INVESTIGATION

OF

LANSING AND COLLEGE

ROAD MATERIAL

BY

M.M.BUCK AND F. LOSSING

1911

This thesis was contribulted by

Mr. M. M. Buck

under the date indicated by the department stamp, to replace the original which was destroyed in the fire of March 5, 1916.

CONTENTS.

The Object.

The object of this thesis is to determine the chemical and physical properties of the Liquid Asphalt so called and used by the Indian Refining Company during the summer of 1909 in resurfacing the Lansing and College road.

It is not the object of this thesis to determine whether this material is an economical and satisfactory one to use in road construction or in road resurfacing because it has been proven to all that it is of no practical use in such work. The fact that the Lansing and college road, since being resurfaced with this Liquid Asphalt, has been such a striking failure from start to finish has shown without a doubt that the material used in the renewal is worse than useless for such purposes.

It is the object of this thesis to determine the chemical and physical characteristics of this Liquid Asphalt in order that material having similar properties may be avoided in future road renewals and construction. Some of the condemning physical properties of the material are well known to those familiar with the road since its renewal and those properties are mentioned in another part of this thesis under, History of Material.

History of the road.

In a thesis, entitled "Macadam Road From Lansing to the College", written by R.Rasmussen and I.M.Phippeny, who were senior engineers at M. A. C. in 1906, a very complete history and description of the original road is given and anyone wishing information on that part of the history of the road should refer to that thesis.

It is sufficient here to say that this original macadam road was built in the year 1906 by Prof. C.L.Weil,at that time, the head of the Engineering Department at M. A. C. ,who took up the contract when a Saginaw contractor dropped his contract. Prof. H.K.Vedder of M. A. C. was made Engineer by the Lansing Business Men's Association, for the road. The grades were established by F.F. Rogers, deputy state highway commissioner. The specifications were class "E" as made by the Mich. State Highway Dept.

In the early part of May 1906, grading was commenced. The grading was done entirely by wheel scrapers while the shoulders were built up by earth from wagons. When the road-bed was made to correspond to the profile both horizontally and vertically, a ten ton steam roller was used to harden the subgrade to such an extent that the roller would not make an impression in the earth. Then stone which had gone thru a 3 inch mesh was dumped upon the subgrade and spread wiyh shovels and rakes to a thickness of 4 1-2 inches. The roller was run over the stone so spread until the thickness was reduced to 3 1-2 inches. When this had been done a binder of stone from the 1 inch mesh was spread to a thickness of 1-2 to 3-4 inches.and again rolled. Then the last course of 1 1-2 inches stone and the binder were spread to a thickness of 3 1-3 inchesand rolled down to a thickness of 2 1-2 inches making a total thickness of 6 inches. The specifications were adhered to very strictly according to Prof Reed, who was inspector of the job.

The orginal macadam road was a very good road and served as a model macadam road for the state while it was in a good state of preservation. However by the year 1908 it was found that because of the heavy and extensive traffic that passedover it, the surface had begun to rut and was starting to disintergrate. The road-bed itself was in a very good condition and the surface was still impervious to water but the surface was so rough that it was thought if some attempt were not made to put a protecting coat of some kindof material that the whole road would go to pieces

Accordingly the Lansing Business Men's Association took up the proposition of resurfacing the road with some kind of asphaltic material. It was then that the Indian Refing Co. of Cincinnati, Ohio, a corporation of that state, came forward with the proposition to the Lansing Business Men's Association to resurface the road, with their material at a very cheap lump price.

There was no real contract or agreement between the Association and the Company. Letters between the two parties being the only thing that could be called a contract. Neither were there any specifications as to the nature of the product to be used, the amount and quality of the resurfacing to be used. It was not specified as to how the material was to be applied to the road.

The Indian Refining Co., simply said to the Association in letters ,"We will resurface the road with our material and crushed limestone and will guarantee the work for a period of 18 months. For the resurfacing you are to pay us the sum of $1,500.00". The Association accepted the proposition by saying , "We take your proposition. You are a big corporation capitalized at one million dollars in the state of Ohio and therefore we think your word guarantee means a good road and so we will not make any agreement or specifications. Go ahead and build the road to suit yourselves." That is all there was to it. The company was given full swing to do as they pleased.

A copy of a letter obtained from the Sec. of the Association. written by the Indian refining Co. is included in this thesis. It is the only thing like a contract and specificationthat the two parties had.

The road as built has proved to be a gigantic failure that only those who have had to travel by and over can fully appreciate. In the spring of the year 1909 after the road was built, the road was asea of Liquid Asphalt. The material softened up under the action of the sun's rays so much that it stuck to wheels of the vehicles passing over it and to anything else that came in contact with it. In the winter the material is hard and brittle. Since the resurfacing of the road the Liquid Asphalt has hardened to a certain extent but it has continued to rut and creep under the action of the traffic until the original macadam road is beginning to show thru.

About a year after the resurfacing of the road it was in such a bad shape due to ruts that the Company attempted to repair it. They removed some of the ruts by picking off the limestone and Liquid Asphalt with hand picks. They continued this repair work until they saw it was of no use to do more. The only effect of this repair work was to smooth up that portion of the road for a short period but now it is as bad as ever.

The summary of the whole thing is that the Lansing Business Men's Association attempted to get something for nothing and failed. The resurfacing of the road was undertaken with a man superintending the work who was not competent todo such work. This improper laying of material suitable for road surfacing could have but one result and that is that it is worse than a complete failure. It has not only made a very poor road but it has rendered the further improvement of the macadam road a most difficult proposition.

Penetration Test :- This test as applied in the examination of the material under consideration was used to determine the hardness of the material, and this was accomplished by determining the distance a weighted needle would penetrate into the specimen examined.

In order that this test may be compared to other similar tests a standard needle was used. This needle was weighted with a one hundred gram weight. The tests were made on the material at a standard temperature of seventy-seven (77) degrees Fahrenheit. The needle so weighted was allowed to descend for five seconds as determined by the pendulum on the penetrometer. The penetration of the needle is read upon a graduated dial which is so graduated and geared to the rack that it measures the penetration in one-tenths mm. The dial is divided into three hundred and sixty (360) degrees, each degree representing one-tenth of a millimeter penetration of the needle.

