Variations of Flow Number of Asphalt Concrete Due to Human Effects

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ABSTRACT

Flow number (N) of Asphalt Concrete (AC) is an important property relating the number of load repetition an AC material can sustain without having any permanent deformation on it. This property is determined in laboratory using very sophisticated equipment. This study shows the flow number of a mix can vary from contractor to contractor and so on; to study the flow number of the AC specimens that are determined. Then, the results are analyzed. The results show that the same mix may have statistically different flow numbers for the same contractor. The same mix may have statistically different flow numbers for different contractors. The mix with same mix factors might have statistically different flow numbers.

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1.0 Introduction

The flow number (N) is the number of load cycles at which tertiary flow begins or permanent damage occurs in material. Tertiary flow can be differentiated from secondary flow by a marked departure from the linear relationship between cumulative strain and number of cycles in the secondary zone (Islam et al. 2019). It is assumed that in tertiary flow, the specimen's volume remain the constant. The N-value is important as it can be correlated with rutting potential of flexible pavement. The final evaluation is an evaluation of the rutting resistance of the mixture using the flow number test defined by the American Association of State Highway, and Transportation Officials (AASHTO) TP 79 (AASHTO TP 79 2015) using the Asphalt Mixture Performance Tester (AMPT). The test is conducted at the 'high' pavement temperature calculated by the LTPP Bind 3.1 software program for a specific project location. An unconfined flow number test with a repeated deviatoric stress of 87 psi (600 kPa) and a contact deviatoric stress of 4.4 psi (30 kPa) is used in this study. The test is conducted on specimens that are short-term conditioned for two hours at the compaction temperature to simulate the binder absorption and stiffening that occurs during construction.

In the flow number test, the permanent strain at each cycle is measured, while a constant deviator stress is applied at each load cycle on the test sample (Figure 1). Permanent deformation of asphalt pavements has three stages (Biligiri and Way 2013):

a. Primary or initial consolidation
b. Secondary, and
c. Tertiary or shear deformation

Figure 1 shows the three stages of permanent deformation. The N-value is taken as the loading cycle, at which the tertiary stage begins following the secondary stage. Justification for selection of N-value criteria is determined using the Francken model, which is discussed below.

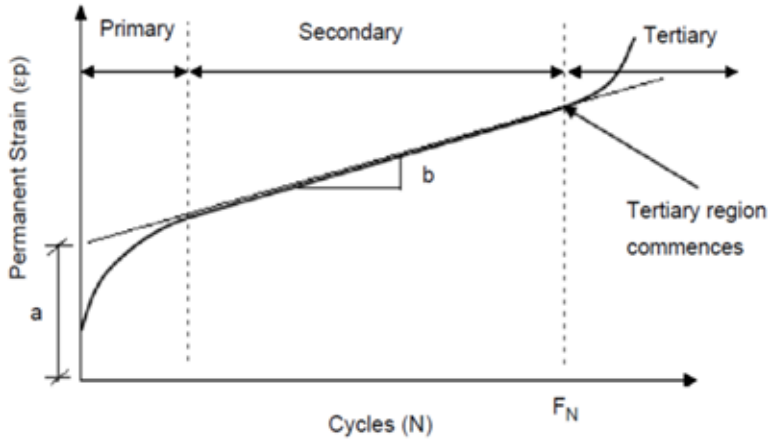

Figure 1. Relationship between Permanent Strain and Load Cycles (Biligiri and Way 2013)

The current study used testing conditions and criteria for N testing described in AASHTO TP 79 (AASHTO TP 79 2015) for unconfined tests. The recommended test temperature, determined by LTPP Bind Version 3.1 software, is the average design high pavement temperature at 50% reliability for cities in Colorado. Tests are conducted at a temperature of 55 °C with an average deviator stress of 600 kPa and a minimum (contact) axial stress of 30 kPa. For conditioning, samples are kept in a conditioning chamber at the testing temperature for 12 hours prior to testing.

2. Results and Analysis

2.1 Same Mix by Same Contractor

To investigate the variation of flow number by a single contractor for the same mix, the mix SX(100) PG 64-28 is randomly selected (Table 1). SX(100) means the number of gyration is 100 when the mix was produced/designed. PG 64-28 is the type of asphalt binder used. The paving contractor is APC Southern (APC), with the binder material provided by Suncor, and aggregate provided by Valardi. Different numbers such as 19655 P20 14, 19655 P21 14, etc. are mix identification number.

