EVALUATION OF PERMANENT DEFORMATION OF ASPHALT RUBBER MIXTURES USING FLOW NUMBER TEST

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ABSTRACT

The use of asphalt rubber mixtures has been constantly increasing in Brazil since the first application in the beginning of the millennium. Several studies affirm that asphalt rubber mixtures have better resistance to rutting at critical situations, such as slow heavy traffic and high temperatures. This study used the flow number test to analyze the characteristics of asphalt rubber mixtures regarding to their ability to withstand permanent deformation. Twenty four asphalt rubber mixtures were produced and eight conventional asphalt mixtures were used as control mixes. Basalt and granite aggregates were used at different dense gradations with maximum diameter size of 19mm, 12,5mm and 9,5mm and a 9,5mm gap graded gradation. The flow number test was done in specimens conditioned at 54°C and applying an unconfined cyclic load of 600kPa. The results of these tests showed all the asphalt rubber mixtures had higher flow number values, when compared to the conventional asphalt mixtures. The analysis of the data obtained in the tests indicates that asphalt rubber mixtures have better resistance to permanent deformation, when compared to conventional asphalt mixtures.

Keywords: flow number test, asphalt rubber mixture, permanent deformation.

1. INTRODUCTION

The firsts applications of rubberized asphalts were done about fifty years ago in the United States and about 15 years ago in Brazil. Since then, the methodologies have been enhanced to increase the use of waste rubber in asphalt pavements. The experience around the world shows that the rubberized hot mix asphalt (RHMA) has higher durability, since it has better resistance to fatigue cracking, to reflective cracking and lower temperature susceptibility, withstanding better to permanent deformation.

Rutting or permanent deformation of hot mix asphalt (HMA) is usually associated to poor selection of materials, poor design projects, inappropriate quality control, high temperatures and heavy and slow traffic loads. Laboratory tests can be performed to estimate the permanent deformation potential of HMA. The most popular tests are wheel simulators, such as LCPC (*Laboratoire Central des Ponts et Chausseés)* and Hamburg, and creep tests, applying static or cyclic loads, such as the flow number test.

The flow number (FN) test uses HMA specimens that are compressed axially applying a haversine waveform with a wavelength of 0.1 seconds followed by a rest or dwell period of 0.9 seconds, performed at temperatures usually ranging from 50°C to 60°C [1]. The number of cycles and the accumulated strain is recorded during the test until 10.000 cycles, or until the specimen reach 5% of axial strain, or until tertiary flow occurs, whichever comes first.

The accumulated permanent deformation or plastic strain can be defined by a primary, secondary and tertiary region. In the primary region de permanent deformation increases rapidly, but at a decreasing rate. At the secondary region, the permanent deformation rate is constant until it starts to increase, which indicates the beginning of the tertiary region or tertiary flow. The point of the beginning of the tertiary flow is the Flow Number (FN).

In Brazil, some field studies were developed to analyse the rutting resistance of RHMA [2-3]. The conclusions always indicate that the use of rubberized asphalt enhance the resistance to permanent deformation.

Laboratory research also has been performed to predict the ability of RHMA to withstand rutting [4]. However, there are few records about the use of the configuration of Flow Number Test to assess these type of mixtures.

In this study, the Flow Number test was used to analyse rubberized hot mix asphalt and control HMA. The main objective is to determine the resistance to rutting using this test configuration.

2. TESTS AND MATERIALS

Three dense gradation, specified as 19mm, 12.5mm and 9.5mm, accordingly to the aggregate maximum size and a 9.5mm gap graded gradation were used in this study to prepare the hot mix asphalts. The aggregates have granitic and basaltic origin. Figure 1 shows the gradations for both aggregates and Table 1 shows their characteristics.

