THESIS

AN ANALYSIS OF THE PAVEMENTS OF LANSING, MICHIGAN

D. L. WERNETTE R. S. CLARK

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An Analysis of the Pavements of Lansing, Michigan.

A Thesis Submitted to

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MICHIGAN AGRICULTURAL COLLEGE

By

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Candidates for the Degree of

Bachelor of Science

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Thanks are due to Mr. Eckert, City Engineer of Lansing, for his co-operation and help in the matter of records and estimates, and also to his brother, Mr. Alfred Eckert, Assistant City Engineer of Saginaw, for his kindness in furnishing sample specifications.

SECTION A.

A BRIEF HISTORY OF PAVING IN GENERAL

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Paralleling as it does the history of civilization itself, the history of paving is indeed an interesting one, but like civilization the dawn of its history is shrouded in the mystery of remotest antiquity. Conjectures only can be made as to the date of the first attempts at road surfacing, and it is a profitless thing to guess about, but the Romas historian Atrabo avers that the streets of Babylon were paved as early as the year 2000 B.C. The word pavement is directly from the Latin pavimentum, a floor of rammed or beaten earth, which word is derived in turn from pavire, to beat, and the term was applied originally to the footway or sidewalk of rammed earth at the side of the street rather than to the roadway proper for vehicles and beasts of burden. For traffic of barefooted porters and bearers and unshod donkeys and camels a path of hard earth sufficed, and the early Babylonian pavements were undoubtedly such. Most historians of the periods of Chaldean, Assyrian, Babylonian, Persian, and Egyptian power speak of the Royal Highways, but few fail to mention the enormous clouds of dust which attended and half stifled all troop columns, so that the assumption may reasonably be made that earth was the road material of ancient times.

The extension of inland domains and of commerce overland, however, made necessary long before the Christian Era the adoption of more permanant materials for the construction of trunk roads. Very briefly, paved roads have been built for two general reasons, viz: political reasons and economic reasons.

It was for political reasons that the Romans, about the year 320 B.C. adopted from their rival city Carthage the idea of armoring earth roads with stones. The natural lava of that volcanic region furnished abundant material for the first constructions, the soldier-rulers of that time realized that communication and transportation must knit each conquored province to the Golden City if the Empire was to stand, and each general, returning victorious with a host of captives, saw in road building an eternal monument to his own greatness. Thus it was that the arrowy white lava tracks spread from the gates of Rome to the extreme frontiers of the Empire in Saxony and the Pyrenees, that the dedication of a new Way followed each successful campaign, and that the terms, Roman, conquorer, and road-builder became in a sense synonymous. These Roman paved ways were built at a tremendous cost of labor and human life, but captive labor and the lives of captives were of course not considered for an instant. The rapid movement of

the General's Legions and Squadrons demanded the shortest routes ---- and straight as a string the General made his roads. The Empire was to stand forever ---- and as an eternal foundation a three to five foot course of rocks was laid, cemented together with natural cement. The way must be made smooth for the feet of runners and strong for the wheels of chariots ---- and the wearing course was accordingly made of large smooth lava stones, irregular in shape but fitted cunningly together at the edges. Expense was nothing ---- permanence everything.

Political or military paved roads had the whole field to themselves until the end of the eighteenth century, although the extremely heavy construction of the Roman roads was modified somewhat in the Calaph's Cordova highway of the tenth century and others of the few paved roads that the Middle Ages witnessed. Cobble stones were indeed used in a few cases in Europe and America during the seventeeth century, but they were more generally viewed as being in the nature of extravagant luxuries than anything else. The great plagues of the Dark Ages may well be laid, in part at least, at the door of the unsanitary street conditions and lack of paving.