Table 1. Generic Information of 19655 Mix

19655 P20 14	19655 P21 14	19655 P23 14	19655 P24 14	19655 P28 14	19655 P37 14	19655 P48 14	19655 P87 14	
Contractor	APC	APC	APC	APC	APC	APC	APC	APC
Refinery	Suncor	Suncor	Suncor	Suncor	Suncor	Suncor	Suncor	Suncor
Pit	Valardi	Valardi	Valardi	Valardi	Valardi	Valardi	Valardi	Valardi
Date	July 2014	July 2014	July 2014	July 2014	July 2014	Aug 2014	Sep 2014	Oct 2014

The N-values vary from 120 to 531 with an average value of 261, and standard deviation of 125, as shown in Figure 2. To determine whether this data is statistically significant or not, a one-sample t-test are conducted. The t-test requires the data to be normally distributed. Three normality tests (Cramer-von Mises, Anderson-Darling, and Shapiro-Wilk) are conducted, and all of them showed the data is normal. The t-test showed the 95% Confidence Interval (CI) boundaries to be 150 and 372, with the mean value of 261. This means all the mixes, except for 19655 P21 14 and 19655 P87 14, are statistically the same. Therefore, a conclusion can be made that the same mix may have statistically different flow numbers for the same contractor.

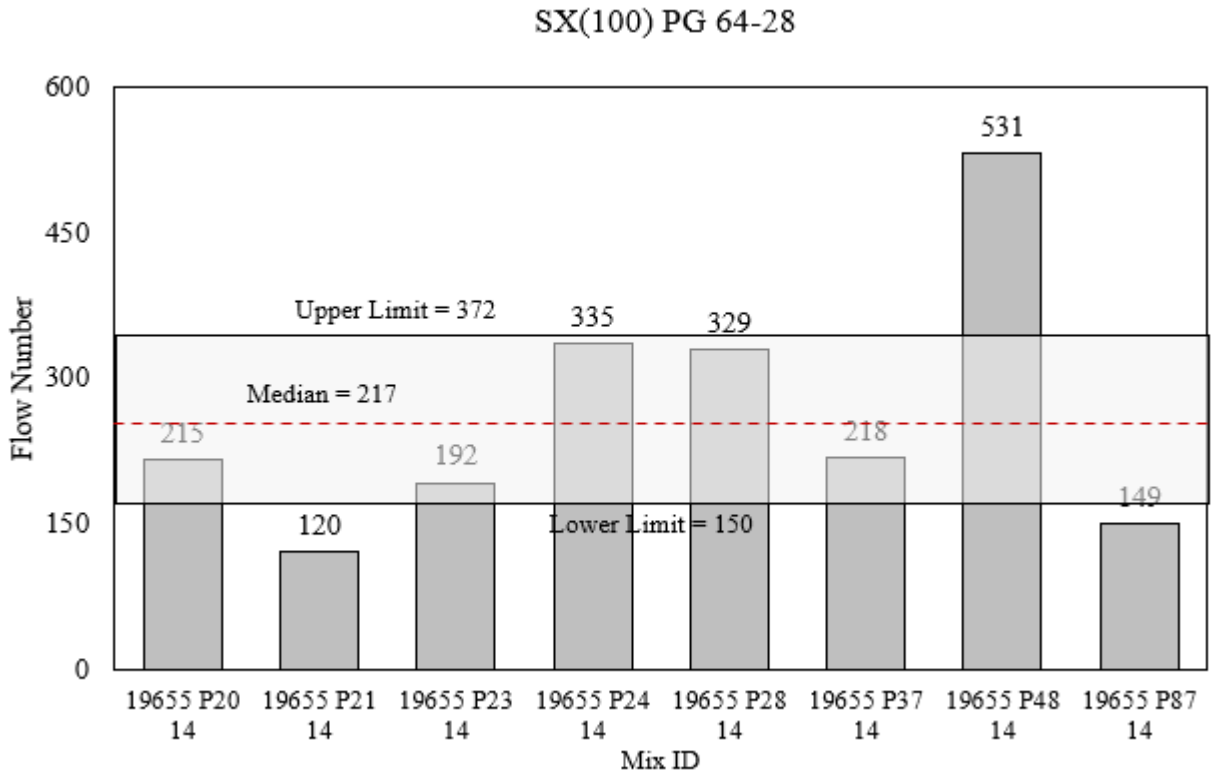

Figure 2. Flow Number of Eight Specimens of SX(100) PG 64-28 Mix

2.2 Same Mix by Different Contractors

To investigate the difference in flow number for the same mix prepared by different contractors, SX(100) PG 76-28 mix has been selected. The average flow numbers from four contractors, 19128, 18842, 19458, and 19677, are presented in Figure 3.