The apparatus used was the N.Y. Testing Laboratory Penetrometer No 16, and is manafactured by Howard and Morse at 1197-1211 DE Kolb Avenue, brooklyn, N.Y. There are two standard needles with the machine. The weight of the needle -point consists of the needle itself, the weight of the needle-bar, the weight of the weights to be slid on the needle-bar. Of these removable weights there were two , one of which was marked fifty (50) grams, and the other one hindred and fifty (150) grams. All these weights were removed and weighed separately upon an accurate balance and the data for the same is given below:

Weight of needle No. 1	2.5000 grams
" " " " 2	2.4792 "
" " " -bar	47.4952 "
" " 50"gram weight	49.9992 "
" " 150 " "	149.9718 "

An attempt was also made to determine the weight upon the point when the needle bar is released by means of the plunger or in other words to determine if there is any reduction of the weights due to friction when the needle bar slides through the plunger, when it is released by pressing in on the plunger but it was found that it was not possible to measure this reduction by means of an ordinary balance but there is no doubt but what there is considerable loss due to friction.

Value of the test: The penetration test is a convenient one to use for identification,control,and comparison of oil or asphaltic products used in road construction. According to thex standards or specifications laid down by Hubbard in his book, "Dust Preventives and Road Binders" no oil product should be used in macadam construction with a penetration higher than 25 m m when tested at 77°F with a number 2 needle for a period of five seconds drop under a weight of 100 grams. Futhermore he says,"On the other hand, it is rarely necessary to require a penetration as high as that for asphaltic used in topping off an asphaltic pavement, for the reason that the upper course of macadam has a much greater inherent stability than the sand course of asphaltic pavement. A penetration of from 10.0 to 15.0 mm is usually considered sufficientfor road work. If a material having much lower penetration is selected its susceptibility to temperature changes will have to be considered.

An attempt was made by us to obtain the penetration of the material as we found it after wechad removed the water in it which had proberly gotten there due to the exposure to the rain since the road was repaired. The so called Liquid Asphalt was brought down to the standard temperature for testing (77°F) by imerging in water .The standard weight of 100.0 grams was used

on the needle . The material was to soft so that the needle dropped out of sight in it very quickly, the material did not seem to retard the fall of the needle at all. An attempt to get the penetration of the material with the water left in it was made but no better results were obtained than with the dehydrated Liquid Asphalt.

Some of the dehydrated material was placed in an iron retort and distilled as described under "Distillation" in another part of this thesis. The residue thus obtained from the retort was treated with the penetrameter but it was far to soft to allow its penetration to be taken.

In another part of the distillation test some of the material was distilled in a glass retort but the residue thus obtained was a hard crusty coal like material and was not in a liquid form so the penetration was not taken.

In another part of this thesis under distillation the material was distilled to 370°F. In the test with the iron retort the temperature was carried up to 370°F.

Therefore somewhere between 370°F and 370°F there probablyis a residue that we could measure the penetration but owing to the poor temperature control that we had we were not able to determine at what temperature we would have such a residue.

One of the essential characteristics of all asphaltic or bitumnious material used for road building purposes is that its hardness shall increase the longer the material is exposed to climatic conditions especially sunlight. It has been demonstrated that asphalt will not harden unless it has been exposed to the sunlight.Having this essential property in mind,we determined in the limited yime we had to see how this Liquid Asphalt would act in the sun, to see if it would harden as it should if it was to be used for road purposes.

The pure dehydrated was not used becaus e we had such a limited time to expose it to the weather that we did not think it would harden to any appreciable extent. Therefore we took some of the dehydrated material and mixed it with sand so that it would be in a more divided stateand hence more exposed to the weather. The sand and Liquid Asphalt were mixed to a ratio of six parts of sand to one of asphalt by weight. The sand used was obtained by seiving ordinary gravel sand through a number twenty (20) sieve. This sand was driedand heated and while hot was mixed with the asphalt. The asphalt was also heated up to 1[illegible]0°F before it was mixed with the sand in order to expel all water and also to aid in mixing the two materials. The hot dehydrated tar material and sand was mixed together as well as it was possible and the combined material ,while still warm, was moloed into two inch cubes. Thirty of these cubes were made each day for a week. This made a total of 130 cubes to be tested. On the day after they were made the penetration the cubes were taken and at the end a week it was again taken and so on forone month.Ten readings were taken on each cube and the average taken as the penetration for that time.The cubes were exposed to the warmest weather conditions by placing them out in the sunlight. Each time the cubes were tested they were brought as near to 77°F as was possible.The weight used was 100 grams and the time of dropping was five seconds.

Because of the great number of specimens and of the number of readings on each cube , by taking the average it is possible to determine if this Liquid Asphalt has any hardening properties. One set of readings does not show much but the average of all the sets show how the hardness is varying.

Data from penetrometer readings on the two inch cubes made from the sand and dehydrated Liquid Asphalt.

Ratio of asphalt to sand 1 ; 6.

Temperature of mixing 100°F

" " testing 77°F

Penetration measured in $\frac{1}{10}$ mm.

Weight on needle 100gms.

Number of specimen	Average of ten penetration readings. After 7 days exposure.	After 14 days exposure.	After 21 days exposure.	After 28 days exposure.
1	51.5	59.6	60.6	62.5
2	31.3	45.0	47.0	48.1
3	58.0	98.8	81.0	89.5
4	48.9	53.2	58.0	82.1
5	31.2	57.5	41.0	25.3
6	55.8	123.3	89.0	70.9
7	33.8	78.1	63.0	41.6
83	35.1	107.4	73.0	55.8
9	35.1	82.0	69.0	54.8
10	39.1	74.9	71.0	59.2
11	41.6	79.4	51.0	42.9
12	44.3	62.0	47.0	34.9
13	59.4	81.6	39.0	62.0
14	35.3	71.2	45.3	41.5
15	35.3	148.7	67.2	62.2
16	85.2	145.0	93.5	90.5
17	46.2	133.5	64.5	59.5
18	29.4	146.4	83.1	77.1
19	79.3	79.9	85.5	79.5
20	56.2	74.8	64.1	65.1
21	50.0	87.9	71.1	66.2

Average of ten penetration readings.

