Laboratory Investigation of the Important Commercial Bitumens in use in Massachusetts.

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The object of this thesis is a comparison between the results of physical tests performed on refined asphalts and asphaltic cements with the specifications for asphalts to be used in the construction of bituminous concrete roads, and also a comparison between the results of physical tests on samples of bitumen extracted from pavements of various ages with present day specifications for the asphalt in the construction of sheet asphalt pavements.

The procedure was to analyze the commercially important refined asphalts and asphaltic cements, and also samples of asphalt extracted from pavements. We compared these results with typical present day specifications.

The results obtained were inconclusive because of the fact that we were unable to obtain all of the information which we expected to obtain. Furthermore, two of the authors went into the special course in Naval Architecture in preparation for government service, and hence were unable to give much assistance to the third student after this special course had started.

The physical tests mentioned in this thesis were performed in the same manner as those fully described in Hubbard's Dust Preventives and Road Binders from page 324 to page 371 in the 1910 edition.

TABLE OF RESULTS OF THE AUTHORS' TESTS.

(1) Refined Asphalts.

	Mexican Sheet Asphalt	B	C	Bermudez	Californian	Texan	Trinidad
Specific Gravity	1.05	1.03	1.03	1.08	1.02	0.999	1.40
Melting Point	70.5°C.	64.0°C.	65.5°C.	63.0°C.	58.0°C.	97.0°C.	88.5°C.
Penetration ⊕	33.3	63.3	35.1	18.0	22.1	14.2	2.5 *
Volitization Loss at 163°C.	0.07%	0.7%	0.06%	3.2%	0.3%	0.2%	0.5%
Penetration after Volitization ⊕	25.1	46.3	46.1	6.7	12.5	5.4	0.8 *
Total Bitumen	98.8%	99.6%	99.7%	94.4%	99.8%	99.5%	58.2%
Percent Ash	0.0%	0.0%	0.6%	3.5%	0.0%	0.5%	36.7%
% Bitumen insoluble in 86° Naptha	32.4%	30.3%	35.7%	33.5%	17.8%	30.7%	31.3%
Fixed Carbon	12.9%	11.1%	11.1%	11.4%	9.0%	14.0%	14.4%
Ductility	112.5	82.0	101.0	31.5	112.5	3.5	3.0

* 200 g. acting for 10 sec. Others were 100g. – 5 sec.

⊕ Penetrations measured in $\frac{1}{100}$ths of a centimetre

TABLE OF RESULTS OF THE AUTHORS' TESTS.

(2) Asphaltic Cements.

	Mexican	Bermudez	Californian	Texan	Trinidad
Specific Gravity	1.06	1.07	1.03	1.03	1.18
Melting Point	66.5°C.	57.0°C.	60.5°C.	63.0°C.	61.0°C.
Penetration ⊕	38.8	40.4	‡	46.4	41.1
Volitization Loss at 163°C.	0.05%	4.3%	‡	0.6%	5.3%
Penetration ⊕ after Volitization	38.8	16.8	‡	36.8	10.6
Total Bitumen	99.1%	93.8%	98.7%	99.3%	76.6%
Percent Ash	1.1%	3.5%	0.2%	0.0%	17.2%
% Bitumen Insoluble in 86° Naptha	46.1%	25.6%	23.4%	30.4%	81.1% *
Fixed Carbon	16.9%	9.9%	9.6%	12.1%	10.5%
Ductility	‡	40.5	‡	53.5	61.0

* Result Doubtful

‡ Results not obtained owing to an insufficiency of material to perform the tests.

⊕ Penetrations measured in $\frac{1}{100}$ ths of a centimetre.

TABLE OF RESULTS OF AUTHORS' TESTS

Samples obtained from pavements

	Devonshire Street	Kilby Street	Temple Place	Court Square
Age (1917)	12 yrs	13 yrs	17 yrs	13 yrs
Specific Gravity	1.09	1.06	1.12	1.18
Melting Point (°C)	49.0	61.5	51.0	79.0
Penetration +	60.3	36.0	82.7	8.5
Volatilization Loss at 163°C	2.1 %	2.3 %	6.7 %	2.0 %
Penetration after Volatilization +	29.7	23.9	17.9	3.0
Total Bitumen (CS_2)	96.7 %	88.1 %	97.9 %	80.6 %
Percentage of Ash	4.32	7.4	10.8	7.8
% Bitumen insoluble in 86° Naphtha	31.9	32.8	56.5	13.0
Fixed Carbon	9.81	7.7	4.45	10.0

