pp. D21.1. Web. 15 Nov. 2017.

Appendix A

4.75mm measurements for size and squareness test

Rotation	A	B	C	D
1	0.002	0.004	0.008	0.012
2	0.004	0.004	0.004	0.002
3	0.002	0.002	0.002	0.002
4	0.002	0.002	0.002	0.002

Rotation	A	B	C	D
1	0.002	0.002	0.004	0.004
2	0.002	0.002	0.004	0.002
3	0	0	0.004	0.002
4	0.002	0.002	0.002	0.002

Rotation	A	B	C	D
1	0.008	0.008	0.004	0.012
2	0.002	0.002	0.002	0.002
3	0.004	0.004	0.004	0.002
4	0.004	0.004	0.008	0.002

Rotation	A	B	C	D
1	0.002	0.00	0.002	0.004
2	0.002	0	0.004	0.004
3	0.002	0.002	0.002	0.002
4	0.002	0.002	0.008	0.008

Rotation	A	B	C	D
1	0.002	0.002	0	0
2	0.002	0	0	0
3	0.008	0.002	0.004	0.008
4	0.002	0.002	0.002	0.002

Appendix B

12.5mm measurements for size and squareness test

Rotation	A	B	C	D
1	0.002	0.002	0.002	0.002
2	0.004	0.004	0.004	0.004
3	0.002	0.004	0.004	0.004
4	0.000	0.000	0.002	0.004

Rotation	A	B	C	D
1	0.004	0.004	0.004	0.004
2	0.008	0.000	0.000	0.004
3	0.004	0.004	0.004	0.008
4	0.004	0.008	0.004	0.008

Rotation	A	B	C	D
1	0.008	0.002	0.004	0.000
2	0.004	0.004	0.004	0.004
3	0.012	0.004	0.008	0.008
4	0.000	0.002	0.004	0.004

Rotation	A	B	C	D
1	0.004	0.000	0.004	0.002
2	0.004	0.000	0.004	0.004
3	0.002	0.002	0.004	0.004
4	0.000	0.008	0.002	0.004

Rotation	A	B	C	D
1	0.000	0.002	0.002	0.004
2	0.004	0.000	0.002	0.004
3	0.002	0.002	0.004	0.002
4	0.002	0.002	0.002	0.002