Number of specimen	After 7 days exposure	After 14 days exposure	After 21days exposure	After 28 days exposure
22	101.5	111.5	111.2	106.9
23	67.2	137.7	56.7	49.7
24	72.6	134.7	76.7	73.8
25	56.5	131.7	79.7	74.4
26	61.0	70.7	76.6	71.7
27	161.6	144.9	179.7	97.2
28	156.3	181.6	159.6	120.7
29	149.3	172.0	203.1	111.0
30	187.9	167.1	232.4	134.6
31	167.6	182.2	135.1	128.4
32	172.2	192.2	198.6	139.5
33	149.0	182.0	205.1	134.2
34	151.7	170.0	234.1	150.6
35	208.8	209.2	216.3	237.2
36	173.4	175.8	192.4	142.8
37	130.5	176.3	176.3	135.1
38	125.8	130.5	184.1	107.7
39	109.0	145.3	193.2	179.4
40	164.1	174.8	176.5	137.7
41	164.1	174.8	176.5	137.7
42	151.9	201.6	236.1	130.3
43	110.6	134.9	194.3	143.8
44	117.4	136.8	176.1	127.0
45	132.6	166.4	111.7	183.3
46	181.9	230.1	234.6	189.6
47	159.5	214.3	236.3	181.2
48	113.9	143.2	205.1	132.7

Average of ten penetration readings.

Number of specimen	After 7 days exposure	After 14 days exposure	After 21 days exposure	After 28 days exposure
49	125.6	161.5	214.5	154.8
50	154.1	191.9	196.1	147.6
51	157.0	218.3	236.4	150.0
52	158.9	210.3	221.7	179.6
53	199.5	249.9	196.8	201.5
54	150.3	172.9	215.7	176.6
55	109.9	156.3	193.5	156.3
56	140.3	211.0	227.0	189,9
57	163.7	133.7	179.9	143.0
58	171.0	160.3	189.5	153.0
59	197.6	111.5	167.4	176.1
60	152.4	150.2	168.1	131.6
61	131.9	191.8	240.3	101.7
62	161.6	141.4	181.5	140.6
63	154.4	148.0	178.1	136.9
64	130.1	177.3	211.3	157.2
65	129.9	138.9	170.8	101.6
66	201.7	169.2	225.0	176.8
67	178.0	159.6	209.0	154.3
68	152.0	161.7	232.2	125.6
69	190.9	168.6	200.8	164.8
70	179.1	155.3	214.5	131.6
71	200.1	203.6	211.2	173.1
72	149.3	164.8	181.3	121.2
73	163.4	176.2	127.0	133.7
74	130.1	123.1	171.9	111.8
75	156.8	191.7	255.3	132.7

Average of ten penetration readings.

Number of specimen	After 7days exposure	After 14 days exposure	After 21 days exposure	After 28 days exposure
76	174.9	220.9	200.5	186.1
77	220.0	176.9	159.4	198.8
78	194.9	194.3	210.2	171.2
80	139.6	111.4	163.8	121.6
81	177.8	190.4	175.6	152.7
83	211.7	138.6	221.3	187.6
84	151.2	125.8	120.8	130.2
85	163.4	136.7	133.9	141.9
86	139.9	143.8	169.6	115.7
87	105.2	167.6	170.7	66.1
88	157.6	212.3	167.2	115.1
89	145.3	211.3	156.6	101.7
90	101.9	139.3	134.3	79.6
91	124.5	210.4	93.0	57.2
92	112.7	161.7	151.2	68.1
93	158.2	148.6	148.3	109.3
94	171.0	183.2	184.8	121.6
95	136.6	156.3	166.5	91.7
96	165.1	166.7	170.1	123.1
97	161.1	169.6	139.9	119.6
98	154.3	184.1	168.8	110.1
99	149.9	170.8	239.8	101.7
100	163.6	185.1	160.2	119.7
101	154.3	184.1	166.8	110.0
102	160.2	184.1	166.8	110.0
103	89.6	169.5	139.9	61.2
104	39.8	138.0	109.5	51.3

Average of ten penetration readings.

Number of specimen	After 7 days exposure	After 14 days exposure	After 21 days exposure	After 28 days exposure
105	128.9	172.4	143.9	79.6
106	103.4	173.6	166.6	53.7
107	117.8	174.6	172.9	63.1
108	133.1	125.2	169.3	71.6
109	127.6	153.9	105.0	69.8
110	136.3	137.7	132.8	93.1
111	148.6	172.9	108.6	91.7
112	152.1	146.2	141.9	101.6
113	133.9	207.5	183.6	83.1
114	133.0	1[illegible]1.4	109.9	81.0
115	145.3	145.9	163.3	93.6
116	138.8	168.3	147.1	38.7
117	127.7	265.1	178.4	168.3
118	136.7	163.4	78.1	169.1
119	137.8	162.5	99.2	38.1
120	114.8	121.1	67.1	53.3
121	121.4	149.5	95.8	86.9
122	123.6	173.8	73.2	85.2
123	117.9	114.1	64.5	57.1
124	109.2	193.1	120.6	111.8
125	121.0	225.9	129.4	121.3
126	102.1	173.8	39.5	78.7
127	106.4	131.8	73.4	67.3
128	81.4	130.5	90.1	85.6
129	127.5	1317	119.4	108.5
130	154.8	159.1	85.6	76.9

Average of ten penetration readings.

Number of specimen	After 7 days exposure	After 14 days exposure	After 21 days exposure	After 28 days exposure
131	130.7	153.9	117.3	119.7
132	153.5	117.3	101.3	90.6
133	209.0	227.5	139.9	65.3
134	106.5	98.9	61.9	60.7
135	124.2	99.2	61.9	66.1
136	140.4	83.3	87.2	64.7
137	192.6	105.6	89.4	71.8
138	112.8	144.9	72.8	59.3
139	95.2	90.2	74.2	53.1
140	124.2	88.4	69.4	51.3
141	116.5	73.8	64.7	63.7
142	105.5	78.8	84.7	50.1
143	105.0	109.3	56.4	50.1
144	123.1	109.5	74.9	58.3
145	118.2	98.9	50.7	41.6
146	107.8	86.1	76.4	58.1
147	156.6	200.8	163.1	88.3
148	163.1	90.2	76.2	54.3
149	116.9	178.5	82.6	71.9
150	134.2	155.3	92.0	68.3
151	134.7	139.4	94.5	71.4
152	226.0	128.8	133.7	108.5
153	139.4	170.9	111.8	98.7
154	136.7	150.4	109.0	83.1
155	162.7	176.6	117.3	91.6
156	181.5	193.1	126.3	105.3
157	208.1	106.4	125.7	104.7

Average of ten penetration readings.