About the year 1830 it would seem that the civilized world awoke to the belief that economic reasons

might justify the paving of city streets, without involuntary labor and at a cost which the added sanitation and convenience of traffic would show a profit over. In 1835 a pavement of wood blocks was put into service in New York City, and the scheme was later (1839) adopted for the streets of London. Bituminous surfacing was tried in Paris in 1839, and the progress of the art of paving from that time to this has been steady. Brick paving was in use in Japan in 1800, and in Holland to a slight extent in the seventeenth century, but the first successful brick pavement in the United States was laid in Charleston, W. Va. in 1870. The growth of the portland cement industry has made possible the construction of concrete roads upon a large scale only since 1900.

These three materials: asphalt, brick, and cement concrete, and to a lesser extent stone blocks and wood blocks, are the principal materials in use for paving today, and the streets of American cities and villages bear witness to the excellence of each when properly laid and subjected to the sort of traffic for which it is suited.

SECTION B.

A HISTORY OF THE PROGRESS OF PAVING IN LANSING.

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For many years after its foundation in the early part of the 19th century Lansing consisted mostly of a dam and grist-mill, a blacksmith shop, and a store or two, but even during that period the place was celebrated for its inaccessability. When before the first railroad invaded Ingham county, Lansing was named as capital of the state, there was of course considerable induced traffic in its direction with the inevitable effect upon the dirt trails leading thither. In fact we read in an early history of the city that as late as 1850 there were heard from the mud-wearied Legislators numerous opinions to the effect that a less objectionable site for a State Capital might well have been chosen! It may be that the completion, in 1852, of the Detroit Plank Road on what is now Michigan Avenue did something to relieve the situation, and it is certain that the arrival of the M.C. Railroad in 1862 must have done so, but at any rate the capital stayed and Lansing grew and throve.

The need of pavements was painfully evident, but the hard times of the reconstruction period prevented their materialization until 1878 when the first attempt at municipal paving was made. In that year a section of Washington Avenue was paved with round cedar blocks set

endwise on a sand cushion and packed closely together. Capitol Avenue from Ottawa to Allegan, and Michigan Avenue from Capitol to the Grand River were later paved with the same material. The paving was two rods wide, in the middle of the street, the shoulders and gutters being of cobbles. This cedar pavement was satisfactory for a few years, but it proved to be short lived as water easily penetrated the end grain of the blocks. When we say that the cedar block pavement was cheap and quickly laid we have about completed the list of its good points.

Manifestly there was need for a paving material more lasting than wood, and it was found in brick. In fact it was generally supposed at that time that a brick pavement would last indefinately. The first brick pavement was laid in 1894 on Capitol Avenue from Ottawa to Shiawassee, two blocks, and the next year a block or two each were laid on Michigan Avenue, Washington Avenue, and Shiawassee Street. These brick were laid without filler, upon a sand foundation, and the fact that some of them are bearing traffic today, after 26 years of service bears witness to the excellence of the materials. Motor truck traffic in the modern sense of the word was then undreamed of, and it is not surprising that its severity has at present brought many of these old pavements to a pitiable condition. They were never planned for it. With a few exceptions all the pavements that were laid in Lansing between 1894 and 1910 were of

brick. In 1908 the use of cement concrete as a foundation for paving brick was tried. A sand cushion was used between the concrete and the brick, as it was thought that in no other way could the proper resistance to impact be obtained. Later grew up faith in the so-called monolithic brick construction. This consists in brick bedded in the still green surface of the concrete foundation, and having their joints well filled with thin cement grout. These pavements are satisfactory under the most severe traffic conditions, but they possess the fault of being very difficult to repair after they once begin to fail.

The first Asphaltic concrete was laid in 1910, and is still in excellent condition, the gutters being of monolithic cement concrete construction. For a couple of years (1911 and 1912) several blocks of cement concrete pavements were laid, but the extreme danger of damage by frost to this type of pavement as well as the difficulty of repairing it led to its rejection in favor of asphaltic concrete.