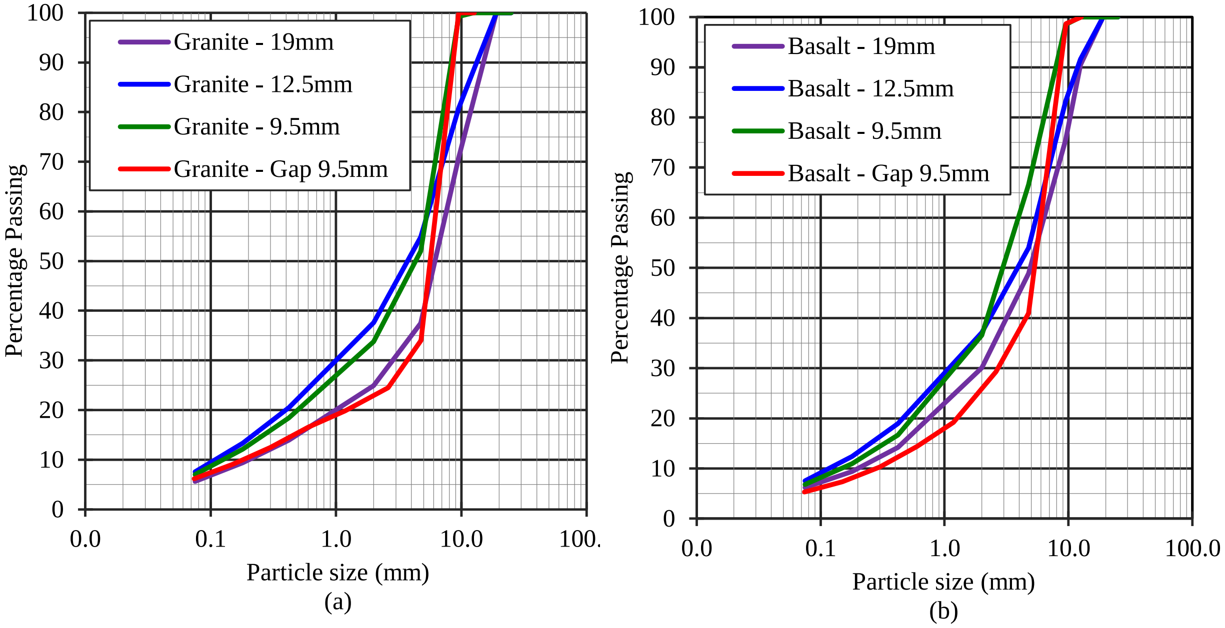

FIGURE 1: Hot mix asphalt gradation; a) granitic aggregates; b) basaltic aggregates

TABLE 1: Characteristics of granitic and basaltic aggregates

Characteristic	Standard	Aggregates	
		Granite	Basalt
"Los Angeles" Abrasion Loss	ASTM C 131	30	17
Flat and Elongated Particles (Ratio 1:5)	ASTM D4791	3	7
Soundness of aggregates (5 cycles)	AASHTO T-104-99	1.5	0.9

In Brazil, terminal blending is the most used methodology to produce asphalt-rubber (AR). Three samples were obtained from commercial providers (AR1, AR2, AR3) and their characteristics are shown in Table 1. Also, a not modified binder was used to produce control asphalt mixes, specified as 50/70 as shown in Table 2.

TABLE 2: Asphalt binder characteristics

Characteristic	Standard	Asphalt Binder			
		AR1	**AR2**	**AR3**	**50/70**
Rotational Viscosity at 160ºC, 20 rpm, spindle 3	ASTM D 6114	2140	2290	2250	N/A
Rotational Viscosity at 175ºC, 20rpm, spindle 3	ASTM D 6114	1360	1510	1470	N/A
Rotational Viscosity at 185ºC, 20rpm, spindle 3	ASTM D 6114	840	990	950	N/A
Rotational Viscosity at 177ºC, 20rpm, spindle 21	ASTM D4402	N/A	N/A	N/A	58
Penetration (100g, 5s, 25°C) (Pen)	ASTM D 5	44	43	57	53
Softening Point (Pa)	ASTM D 36	57	61	59	49
Storage Stability	ASTM D 5892	4	4	3	N/A
High Performance Grade (°C)	ASTM D 6373	76	76	76	64
High True Grade (°C)	ASTM D 6373	79.5	79.5	78.3	65.2

N/A Not applicable

The use of four gradations, two aggregates sources and four asphalt binders generated 32 asphalt mixes. The Marshall compactor was used for the volumetric design of the asphalt mixes, using 75 blows on each side of the specimen. The design binder content was defined to obtain air voids of 4% for dense gradations and 5% for gap gradations. The selected binder content for the asphalt mixes is shown in Table 3.