Number of specimen	After 7 days exposure	After 14 days exposure	After 21 days exposure	After 28 days exposure
158	176.4	215.0	138.0	119.3
159	202.6	104.1	123.2	101.1
160	157.3	175.6	130.5	117.6
161	210.7	137.3	140.8	97.3
162	176.6	192.4	146.3	121.6
163	170.0	136.3	147.9	117.9
164	164.4	195.0	103.4	73.1
165	162.0	97.3	115.5	84.3
166	132.6	125.6	89.9	78.1
167	168.9	137.1	119.1	85.5
168	172.8	156.4	114.4	81.2
169	133.0	176.3	93.2	67.7
170	116.3	93.5	74.5	64.5
171	129.3	176.4	100.7	71.0
172	152.8	185.4	129.6	83.7
173	130.8	215.0	111.4	91.2
174	128.9	124.3	111.4	96.7
175	230.7	218.2	179.2	137.1
176	191.0	173.0	181.9	148.6
177	213.0	164.1	135.8	125.3
Average	135.65	167.00	134.10	103.7

An inspection of the results obtained in this penetration test as shown by the averages of 1770 readings taken every seven days with the penetrometer shows that the material does not possess the property of hardening in the sunlight to any great extent. At the end of the fourteen day period the hardness was less than it was at the end of the seven day period by 1.935 mm. At the a end of twenty-one days the hardness had increased by .365 mm over that at the end of the seven day period. At the end of twenty-eight exposuse the hardness had increased 3.495 mm since the readings were taken at the end of the seven day exposure. As to the results obtained in the test, it cannot be said they are of any great value except that it shows the material does not harden to any extent when exposed to the sun. This test also shows that the material is extremely sensitive to to temperature changes for one or two degrees makes a great difference in the penetration. This susceptiblness to weather conditions is also shown by the weather effect upon the road since its construction, for as soon as the weather begins to become warm the Liquid Asphalt starts to melt and stick to the wheels of the passing vechicles.

General Methods Of Analysis.

General methods od analysis of the material are those suggested by the American Society of Civil Engineersin " Revised Methods Adopted by the Special Committee on Bituminous Material for Road Construction."

These methods are given in full in " Dust Preventives and Road Binders", by Hubbard and also in " The Modern Asphalt Pavement" by Richardson. So far as it is possible to do so these methods were followed out for the determination of the chemical and phytsical properties.

The chemical tests run were those for free and fixed carbon, distillation (fractional), solubilityin carbon bisulphide, carbon tetra chloride and 87° Baume naphtha, mineral matter, paraffin in the oils distilled,and combustible matter in the material now on the road.

The physical tests that the material was subjected to werethose for penetration, viscosity, present hardness, and property of hardening in the sunlight.

Lansing, September 5, 1908.

Lansing Business Men's Association,

Lansing, Michigan.

Gentlemen:- A representative of our company, Mr Arthur P. Lord has this day been over the macadam road from Lansing to the College and noted to the condition thereof. We propose to treat this road , approximately 18900 yards, with our product and limestone in such a manner that when the job is completed all the ruts and the depressions and the like will be filled leaving a smooth and even surface with a uniform crown to the road. We propose to guarantee this workto last in good repair for a periodof eighteen months under ordinary conditions and any defects or trouble that may arise with it, we will fix at our expense, leaving material here with which to do the same.

For this work, when properly done in a satisfactory manner, our charge will be the sum of $ 1500.00, payable thirty days after completion.

If notified of the acceptance of this offer by the tenth of Sept., we will endevor to commence work on the job by the 15th of Sept.,delays occasioned by transportation excepted, and weather conditions being favorable will complete the work this fall. Should we be unable to complete the work on accountef weather conditions,

conditions, we will finish it earlyy in June of the next year or as soon as weather will permit.

Very respectfully,

Indian Refining Company.

By (Signed) Arthur P. Lord.

VISCOSITY

The viscosity of the liquid asphalt was determined by the Engler Viscosimeter at a temperature of 95°C or 163°F. The apparatus consists of two vessels, one placed inside the other. The inner vessel is to contain the fluid bitumen whose viscosity is desired and is supported in the outer vessel in such a way that the liquid used in the outer vessel for heating purposes, extirely surrounds the inner vessel. The outer vessel is heated by means of a gas jet ring placed under the vessel. The liquid used in the outer vessel should be some heavy oil that can be heated to a high temperature and not boil over like a light oil will. To the conical bottom of the inner vessel is fitted an outflow tube that is exactly 20 mm long and whose top diameter is 2.9 mm and whose bottom diameter is 2.8 mm. This tube is closed by means of a pointed hard wood stopper and is opened by withdrawing this stopper when it is desired to stop the flow. The inner vessel is fitted witha cover. Both vessels are fitted with a Centigrade thermometer. The one in the outer vessel serves only to regulate the heating medium While the one in the inner vessel is the means of telling when the fluid is of the proper temperature for getting the viscosity. The entire apparatus is made of brass. Under the outflow tube is set a graduated flask.

First the time by water at 95°C which is required to fill the flask is determined and then the time required by the Liquid

Asphalt at the same temperature to fill the samevolume is determined The ratio of the time required by the asphalt to the time required by the water is the viscosity of the asphalt. Time determinations we were made by means of a stop watch.

The value of the test is that if the material is to be applied to a road it is necessary to know at what temperature this can be done most advantageously. It also serves as a means of identification of different binders.

The standard temperature as given by Hubbard is 25°C but this material was found to be to stiff at that temperature and by expermenting with the material it was found that 95°C was the only temperature that could be used because above that temperature the material was frothy and below that it was to stiff to run at all.

DATA

Temperature in all cases was 95°C .

Volume was 200.0cc.