+ penetrations given in $\frac{1}{100}$th of a centimetre

TABLE OF RESULTS OF AUTHORS' TESTS

Samples obtained from pavements

	Massachusetts Avenue	Arch Street	Columbus Avenue
Age	16 yrs	6 yrs	11 yrs
Specific Gravity	1.06	1.06	1.15
Melting Point (°C)	60.5	78.3	75.0
Penetration +	41.0	17.8	15.4
Volatilization Loss at 163°C	0.61 %	0.69 %	1.08 %
Penetration after Volatilization +	26.6	14.5	13.1
Total Bitumen (CS_2)	95.9 %	96.8 %	77.1 %
Percentage of Ash	5.7	1.9	14.7
% Bitumen insoluble in 86° Naptha	38.2	34.4	19.6
Fixed Carbon	11.4	14.1	7.81

+ penetrations given in $\frac{1}{100}$th of a centimetre

Discussion of Results.

Specific Gravity. The specific gravity test serves as a means of identification of the amount of mineral matter present in the asphalts. Solid native bitumens usually have a specific gravity of about 1.04. If the specific gravity is higher than 1.04, as it is in Bermudez and Trinidad asphalts, we expect to find considerable mineral matter. This fact is shown by the results obtained in the percentage of ash experiment. Refined Trinidad asphalt, which has a specific gravity of 1.40, the highest of all the asphalts we have analyzed, has a percentage of ash of 36.7, which is also the largest value among the refined asphalts. That the specific gravity is directly related to the percentage of ash is shown by the results of these two tests in the table of analyses of the refined and the cement asphalts; in practically every case, the greater the specific gravity is, the greater the percentage of ash is.

Melting Point. The melting point of an asphalt varies with its hardness and brittleness and determines in what localities with respect to climatic conditions it could be used so as to produce the best results under the existing traffic conditions. As the melting point of an asphalt rises, the material becomes harder and more brittle. In very warm climates the use of a very low melting asphalt is prohibitive, for traffic leaves tracking in going over the pavement. In Massachusetts, any of the asphalts we have analyzed will stand the summer conditions without any bad results.

Penetration. The penetration test is one which determines the hardness and brittleness of an asphalt and its likelihood of being used without fluxing with a light asphaltic oil. The penetration varies directly with the amount of oil mixed with the asphalt. There are certain asphalts, such as the Mexican asphalts of the Standard Oil company, which are refined to such a consistency that fluxing with a lighter oil is unnecessary for construction work. On the other hand, there is the other extreme, Trinidad asphalt, which cannot be used without fluxing because of the very low penetration. Usually the deciding factor of an asphalt pavement, after the traffic and climatic conditions are taken into account, is penetration. In different latitudes the proportion of oil to asphalt must be varied to meet the climatic changes so as to produce a successful pavement. Of all the refined asphalts we have analyzed, the only one which could be used in Massachusetts without fluxing is the Mexican asphalt of the Standard Oil Company. The remainder must be fluxed if a pavement is sought which does not crack or rut soon after it is laid.

Volatilization. Although the volatilization test is purely an arbitrary one, it proves to be of considerable value. This test is not a quantitative analysis of the particular kinds of volatile oils in the original material, but the tendency to give up these oils. The loss in weight is a fair indication of the amount of volatile oils which may be driven off in the course of time after application to the road. Also, the character of the residue is similar to that left eventually in the road. If, for any reason, a material is desired which does not change its penetration materially, one which shows a small volatilization should be chosen. As a rule, those asphalts showing the largest percentage of volatilization have the greatest change in penetration taking place. This fact is shown by comparing the results of penetration after volatilization of Bermudez and Trinidad cements. As the penetration of these asphalts is low in the refined material, the fact that the penetration is low after performing the volatilization test is self-explanatory, for most of the flux has been vaporized. On the other hand, Mexican and Texan cements change slightly in penetration before and after volatilization, and show that the percentage of volatilization is low.

Bitumen Soluble in Carbon Bisulphide. Solid native bitumens, as a general rule, are not very soluble as they contain a large amount of mineral matter which is insoluble in chemically pure carbon bisulphide. This is characteristic of Trinidad asphalt which is a material more rocky in its natural state than any other asphalt. Bermudez also shows a low solubility in carbon bisulphide, but not as low as Trinidad. A comparison of the solubility tests and the ash and fixed carbon tests brings out the fact that insolubility varies directly with the amount of mineral matter present. The solubility of a bitumen is entirely independent of its character and consistency.

Fixed Carbon. The fixed carbon determination serves as an indication of the mechanical stability of an asphaltic oil. Native asphalts average from 11 to 15 percent of fixed carbon. This test is relatively unimportant in comparison with the other tests as it is seldom the determining factor in the selection or the rejection of any asphalt to be used in road construction.