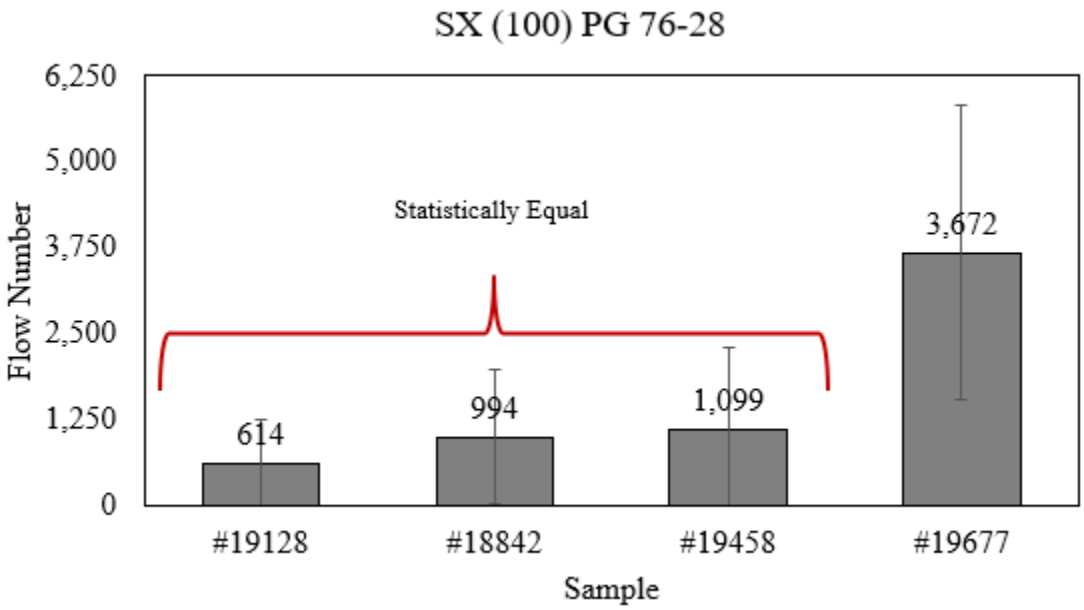

Figure 3. Flow Number of a Mix by Different Contractors

Normality tests (Cramer-von Mises, Anderson-Darling, and Shapiro-Wilk), show only projects #18842 and #19677 to be normal. The pairwise-comparisons test result shows mixes, 19128, 18842, and 19458 are statistically the same (Table 2). Therefore, a conclusion can be made that the same mix may have statistically different flow numbers for different contractors.

Table 2. Pairwise Comparisons using t-tests to Determine Whether Statistically Different

	19128	18842	19458
18842	Equal	-	-
19458	Equal	Equal	-
19677	Different	Different	Different

2.3 Flow Numbers of a Mix

To evaluate the flow number of a mix with different mix factors, the mix SX(100) PG 76-28 has been selected. The flow numbers for SX(100) PG 76-28 mix by different contractors are presented in Figure 4. The graph shows that the flow number of this mix varies from 82 to 6,343, with an average number of 1,578, median of 810 and a standard deviation of 1,837. As per AASHTO, a mix is considered good for traffic greater than 30 million ESALs if it has a flow number greater than 740. Although the average flow number is 1,482, nearly half of the samples had a flow number less than 740. Therefore, it is very difficult to conclude whether this mix is considered good for traffic greater than 30 million ESALs. Comparing this result with the previous binders, the flow number increases with an increase in high-temperature grade of the binder. A similar observation are found for the SX(75) mix. Normality tests Cramer-von Mises, Anderson-Darling, and Shapiro-Wilk did not show sufficient evidence of the data to be normal. The t-test showed the 95% CI boundaries to be 893 and 2,262. Out of 33 specimens, only 7 specimens are within the 95% CI boundaries.