Since 1914 asphaltic concrete has been in turn superceded by sheet asphalt which is just as satisfactory and cheaper. Recent improvements in methods of refining and treating the asphaltic ingrediments have made possible the construction of asphalt wearing surfaces that will not iron out into waves under any but the very heaviest of trucking traffic, and for that matter most of the streets that have been paved in Lansing during the

past six years are in residence districts or at most upon moderate traffic streets. A standard parabolic section with 6" crown has been adopted, as will be discussed in a later section, and there is but little variation from it in the pavements that are at present being laid.

SECTION C.

THE OBJECT OF THIS THESIS.

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The object in the preparation of this thesis is to investigate and report on the relative efficiency (or economy) pf the several types of pavements that are at present in use in Lansing. Taking into account the first cost of a typical sample of each of the principle kinds, as well as the present traffic over it and the cost of its upkeep and replacement, we shall point out which kind has been the cheapest in money outlay per unit of traffic service rendered, and which type bids fairest to most economically meet the pavement needs of Lansing during the next few years.

The first, or analytical object is chiefly of statistical interest, while the second is the perpetual problem that confronts municipalities everywhere.

SECTION D.

ASSUMPTIONS.

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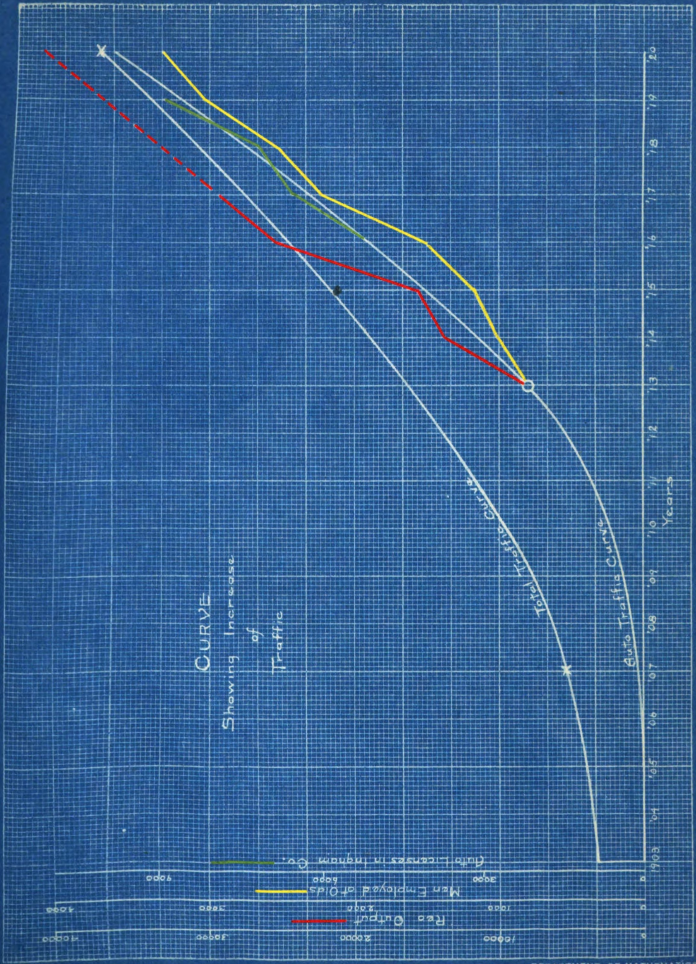
ASSUMPTIONS.

In the computation of the matter for the table showing the street traffic census and for the total volume of traffic over the various sections described later, two assumptions seemed necessary. They are:

1. The motor traffic on the streets of Lansing, has increased approximately in the same proportion as the output of several of the leading manufacturing concerns of the town and also the number of automobile licenses issued in Ingham County.