Material used	Number of trial	Time required		Viscosity
Water	1	47.6 sec.		
"	2	47.4 "		
"	3	47.0 "		
	Average	47.33		
Liquid	1	26 min 35.6 sec.		33.71
Asphalt with	2	27 " 44.4 "		35.17
water content	3	30" 23.2 "		38.73
			Average	34.40
Deyydrated	1	19 " 20 sec.		24.62
Liquid	2	19 " 40 "		24.89
Asphalt	3	17 " 50 "		22.61
	4	17 " 30 "		22.39
			Average	23.65

The data shows two remarkable results. First it will be noted that even at 95°C it took the dehydrated material twenty-three and sixty five hundredths as long to run out as it did the water. With the material as we found it with the water init , it took 34.40 times as long as it did the water.

Secondly ,from a comparison of these two results it will be seen that the water seemed to make the water more stiff.

Specific Gravity

The specific gravity was found by filling a graduated flask of 10cc volume when full of water at 60°F . The net weight of the liquid asphalt at 60o F divided by the volume of water(10cc) gives the specific gravity. This method is close enough for practical purposes by using proper care.

The value of this test is mainly one as a means of identification, but with the other tests is of service in determining the suitability of the material for road purposes. As applied to the oil products the specific gravity is a rough indication of the amount of heavy hydrocarbons which give body to the material. No oil having a specific gravity less than 0.95 should be used as a permanent binder and those whose specific gravity lies from 0.98 to 1.00 are preferred.

Specific Gravity at 60.0°F

	Original Liquid Asphalt	Dehydrated Liquid Asphalt
	0.989	0.954
	0.991	0.955
	0.984	0.957
Average	0.9880	0.9553

Fixed Carbon

This determination is made according to the methods of of the American Chemical Society as described in there Journal. From one to two grams of the dehydrated material is placed in a platinum crucible having a tightly fitting cover. It is then heated over the full Bunsen burner for seven minutes. The crucible is supported on a triangle with the bottom 6-8 cm above the burner. The flame should be at least 20 cm high and the determinations should be made in a place free from drafts. The residue is the fixed carbon.

The value of this test is that it indicates the mechanical stability of the material. Paraffin oils show but little fixed carbon but the asphaltic material has more fixed carbon. If free carbon is absent then fixed carbon is desired. Native asphalt averages from 12 to 14 per cent carbon.

DATA

Number of the test	Weight of Material	Fixed By Weight	Carbon By Percent
1	1.8130	0.3341	18.43
2	2.5015	0.4789	19.14
3	1.1708	0.2314	19.76
4	1.7841	0.3449	19.44
Average for dehydrated material			19.19
1	1.6300	0.4015	24.64
2	1.8710	0.3552	19.03
3	2.0193	0.4006	19.83
4	1.7048	0.4254	24.94
Average for residue after distillation up to 270°C			22.11
1	1.6310	1.4547	83.05
2	2.1815	1.7927	82.18
Average after distillation up to 370°C			82.62

These tests show that the material has an excess of fixed carbon over that laid down in specifications.

TOTAL BITUMEN.

For all practical purposes all organic matter soluble in carbon bisulphide is considered as bitumen in this determination and the total bitumen found by dijesting the material to be examined in this solvent and filtering off the insoluble residus.From one to ten grams of the dehydrated material is weighed out into a 200 c.c. Erlenmeyer flask and traeted with 100 c.c.of C.P. carbon bisulphide.The flask is loosely corked and shaken at intervals until the large particle are broken up,when it is set aside for not less than fifteen hours.At the end of this time the contents of the flask are decanted off upon a weighed Gooch crucible fitted with amphibole asbestos filter.The residus remaining in the flask is washed out on the filter.The insoluble matter if there is any is finally brought upon the filter and dried for a time at 100°C. and then weighed.The weight of the total residue deducted from that of the original material gives the weight of the bitumen soluble in cold $C.S_2$.

Bitumen soluble in carbon bisulphide.

Dehydrated Material.	Residue at 270°C.	Residue at 370°C.	
99.78%	93.46%	77.36%	
99.78	90.86	76.41	
99.70	90.65		
99.78	91.65		
99.76%	91.65%	76.885%	Average.

FREE CARBON.

The determination of the free carbon in the material is done in connection with the determination of the bitumen

soluble in carbon bisulphide.The insoluble residue left on the filter in the Gooch crucible is dried and weighed as desribed in the bitumen determination and then it is burned and the ash left,after burning determined by another making another weight.The weight of this ash subtracted from the weight of the residue gives the weight of the free carbon in the substance.

Data;

Percentage of Free Carbon in:-

Dehydrated Material.	Residue after Distillation to 270°C.	Residue after Distillation to 370°C.
0.0448%	1.37%	8.874%
0.0252	1.00	8.410
0.480	1.53	
0.0280	1.08	
0.0365%	1.295%	8.642% Aver

The amount of free carbon has a great effect upon the specific gravity.It is not desired in a tar or asphalt to be used for road purposes.Tars of a petroleum nature whose specific gravity is high (1.1 to 1.3) contain from 0.12 to 0.30 percent free carbon.

The effect of free carbon in road material is to reduce the binding strength of the bitumen.Fre carbon also reduces the water proofing value of a tar roa binder.It also retards the absorption of the tar by the porus surfaces to which the binder is applied.

In ordinary bituminous road construction,both from the stand point of efficiency and economy a low carbon tar is to be prefered to a high carbon tar whose bitumen content is of the same consistency.From the above it is seen that free

carbon may affect the physical properties in two ways.First in a mechanical way by it s actual presence in the asphalt. Second,by combining with other substances.While at a high temperature,to form undesirable compounds with them.

NAPHTHA.

In the test with naphtha the determination of the bitumen insoluble in the naphtha is the object.This determination is made the same way that the total bitumen soluble in carbon bisulphide is determined,except that naphtha is the solvent used.The percent of bitumen insoluble in 87° Buame naphtha is reported upon the basis of total bitumen taken as one hundred.The difference between the material soluble in carbon bisulphide and that insoluble in naphtha is the bitumen insoluble in naphtha.Thus in a certain instance it is found that the material insoluble in carbon bisulphide amounts to 10% and that insoluble in ~~carbon bisulphide~~ naphtha is 10.9%,then the percent of bitumen insoluble in 87° naphtha would be calculated as follows;

$$\frac{\text{bitumen insoluble in naphtha}}{\text{total bitumen}} = \frac{10.9-1.0}{100-1} = \frac{9.9}{99.} = 10.\%$$

The term Asphaltenes is applied to the bitumen insoluble in naphtha and malthenes to that portion which is soluble. The asphaltenes tend to give body and consistency as well as adhesive properties to the product so that this determination serves as an indicator of the medhanical stability of material as well as its binding qualities.