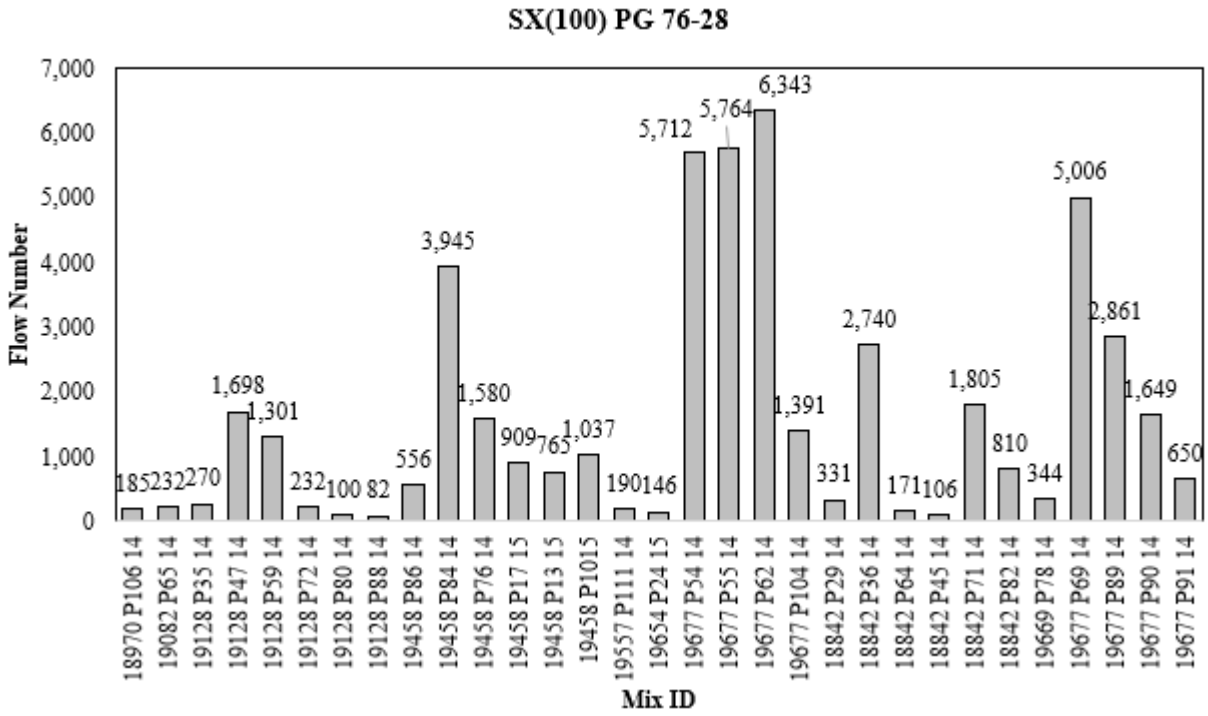

Figure 4. Flow Numbers for SX(100) PG 76-28 Mix

As listed in Table 3, there are seven mixes whose mix factors are the same, but their flow numbers are not statistically the same. To clarify, the mixes by Kiewit, Martin Marietta, or Simon Construction have similar mix factors in every category, but the flow numbers are statistically different. Table 4 also shows that mixes with different properties have statistically the same flow numbers.

Table 3. Generic Information of SX(100) PG 76-28 Mix

	Paving Contractor	Binder Supplier	Region	Date	Vbe (%)	Va	VMA (%)	VFA (%)	AC (%)	Pit
18842 P29 14	Kiewit Construction	Suncor	2	7/2014	12.61	6.68	18.1	64.3	6.30	Tezak / Fountain / I-25 Millings
18842 P36 14	Kiewit Construction	Suncor	2	8/2014	14.32	4.56	15.8	72.5	6.30	Parkdale/ Tezak
18842 P45 14	Tezak	Suncor	2	8/2014	12.53	6.93	18.2	62.2	5.20	Tezak / Fountain / I-25 Millings
18842 P64 14	Kiewit Construction	Suncor	2	9/2014	12.53	6.85	18.2	62.4	6.30	Tezak / Fountain / I-25 Millings