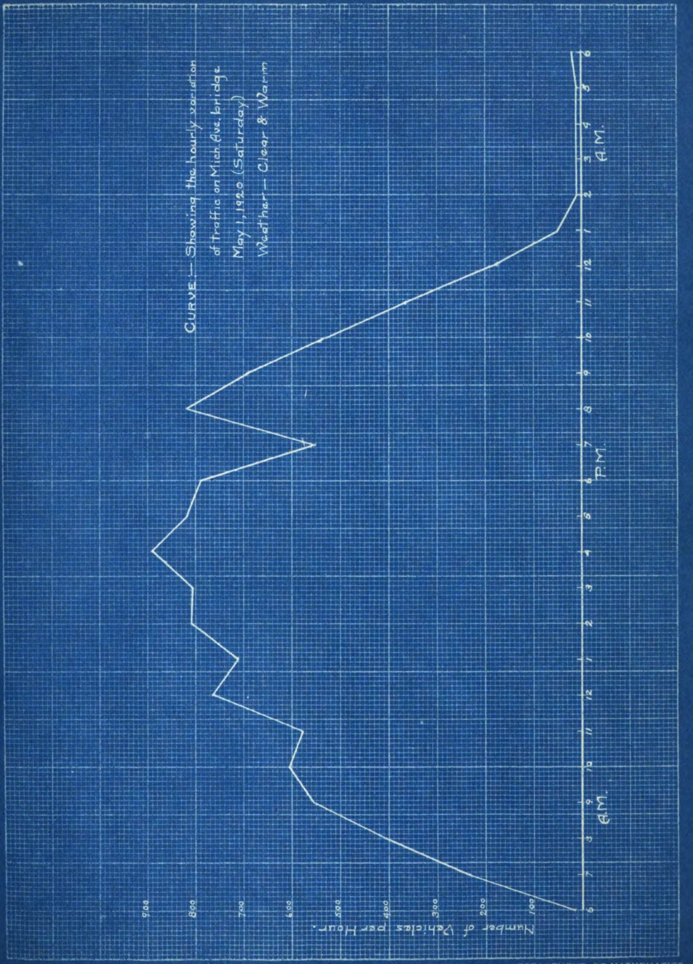
2. The hour-to-hour changes in the intensity of traffic upon the several selected typical sections of pavement may be assumed as being about the same for all of them.

The intensity of traffic upon any street is variable. It varies from hour to hour during the day, from day to day during the week, as well as seasonally. These changes are not very great, but are fairly regular and will not differ greatly from year to year. There are other and greater changes, however, which cannot well be left out of account. For example, the motor traffic upon Lansing's streets fifteen years ago was practically zero while today 96% of all the traffic upon the same streets is motor driven.


CURVE
Showing Increase
of
Traffic
Total Traffic Curve
Auto Traffic Curve
Years
Auto Licenses in Ingham Co.
Men Employed at Olds
Reo Output

Conversely, during the same period horse-drawn traffic had dwindled from 100% to a bare 4% of the total. Also the total volume of traffic is now almost seven times what it was in 1907, as is shown by a comparison of our figures with those of the census taken in that year. As traffic data for the intervening years is not available, it had to be supplied through some sort of an assumption, and #1, above, was adopted. The assumption seemed to us to be a fair one that the total traffic has increased in about the same proportion as a combined curve of the output of several of the automobile plants and the total number of licenses issued for automobiles in the county of Ingham. As we have plotted it the curve combines the growth of the Olds and Reo factories with the license data. From these the direction of the curve is determined during the years when no census data was taken. The average ratio between our census figures and those of Mr. Angell in 1907 is 7:1, and accordingly the curve passes through a point in 1907 having one seventh of the maximum ordinate. The best that can be said for this curve is that it is an approximation, but we feel that it is as good an approximation as we can arrive at with the data at hand.