Latest Specifications of the American Society of Municipal Improvements for Asphaltic Cement for Bituminous Concrete.

	A	B	C	D	E
Specific Gravity	.970 – 1.000	1.000 – 1.030	1.030 – 1.040	1.025 – 1.050	1.040 – 1.060
Penetration	75-90	90-100	70-90	85-90	> 40*
Melting Point	> 55°C	> 50°C	> 45°C	> 50°C	
Volitization Loss	< 1%	< 2%	< 2%	< 2%	< 3%
Penetration of residue	not less than one-half original				
Total Bitumen	> 99.5%	> 99.5%	> 99.5%	> 99.5%	93-98%
Bitumen soluble in 86° Naptha	70-80%	72-78%	80-88%	67-77%	78-85%
Fixed Carbon	8-10%	11-15%	10-14%	12-18%	11-15%
Ash	1-3%	1-3%	1-3%	1-3%	1-3%

Comparing the results obtained from our tests with the specifications, on the preceding page, of the American Society of Municipal Improvements for asphaltic cements to be used in bituminous concrete, we find that none of the commercial fluxed asphalts analyzed will pass completely under any of the grades given - A, B, C, D, or E. With a little more flux added, the Mexican cement could be used for class D or class E. A similar treatment would enable Californian cement to be used for class B. Fluxing would enable Texan cement to be used under B, C, or D. The Bermudez and Trinidad asphalts seem from these tests to be unsuitable for bituminous concrete under these specifications.

Table of Comparison

	Mexican	Berm.	Calif.	Texan	Trin.
		qualifies for			
Sp. Gr.	E	none	B, C, D	B, C, D.	none
Melting Point	all	all	all	all	all
Penetration	none	none	none	none	none
Vaporization	all	none	*	all	none
Penetration after volatilization	all	none	*	all	none
Solubility in carbon bisulphide	none	E	none	none	E.
% ash	all	none	all	none	none
% bitumen insol. in 86° B. Naphtha	none	A, B, D	A, B, D.	D	none
Fixed Carbon	D.	A.	A.	B, C, A, E.	C.

* not tested

A similar comparison of the results of our tests on refined asphalts with the same specifications gives about the same result. The Bermudez asphalt might be made to qualify for class D by fluxing but the Trinidad asphalt is still unsuitable. The other refined asphalts may be used for the different classes if sufficient fluxing is done.

Standard Specification for
Sheet Asphalt Pavements
(American Society of Municipal
Improvements)

Specific gravity at 77°F - not less
than 1.04
Penetration - 3.5 to 7.5 mm.
Volatilization - not more than 5%
Penetration after volatilization shall
not be reduced more than 50%
of its original value.
Total bitumen not less than 97
percent in carbon tetrachloride

Discussion and Comparison with Typical Specifications.

We tried to obtain the original specifications from the Massachusetts Highway Commission of the samples of pavement which we have analyzed, but the only facts which we could get were few and general. This is probably due to the fact that about fifteen years ago it was not the custom to insert such specifications in contracts. The only specifications required at that time were those for specific gravity and penetration. Therefore, we have decided to compare our results with a typical present day set of specifications for asphalts used in the construction of sheet asphalt pavements.

Specific Gravity. Of all the pavements analyzed none will pass the specific gravity test of the standard specifications. The samples of Kilby and Arch Streets and of Massachusetts Avenue would probably have passed when they were first laid. At present the specific gravity of each is 1.06 and as the specific gravity increases directly with the age, they would in all probability have passed the specification.

Penetration. As penetration decreases with amount of volatile oil vaporized, and as these pavements have had a considerable amount of light oil driven off, only one of the samples pass this specification.

The sample analyzed from Devonshire Street showed a penetration of 6.03 millimeters and will pass the present day specifications. The penetrations of samples of Kilby Street and of Massachusetts Avenue vary so little from the requirement that it would have passed this specification when it was first laid.

Volatilization. As the required specification for volatilization is that it should not be greater than 5 percent, all but one will pass the requirement. As the asphalt gives off its volatile oils with age, it is evident that a great number of years will elapse before the volatilization will show results as high as 5 percent.

Penetration after Volatilization. This test performed after the sample has been subjected to traffic and climatic conditions for a number of years is of no real value in comparison with the specifications adopted for sheet asphalts. All samples but that of Temple Place will pass the specification. As the requirement calls that the penetration shall not be reduced more than 50 per cent of its original value, the majority of the samples will pass. The samples have changed in penetration considerably since they were first laid and will only decrease slightly when heated for 5 hours at a constant temperature of 163° centigrade. This fact is shown in the slight changes in samples of Columbus Avenue and Arch Street, 2.3 and 0.3 millimeters, respectively.