18842 P71 14	Kiewit Construction	Suncor	2	10/2014	15.23	4.88	18.5	73.5	6.30	Parkdale/ Tezak
18842 P82 14	Kiewit Construction	Suncor	2	10/2014	12.53	6.93	18.3	62.3	5.20	Tezak / Fountain / I-25 Millings
18970 P106 14	APC Southern	Suncor	5	11/2014	12.72	5.60	18.2	67.4	6.12	King Pit
19082 P65 14	ACA Buena Vista	Suncor	5	3/2015	13.84	6.85	18.8	63.2	5.70	Avery Pit, ACA Buena Vista
19128 P35 14	Martin Marietta	Suncor	2	8/2014	10.96	6.32	17.1	62.5	5.60	Evans
19128 P47 14	Evans	Suncor	2	8/2014	10.90	6.82	17.6	61.4	5.60	Evans
19128 P59 14	Martin Marietta	Suncor	2	9/2014	10.90	6.82	17.6	60.9	5.60	Evans
19128 P72 14	Martin Marietta	Suncor	2	9/2014	10.00	6.82	17.9	60.2	5.10	Evans
19128 P80 14	Martin Marietta	Suncor	2	10/2014	10.00	6.82	17.6	60.7	5.10	Evans/slate
19128 P88 14	Martin Marietta	Suncor	2	10/2014	10.82	6.83	17.6	61.6	5.60	Evans/slate
19458 P10 15	Simon Construction	Suncor	4	5/2015	9.90	5.30	16.8	61.5	5.05	Granite Canyon, Julesburg, Sedgwick
19458 P13 15	Simon Construction	Suncor	4	6/2015	9.47	5.30	16.5	61.7	4.96	Granite Canyon, Julesburg, Sedgwick
19458 P17 15	Simon Construction	Suncor	4	6/2015	9.55	5.30	16.1	60.7	4.93	Granite Canyon, Julesburg, Sedgwick
19458 P20 15	Simon Construction	Suncor	4	6/2015	10.32	4.40	16.6	60.0	5.30	Granite Canyon, Julesburg, Sedgwick
19458 P76 14	Simon Construction	Suncor	4	6/2015	11.57	6.43	17.3	62.6	5.20	Granite Canyon, Julesburg, Sedgwick

19458 P79 14	Simon Construction	Suncor	4	7/2015	11.57	6.80	17.6	61.4	5.20	Granite Canyon, Julesburg, Sedgwick
19458 P84 14	Simon Construction	Suncor	4	9/2015	11.57	6.75	17.6	61.2	5.20	Granite Canyon, Julesburg, Sedgwick
19458 P86 14	Simon Construction	Suncor	4	10/2015	11.57	6.78	17.6	61.3	5.20	Granite Canyon, Julesburg, Sedgwick
19557 P111 14	A&S Construction	Suncor	2	11/2014	11.71	5.00	17.7	64.6	5.38	Tezak/ Transit Mix
19654 P24 15	Martin Marietta	Suncor	2	7/2015	10.31	5.00	17.6	60.6	5.25	Evans/slate
19669 P78 14	A&S Construction	Suncor	2	10/2014	10.72	6.93	17.7	61.0	5.40	Rocky Ford South/La Junta
19677 P54 14	Elam Construction	Suncor	3	1/2015	10.25	5.18	14.9	65.4	5.50	23 Road
19677 P55 14	Elam Construction	Suncor	3	1/2015	10.54	5.04	15.1	66.6	5.50	23 Road
19677 P62 14	Elam Construction	Suncor	3	2/2015	10.69	5.00	15.2	66.5	5.50	23 Road
19677 P69 14	Elam Construction	Suncor	3	5/2015	11.71	4.43	15.6	71.7	5.50	23 Road
19677 P89 14	Elam Construction	Suncor	3	10/2015	10.69	6.83	16.8	58.9	5.50	23 Road
19677 P90 14	Elam Construction	Suncor	3	10/2015	11.71	5.98	17.0	64.6	5.50	23 Road
19677 P91 14	Elam Construction	Suncor	3	11/2015	11.71	5.88	16.9	65.3	5.50	23 Road
19677 P104 14	Elam Construction	Suncor	3	11/2014	11.02	5.88	18.6	57.6	5.74	23 Road

Note: Green highlighted mixes produce statistically the same flow number.

3. Conclusions

The following conclusions can be made from the study:

- The same mix may have statistically different flow numbers for the same contractor.
- The same mix may have statistically different flow numbers for different contractors.
- Mix with same mix factors might have statistically different flow numbers.

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