Again, being limited as to time, we took only two all day censuses (at Michigan Ave. bridge and on Washington Ave. in front of the Capitol National Bank) and several two or three hour censuses on the other typical streets. This necessitated assumption #2, namely that the hour-to-


CURVE:— Showing the hourly variation
of traffic on Mich. Ave. bridge
May 1, 1920 (Saturday)
Weather — Clear & Warm
Number of Vehicles per Hour.
100
200
300
400
500
600
700
800
900
A.M.
P.M.
A.M.
6
7
8
9
10
11
12
1
2
3
4
5
6
7
8
9
10
11
12
1
2
3
4
5
6

hour changes in traffic are about the same for all the streets in question. This also is evidently not an absolutely true assumption, but the figures for the two all day censuses taken show very parallel changes, #2 was adopted as the only available means of reducing a short census to terms of an all day one. The changes that took place from hour to hour in the census taken at the Michigan Avenue bridge are shown in the second curve. These are the changes that we assumed as being the same for all the streets that we took census on. For the convenience of anyone who wishes to use this data later, however, we include in the tabulated results the actual count taken on each of the short censuses, together with the hours, date, day of the week and weather conditions for which they were taken.

SECTION E.

SURVEY AND CENSUSES

Section E.

SURVEY AND CENSUSES.

There are in Lansing at the present time, May, 1920, about 22.9 miles of pavements. They are of six different kinds, as follows:

1. Brick on sand foundation ----- about 5.3 miles.
2. " " concrete " ----- " 4.1 "
3. Cement concrete ---------- " 2.2 "
4. Bituminous macadam ---------- " 0.8 "
5. Asphaltic concrete ---------- " 7.7 "
6. Sheet asphalt ---------- " 2.8 "

Total about ------ 22.9 miles.

We have made a survey of all these pavements, as regards their present condition, and the results are tabulated in this "Section E" together with the results of the nine traffic censuses taken.

There are also in Lansing at this time about 3.2 miles of sheet asphalt pavement under construction.

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Attention is called to the map of Lansing in the pocket at the back of this volume. Upon this map will be found indicated the location of Lansing's paved streets, with a color key to the several kinds of pavements.

TABLE 1.

LOCATION AND CONDITION OF BRICK-ON-SAND PAVEMENTS.

Location	Year Laid	Cost per Sq. Yd.	Present condition
Michigan from Regent to MCRR	1906	$ 1.63	This stretch is worn and wavey. One of the worst in the city.
Michigan from Grand River to Capitol	1898	0.83	Worn out pavement. Ought to be replaced at once.
Grand from Washtenaw to Michigan	1905	1.75	Old and worn. The street intersections are sagged in several places.
Franklin from Pine to MCRR	1899 1906	1.04 1.38	Fair condition, MCRR crossing in very bad shape.
Turner from Franklin to Clinton	1899	0.94	In very bad condition. Two complete failures on this stretch of pavement.
Ottawa from Logan to Washington	1906	1.63	Worn, Patched with new brick in several places. Curbs cracked and heaved.
Saginaw from Butler to Washington	1908	1.39 1.89	Rough and patched.
Allegan from Walnut to Grand	1903	1.59	Rough and worn out.
Washtenaw from Townsend to Grand	1907	1.41 1.63	Ditto.
Main from Logan to Washington	1907	1.70	Very wavey and rough. Several complete failures on this stretch also.
South from Washington to Platt	1906	1.48	Pavement greatly worn but grade still good. Not wavey.
Capitol from Kalamazoo to Ottawa	1905	1.09 1.67	Not many waves on this stretch, but bricks are badly worn.
Walnut from Allegan to Ottawa	1905	1.82	Ditto

TABLE 2

LOCATION AND CONDITION OF BRICK-ON-CONCRETE PAVEMENTS.

Location	Year	Cost per Sq. Yd.	Present Condition.
Michigan from MCRR to bridge			Pavement about worn out.
Cedar from Michigan to Saginaw	1909	$ 2.06	This stretch is in excellent condition.
Shiawassee from Cedar to bridge	1909	2.04	Also in excellent condition.
Saginaw from Washington to Summit			In very good shape
Larch from Saginaw to Sheridan			In excellent condition including car tracks.
Larch from Franklin to Ferris			In excellent condition except for three spots as shown in photo #3.
Capitol from Ottawa to Shiawassee	1894	1.71	The oldest pavement in the city. Patched in spots with new brick. Wavey.
Kalamazoo from Capitol to Hosmer	1909	1.84	This stretch of pavement is in very good condition still.
River from Washtenaw to the bridge	1910	1.95	Very good condition.
Chestnut from Main to Robert	1910	1.97	Intersection of Chestnut and Isaac is badly sagged. Otherwise in fair condition.
Washington from Main to Mt. Hope	1905 1908		In good condition except that the car tracks are heaved a good deal.
Turner from Clinton to North	1910	1.94	Excellent condition.