TABLE 3: Select binder content for the hot mix asphalts

Aggregates	Gradation	Asphalt Binder			
		50/70	**AR1**	**AR2**	**AR3**
Granite	12.5mm	4.6	5.5	5.3	5.1
	19.0mm	4.5	5.0	5.4	5.2
	9.5mm	4.6	5.3	5.5	5.6
	Gap 9.5mm	5.1	5.9	5.9	5.5
Basalt	12.5mm	5.0	5.6	5.4	5.4
	19.0mm	5.2	6.3	5.6	5.8
	9.5mm	5.2	6.3	6.3	6.2
	Gap 9.5mm	5.8	6.5	6.5	6.1

For the flow number test, three specimens were compacted using the Superpave gyratory compactor at 150mm of diameter and 175mm of height and then cored to obtain 100mm of diameter and 150mm of height, according to AASHTO T 342-11. The target air voids was 5.5%, which is the average value obtained in asphalt pavement construction controls in São Paulo State. The specimens were conditioned at 54°C and then tested applying an unconfined cyclic load of 600kPa. The flow number value obtained in this test corresponds to the number of cycles at which the tertiary flow starts or the number of cycles at which the rate of change of compliance is minimum [5].

3. RESULTS

Table 4 shows the average results of the flow number test and the coefficient of variation, since the tests were performed using three specimen for each hot mix asphalt. These results are also shown in Figure 2 and 3, for asphalt mixes using granitic aggregates and basaltic aggregates, respectively.

Figures 2 and 3 show that hot mix asphalts produced with conventional asphalt binder (50/70), had always the lowest flow number value, independently of the size gradation and aggregate source. On the other hand, the mixes produced with rubberized asphalt had the higher flow number values, ranging from 400 to 3.800. It is well accepted that, the higher flow number, the higher the rutting resistance of the asphalt mix. Then, the rubberized asphalt mixes have higher resistance to withstand distresses associated to permanent deformation.

The asphalt mixes produced with granitic aggregates had higher flow number values than asphalt mixes produced with basaltic aggregates. This behaviour can be associated to the percentage of flat and elongated particles of the basaltic aggregates, which is higher when compared to the granitic aggregates. Additionally, Table 3 shows that hot mix asphalt with basalt had always higher binder content, this could have influenced to obtain a lower flow number value in these mixes.