Data:

Percent of Bitumen insoluble in 87° Buame Naphtha

In Dehydrated Material.	In Residue after Distillation to 270°C.	In Residue after Distillation to 370°C.	
21.28%	46.6%	72.8%	
21.71	49.4	73.4	
19.40	44.3		
20.61	48.5		
20.75	47.2	73.1	Averages.

In the process of the distillation of crude petroleum the first thing that comes off is 87° Buame Naphtha. It is one of the laws of solvents that those oils that are distilled off will, disolve all the things that are left in the residue. So if naphtha is distilled off first then the naphtha will disolve everything that is left in the crude petroleum and whence that part of the asphalt that is not soluble can not come from the crude petroleum or if it not in the same chmical form that it was when in the crude oil. If I get some pitch off a pine ~~off~~ log on my clothes and wish to remove it then I can take some of that pine pitch off that log and distill it and the first oil that comes off is called the natural solvent and will remove the pitch from the cloth.

This fact gives us the clue that all this liquid asphalt can not be the result of the distillation of crude petroleum alone but that it must have something mixed with it that comes from another source but whether that source is true native asphalt can not be said from the test with naphtha.

BITUMEN INSOLUBLE IN CARBON TETRA CHLORIDE.

This determination is made in exactly the same manner as described for total bitumen determination except that tha solvent used is the tetra chloride and not the carbon bisulphide,As in the case of naphtha the results are calculated upon tha basis of total bitumen present.

The bitumen insoluble in tetra chloride have been called carbenes.Little is known of their effec t upon the physical properties of oils and asphalts but as has been shown by Kirschbaum in Mun.Engineering they are,"the result of unnecessarily highntemperatures,and resulting concentration in the production or refinement of large quantities of both natural and oil asphalts".

Data:

Amount of Bitumen Insoluble in Carbon Tetra CHloride. For the dehydrated Liquid Asphalt the average of four tests for insolubility was 0.755%.

This test seems to indicate that the material has not been subject to such high temperatures as to injure it for road purposes.

DISTILLATION TEST.

About 250 c.c. of the dehydrated material is weighed and poured into a tared glass retort of 750 c.c. capacity. A cork stopper carrying a thermometer is then inserted in the cubulture so that the bulb is level with the bottom of the stem leading from the retort.The liquid asphalt is heated gradually by means of a Bunsen burner and the fraction to 110°C. is collected.Then the receiver is changed and another fraction collected between 110° and 270°C.,and the

receiver is again changed and the fraction collected between 270° and 370°C. This is called fractional distillation.

A cold wet towel wrapped around the stem of the retort aids in the condensation of the distillate.

At first the original Liquid Asphalt was distilled to determine the amount of water in the material as we found it at the college before we started to test it. After that the material was first dehydrated and then distilled as the water in it made it very slow work to distill as the material frothed to such an extent that it could not be prevented from running over in the retort and so spoiling the determination.

This test as applied to tars, etc. is a valuable one especially for the purpose of determining their road building properties.

Water in a tar is determined detremental for use as a permanent binder. As the asphalt contains 55.9% of oil whose specific gravity is 0.8667, it is seen to be low in binding qualities.

Distillation Data for Liquid Asphalt.

Original Material.	Dehydrated Material.		
% of water	% of oil up to 170°	to 270°.	370°.
19.8	5.74	41.15	55.9

Paraffine Scale Test on Fractional Oils.

This determination is made according to the method employed by the Standard Oil Company.

Five grams of the well mixed distillate which was left

[illegible]

[illegible]

[illegible]

[illegible]

from the fractional distillation test is treated in a flask with 25 c.c. of 96% ether;after mixing thoroughly 25 c.c. asbestos alcohol is added and the flask packed closely in a freezing mixture of finely cracked ice and salt for at least 30 minutes.The precipitate was quickly filtered off by means of a suction pump using a#589 hardened filter, cooled by means of the above freezing mixture in a suitable apparatus.

The precipitate was washed with one to one alcohol and ethermixture cooled to 0°C. until free from oil.When sucked dry,the paper was removed and the waxy precipitate transferred to a small glass crystal dish.This was then dried and weighed.

Weightn of paraffine scale divided by the weight of the di distillate obtained from the original sample equals the present percent of parrafine scale.

In road oils tha heavy liquid parrafine,when present in ex cess,probably exert a much more undesirable influence upon practical results than the solid paraffine,and for this reason the determination of them is important.By determining the percent of solid paraffine scale we see that it is very small as compared with the liquid paraffine and hence the binding material is again shown to be weak.

Percent Paraffine Scale of Distillations.------

Up to 170°C.	Up to 270°C.	Up to 370°C.	
0.0351%	0.351%	0.934%	
0.312	0.346	0.925	
0;0316%	0.3485%	0.9295%	Average

Summary Of All Tests Results

Dehydrated Liquid Asphalt;

Specific gravity	0.955
Viscosity	23.65
Penetration	Too soft
Total Bitumen soluble in CS_2 at air temperature	99.959%
Free Carbon	0.0362%
Bitumen insoluble in 87° Naphtha at air temp.	20.75%
" " " CCL_4 " " "	0.755%
Fixed Carbon	19.19%
Distillation	
Lightoil up to 110° C by weight	19.8%
Second " " "110-170° C " "	5.74%
Heavy " " "170-270° C " "	25.41%
" " " "270-370° C " "	14.75%
PitchResidue by difference	44.10%
Paraffin Scale	
Of oil up to 170° C	0.0316%
" " " " 170 to 270° C	0.3485%
" " " " 270 to 370° C	0.9295%
Residue after distillation to 270°C	
Bitumen soluble in CS_2 at air temp.	91.655%
FreeCarbon	1.295%
Bitumen Insoluble in 87° naphtha (asphaltenes)	47.20%
Fixed Carbon by weight	22.11%

Residue after distillation to 370° C		
Bitumen soluble in CS_2	(by weight)	76.885%
Free Carbon	" "	8.64%
Bitumen insoluble in 87° Naphtha (Asphaltene)		39.21%
Fixed Carbon	(by weight)	86.02%
Ash or mineral matter		0.58%

These tabulated results are simply the summary of the results obtained under the different tests and as they are there discussed it is not necessary to say anything about them here.