TABLE 3.

LOCATION AND CONDITION OF CEMENT CONCRETE PAVEMENTS.

Location	Year	Cost per Sq. Yd.	Present Condition.
Michigan from Regent to City Lim.	1916	$	Poor condition for so new a pavement. Badly checked and crown cracked.
Larch from Kalamazoo to Michigan	1912	1.63	In good condition.
Cedar from Hazel to Mt. Hope			New and in excellent condition.
St. Joseph from Middle to Pine	1912	1.63	Badly peeled and chipped. Several bad holes in this pavement.
Ottawa from Washington to the river	1911	1.55	Good condition.
Ionia from Capitol to Grand	1912	1.60	Still in excellent condition.

TABLE 4.

LOCATION AND CONDITION OF ASPHALT MACADAM PAVEMENT.

Location	Year	Cost per Sq. Yd.	Present Condition.
Shiawassee from Wash. to bridge	1895	$ 1.19	Still in good condition.
Shiawassee from Cedar to MCRR	1895	1.19	Still in good condition.
Division from Main to Isaac	1907	.90	Well worn, but still in passable condition. Two or three holes only.

TABLE 5

LOCATION AND CONDITION OF ASHPALTIC CONCRETE PAVEMENTS.

Location	Year	Cost per Sq. Yd.	Present condition.
Penn. from Kalamazoo to Sheridan	1914	$ 1.77	In excellent condition.
Bingham from Michigan to Prospect			Condition excellent. Curbs cracked here and there.
Franklin from Otto to MCRR			These stretches of asphaltic concrete are all in about the same condition. The asphalt part of the street is smooth and good, but the part between the car tracks is paved with brick and the jar or heaving of the cars has humped the brick next to the rails up out of line with the rest of the pavement. In some places the hump can be seen over every tie for half a block. This heaving seems to be unavoidable.
Pine from Franklin to Saginaw	1913	1.63	
Pine from Washtenaw to St. Joe	1913	1.76	
Butler from Saginaw to Isaac	1913		
Saginaw from Logan to west city Limits			ALL these stretches are new and in good condition.
Seymour from Ottawa to Saginaw	1914	1.68	
Capitol from Shiawassee to Saginaw			
Grand from Michigan to Shiawassee	1911		
Washington from Main to Kalamazoo			Asphaltic concrete laid over old brick pavement as foundation. Heaved along car tracks.
Capitol from Main to Kalamazoo	1910	2.16	Still in fine shape.

TABLE 5 (Continued)

LOCATION AND CONDITION OF ASPHALTIC CONCRETE PAVEMENTS.

Location	Year	Cost per Sq. Yd.	Present Condition.
Townsend from Main to Washtenaw		$	Good smooth pavement.
Washtenaw from Pine to Townsend	1914	1.71	Excellent at the sides. Heaved along car tracks.
Walnut from Washtenaw to Allegan			Excellent condition.
Logan from St. Joseph to bridge			Excellent condition.
Isaac from Logan to Division			Excellent condition.
Baker from Washington to Cedar			Excellent condition.
Cedar from Hazel to Michigan			In course of construction.

TABLE 6

LOCATION AND CONDITION OF SHEET ASPHALT PAVEMENT.