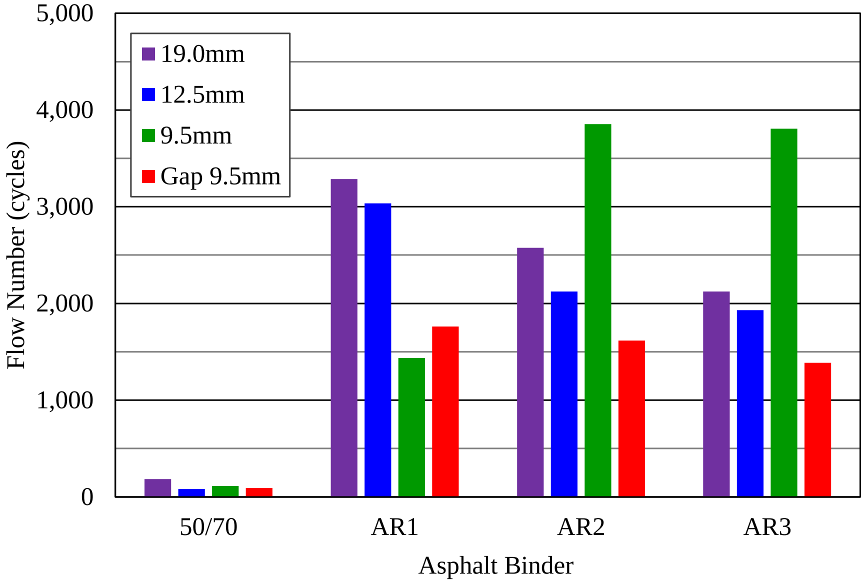

FIGURE 2: Flow number values of asphalt mixtures with granitic aggregates

TABLE 4: Flow number test results

Aggregates	Gradation	Asphalt Binder	Asphalt Binder Content (%)	Flow Number (Cycles)	
				Average Value	Coeficient of Variation (%)
Granite	12.5mm	50/70	4.6	81	21
Granite	12.5mm	AR1	5.5	3,034	26
Granite	12.5mm	AR2	5.3	2,125	22
Granite	12.5mm	AR3	5.1	1,931	26
Granite	19.0mm	50/70	4.5	184	12
Granite	19.0mm	AR1	5.0	3,286	14
Granite	19.0mm	AR2	5.4	2,576	29
Granite	19.0mm	AR3	5.2	2,123	30
Granite	9.5mm	50/70	4.6	113	27
Granite	9.5mm	AR1	5.3	1,436	19
Granite	9.5mm	AR2	5.5	3,855	24
Granite	9.5mm	AR3	5.6	3,808	3
Granite	Gap 9.5mm	50/70	5.1	92	35
Granite	Gap 9.5mm	AR1	5.9	1,762	6
Granite	Gap 9.5mm	AR2	5.9	1,617	27
Granite	Gap 9.5mm	AR3	5.5	1,387	29
Basalt	12.5mm	50/70	5.0	126	14
Basalt	12.5mm	AR1	5.6	2,856	30
Basalt	12.5mm	AR2	5.4	2,554	18
Basalt	12.5mm	AR3	5.4	1,252	4
Basalt	19.0mm	50/70	5.2	44	15
Basalt	19.0mm	AR1	6.3	921	26
Basalt	19.0mm	AR2	5.6	876	15
Basalt	19.0mm	AR3	5.8	831	3
Basalt	9.5mm	50/70	5.2	170	28
Basalt	9.5mm	AR1	6.3	1,205	16
Basalt	9.5mm	AR2	6.3	1,051	20
Basalt	9.5mm	AR3	6.2	897	25
Basalt	Gap 9.5mm	50/70	5.8	70	20
Basalt	Gap 9.5mm	AR1	6.5	419	15
Basalt	Gap 9.5mm	AR2	6.5	569	24
Basalt	Gap 9.5mm	AR3	6.1	718	29

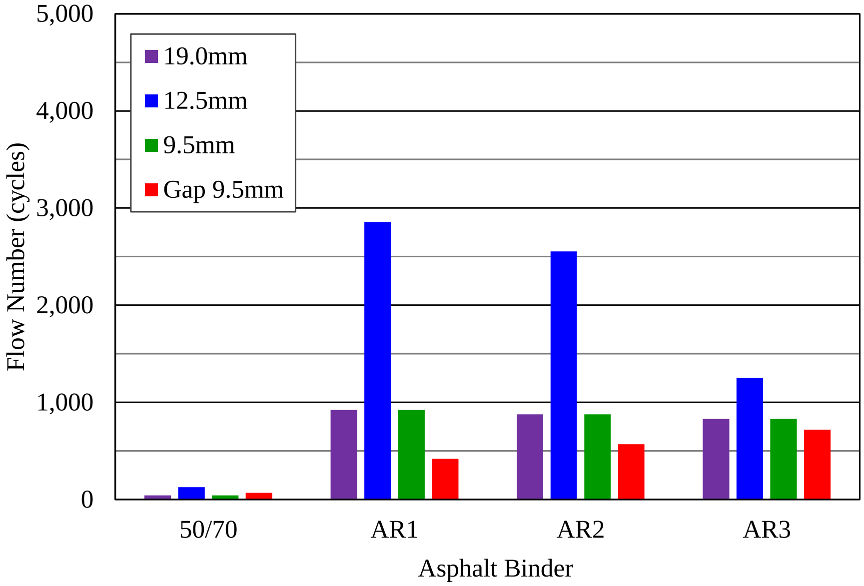

FIGURE 3: Flow number values of asphalt mixtures with basaltic aggregates

The influence of the size gradation of hot mix asphalt in the flow number values was not very clear. However, the Gap 9.5mm had the lowest rutting resistances, but the hot mix asphalt with granitic aggregates and AR1. Regarding the source of the rubberized asphalt binder, there was not a very clear tendency that showed a better behaviour of one of the three samples.

4. CONCLUSIONS

This study performed a laboratory evaluation of permanent deformation of hot mix asphalts using rubberized asphalt. The flow number test was selected to analyse 32 mixtures, with different source of aggregates, gradation and asphalt binder source.

The flow number was dependant of the source of aggregates. In this study, it was noted that granite produced mixtures with higher resistance to permanent deformation, than mixtures produced with basalt. This behaviour can be associated to the shape of aggregates particles and asphalt binder content.

It was noted that hot mix asphalts produced with rubberized asphalt have higher flow number values, when compared to conventional mixtures. This means that the use of asphalt rubber can enhance the resistance to permanent deformation of hot mix asphalt. This behaviour was noted in all three rubberized asphalts, collected from commercial providers.

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