Original Material;

An attempt was made to run some tests on the material that the company removed and piled at the roadside alongside Snyder's and Adam's Additions. We first tried to separate some of the asphaltic material from the limestone and dirt with which it is mixed. We gently heated it for some time and also tried other means of separating them but found that we could not do so without using some solvent and that would change the asphalt so we did not run any solubility tests on the material. The only test that we did run on the material was to determine the combustible matter in it now. Out of ten burning tests run we got an average of 6.59 % combustible.

The Amount of Asphaltum in the "Liquid Asphalt"

In letters found at the office of the secretary of the Lansing Business Men's Association written by the Indian Refining Co. to that association the statement is made that the liquid asphalt put on the road shall contain at least 70% asphaltum and one of the objects of this thesis was to determine as near as may be just how much asphaltum there really is in the material.

For the simple purpose of comparison we have made some tables showing the chemical and physical properties of three substances. The first of these tables gives the properties of Refined Trinidad Asphalt. These values were taken from Hubbard's and Richardson's books refered to in the begining of the thesis, and are the average of a long sreies of tests run on the material by those men. The second table gives the properties of Petroleum Residium also taken from the same text books.

Refined Trinidad Asphalt.

Total bitumen soluable in Cabon Bisulfide	55 %
Bitumen insoluable in 88° Buame Naphtha	60.45%
" " " " $C\,Cl_4$	61.2 %
Fixed Carbon	12.5 %
Specific Gravity	1.4
Penitration	7°
Mineral Matter	35.0%

Residium of Petroleum.

Total bitumen soluable in $C\,S_2$	99.5 to 100 %
Bitumen insoluable in 88° Buame Naphtha	7 " 25 %

Bitumen insoluble in $C\ Cl_4$	----
Fixed Carbon	6 to 10 %
Specific Gravity	0.98 to 1.0 %
Distillation to 370° C,	80.0 to 90 %
Penitration	to a large degree.
Mineral Matter	0.00

Indian Refining Co's Liquid Asphalt.

Total bitumen soluble in $C\ S_2$	99.759 %
Bitumen insoluble in 88° Buame Naphtha	20.75 %
" " " $C\ Cl_4$	0.755 %
Fixed Carbon	19.2 %
Free Carbon	0.04 %
Distillation to 370° C,	55.9 %
Penetration	To a large degree.
Mineral Matter	0.58 %

A casual inspection of these results show thst the liquid asphalt properties are more like those of the petroleum residium than like the Trinidad asphalt.

Asphalt is an extreamly complex material, and on account of the many combinations of hydrogen and carbon that are possible it is dificult to determine just how much asphalt there is in a mixture of bitumenous material. This material might be composed of a mixture of native asphalt, petroleum residium of an asphaltic nature or otherwise, or of the petroleum residium alone, if it came from the fields of the southwest or the far west. However it is possible to get proportions that r roughly fix the per cent of asphalt in the material and some are given below.

Dehydrated Material.

Liquid Asphalt bitumen insoluble in 88° Naphtha, 20.75 %

Trinidad Asphalt " " " " " 60.45 %

Let (x) be the per cent of asphalt in the Liquid Asphalt,

Then x : 100 :: 20.75 : 60.75 , x = 34.33 % asphalt.

Distillation Residue at 270° C.

The residue is 58.84 % of the material started with.

Liquid Asphalt Bitumen insoluble in 88° Naphtha 47.2 %

Then X : 100 :: 47.2 : 64.75 , X = 78.08 %

78.08 x 58.84 = 45.9 % Asphaltum.

Distillation Residue at 370° C.

The residue is 44.1 % of the material started with.

Liquid Asphalt Bitumen insoluble in 88° Naphtha 39.21 %

Then X : 100 :: 39.21 : 64.75, X = 54.86 %

54.86 x 44.1 = 28.6 % Asphaltum,

Dehydrated Material.

Liquid Asphalt Bitumen soluble in C S_2 99.7 %

Trinidad Asphalt " " " " 55. %

Then X : 100 :: 55 :99.7 , X = 55.1 % Asphaltum.

Distillation Residue at 270° C.

Liquid Asphalt Bitumen soluble in C S_2 91.65 %

Then X : 100 :: 55 : 91.65, X = 60.0 %

60 x 58.84 = 35.30 % Asphaltum.

Distillation Residue at 370°C.

Liquid Asphalt Bitumen soluble in C.S_2 76.88 %

Then X : 100 :: 55 : 76.88 X = 71.54 %

71.54 x 44.1 = 31.25 % Asphaltum.

The average of the Asphaltum percentage in the original dehydrated

Liquid Asphalt as found by these six proportions is 38.41 %

All the alalyses seem to indicate at least that the residue obtained in the distillation up to 370° C, had been changed by the application of heat, or that the properties are not what they were before the material was heated. Probably there were some new chemical compounds formed in this heating process, or at least some compounds distroyed. However there could not have been any mineral compounds distroyed or made and so we can take the percentage of mineral ash as indicating the amount of asphalt in the origonal liquid asphalt, when it has been properly refered back to that material. It is found that, by burning the residue, up to 370°, to an ash that the original material contained .58 % mineral matter. Now true asphalt contains 35.0% and petroleum residium 0.0 % . This will that the Liquid Asphalt contains little or no native asphalt.

Summing it all up, it can be said with the authority of our data, that the liquid Asphalt does not contain more than 40 % of matter that is of an asphatlic nature and that there is every indication that the material does not contain over 5 % of native Trinidad or Bermudaz Asphalt.

Our data goes to show that the material does not contain more than half of the asphaltum that the Indian Refining Co. claims that it contains, for they claim that it contained at least 70 % Asphaltum.

Conclusion: From the foregoing tests and the history of the road, no other conclusion can be reached by us except that the material is of no use whatever as a permament binder for road building. The tests which show this up best are the penetration test and the distillation test.

The one shows that the material is far too soft for such purposes and the other that the material contains too much light oil and that it never can be made into material suitable for road building, for at no time in the distillation up to 370° C. was there a point at which the distillation could have been stopped, and a residue could be had that was suitable for road building at all.

Of course the thing that every one wishes to know now is what to do with the road as it now stands. We do not attempt to answer that question for we have not had the experiance to do so, but we do think that there is no use of putting any more of the Liquid Asphalt upon it. It seems to be tha opinion of those with whom we have talked on this subject, and whose opinions are to be regarded as good that to put on another course of macadam is about the only course that is left open now.

Cincinnati, Ohio, March 30, 1911

Dear Sir:-

Referring to your letter of March 28th, we beg to advise that we have no specifications showing how the Lansing College Road was built. We are, however , sending you a copy of some specifications which will give you an idea as to how work of this kind is done.

Yours very truly,
Indian Refining Company

S P E C I F I C A T I O N S

For Asphalt Binder Roadways. Specifications " A " for Constructing New Roads.

(1) The specifications in use by the city or county for grading excavation or enbankment, drainage, rolling, and curbing should preface this specification.

(2) The proposed material, such as crushed stone, gravel, furnace slag, or sand to be used in the roadway should be the best of its kind procurable in the vicinity of the proposed construction.

(3) In the preparation of the roadway the crushed stone material should occupy a trench formed by excavation, to provide lateral support and to prevent the stone particles from spreading.

The Foundation Course;

The size of the crushed stone, in this course, shall be between two and three inches. It should be of hard, sound and durable quality.

When the subgrade has been prepared as provided by the city or county specifications and thoroughly rolled by the Engineer, the foundation course of stone shall be brought upon the road bed and spread.

The depth of this course shall be six (6) inches after rolling or compressing with a steam roller weighing not less than ten (10) tons. The top surface of this course after rolling shall show an evenness and be true to the accepted or designed cross section of the finished roadway and at all places be three (3) inches below the completed surface of the proposed construction.

Preceding the rolling of this foundation course, the stone can be watered sufficiently to assist in the rolling but not with the intention of creating a binding grout.

The rolling shall continue until the foundation stone have become firm and solid and no movement of the stone can be detected. The greatest importance is placed in the rolling and shall be insisted upon by the Engineer in charge.

The Wearing Surface ;

Upon the foundation course as completed shall be placed the wearing surface. This shall have a finished depth of three (3) inches. The mineral aggregate shall be of the hardest quality possible of obtaining and show regular fractures. The size of the stone shall be that which passes a two and one-half (2½) inch opening and be retained on a ~~two and~~ one(1) inch screen. This course shall be rolled once up and back to obtain an even and true surface, as well as a slight compression. The rolling shall be started at the sides and completed at the crown. Should any unevenness appear such depressions shall be built with additional material.

Applying Asphalt Binder.

Upon the surface of the wearing surface so prepared shall be distributed the Asphalt Binder in such a way as to thoroughly coat the surface of the stone particles and

afford a slight excess. The minimum quantity of binder shall be (1) one gallon, the maximum being one and one half ($1\frac{1}{2}$) gallons to the square yard of surface treated.

This course of stone shall not be watered, and the stone before application shall be thoroughly dry. A satisfactory time after rain shall be allowed for the stone to dry.

The Asphalt binder shall be applied at a temperature of about 300°F. by means of asuitable sprinkling can be arranged so as to spray the binder evenly over the surface.

After the application of of the Asphalt binder to the second course of stone, the treated surface shall be given a thin dressing of grit of hard quality. It shall be in size about one half ($\frac{1}{2}$) inch and only sufficient quantity cast over the surface to slightly cover the same, approximately one cubic yard to every seventy-five square yards. The grit is to be applied dry.

FINAL ROLLING.

After the application of the grit to the wearing surface, the final rolling shall take place and then continue until the surface shall show an even and compact mass.

SQUEGEE COATING.

A sealing coat of Asphalt binder shall be applied, approximately one half ($\frac{1}{2}$) gallon per square yard of surface. It shall be applied hot, about 300°F. and cover the entire roadway. The object shall be to seal the top surface. Immediately upon its application the thin covering of sand shall be cast over this coat. When the unnatural heat has left the binder, the roadway is ready for use.

THE ASPHALT BINDER.

The asphalt binder to be used upon this work shall be prepared by mixing of a native solid bitumen fluxed with

a heavy semi-asphalt oil.

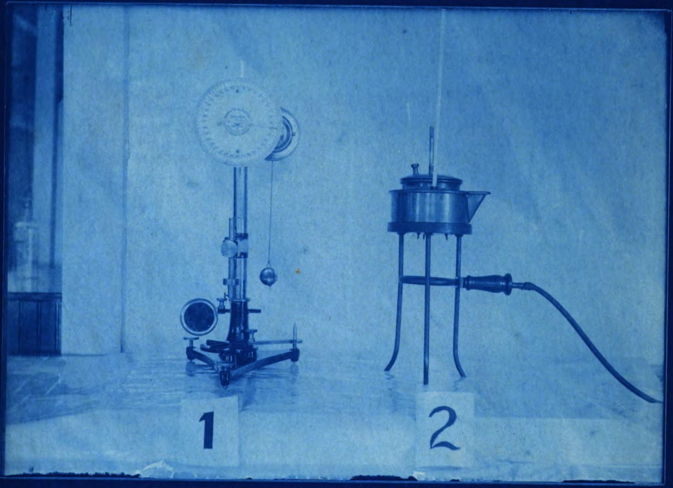
It shall possess a penetration of not less than 100, tested for five(5) seconds at 77°F., with a number two neddle weighed with 100 grams, and not greater than 150 penetration.

The melting point of the binder shall not be below one hundred and sixty(160) degrees Fahrenheit.

The gravity to be approximately 10 Beaume.

It shall be soluble in carbon disulphide to the extent of at least 99%, and not less than 75% in 76° petroleum naphtha at air temperature.

The asphalt binder shall have the quality of binding the mineral aggregate together and possess satisfactory water-proofing qualities.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