Location	Year	Present Condition.
Main from Washington to Grand	1919	New and in excellent shape.
Grand from Main to Washtenaw	1919	New and excellent.
Isaac from Division to Walnut	1919	Part of this is still in course of construction.
Hope from Washington to Cedar	1919	In perfect condition.
Allegan from Logan to Walnut	1919	New and smooth
Sycamore from Ottawa to Ionia	1919	Excellent condition
Genessee from Logan to Butler	1919	Excellent condition
Saginaw from Logan to Butler	1919	Excellent condition.
Shiawassee from Seymour to Washington	1919	Asphalt in good condition.
Larch from Shiawassee to Michigan	1919	Excellent condition.
Shiawassee from MCRR to Penn.	1919	Good condition. A few waves.
Genessee from Becker to Logan	1919	Only the concrete foundation in in place here.

EXPLANATION OF THE CENSUS TABLES.

Section E.

EXPLANATION OF THE CENSUS TABLES.

Two all day censuses and seven shorter ones were taken. The points selected as typical examples of the several kinds of pavement are, in general, those sections on which it is our judgement that maximum traffic occurs.

They are:

Kind of Pavement.	Typical Section.
1. Brick-on-sand	West end of Michigan Ave. bridge.
2. Brick-on-concrete	East " " " " "
3. Cement concrete	St. Joseph St., Pine to Division.
4. Bituminous macadam	No census taken.
5. Asphaltic concrete	Grand Ave., Michigan to Ottawa.
6. Sheet asphalt	West Allegan St.

The two following tables give the results of these censuses. The figures in the column headed "Calc. for 24 hours" are computed as is explained in the note, but those in the column headed "Total Count" are the original data taken in the field.

The figures in the last column, headed "Census in '07" are taken from a thesis on The Pavements of Lansing which was submitted in 1907 by L. D. Angell and W. B. Allen.

TABLE 7

RESULTS OF ALL DAY CENSUS AT THE MICHIGAN AVENUE BRIDGE

Taken on Saturday, May 1, 1920. Traffic both ways.

Weather: Fair and sunny all day.

Hours A.M.	6	7	8	9	10	11	12 PM	1	2	3	4
Pleasure cars and Ford del.	203	268	441	470	480	622	615	683	713	761	
Heavy trucks loaded	9	27	27	21	16	24	20	9	24	30	
Heavy trucks empty	12	38	36	41	29	41	42	47	23	42	
Light trucks	9	22	18	41	18	43	15	29	17	19	
Horse drawn vehicles	3	35	32	35	37	34	21	42	32	40	
Totals	236	408	554	608	580	764	713	810	809	892	

Hours P.M.	4	5	6	7	8	9	10	11	12	AM 6	Totals
Pleasure cars and Ford del.	733	739	519	791	685	523	360	180	100		9905
Heavy trucks loaded	6	5	7	4	1	2	1	1	0		234
Heavy trucks empty	41	27	20	4	0	1	0	1	0		445
Light trucks	15	7	2	13	3	5	1	0	0		276
Horse drawn vehicles	24	12	5	8	6	2	3	2	0		373
Totals	819	790	553	820	695	533	365	184	100		11233

TABLE 8

RESULTS OF ALL CENSUSES TAKEN, SPRING, 1920.

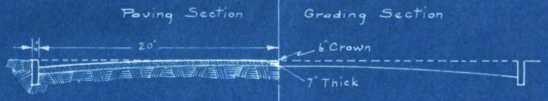
Place taken	Hours	Date	Weather	Total Count	Calc.for 24 hours	Census in '07.
Michigan Avenue bridge	6 A.M. to 12 PM	Sat. May 1st	Fair and sunny	11233	--------	1473
S.Wash. at Capt. Nat.Bank	6 AM to 12 PM	Mon. May 3rd	Fair and sunny	5428	--------	1473
Grand Avenue at Kerns	2 PM to 5 PM	Fri. Apr. 30th	Cool and Showery	1031	4600	550
Michigan east of P.M.R.R.	1 PM to 4 PM	Thu. Apr. 29th	Cool and sunny	1062	4780	635
St. Joe at Sycamore	7 AM to 10 AM	Fri. Apr. 30th	Cool and showery	213	3830	None
Allegan west of Capitol	Noon to 3 PM	Fri. Apr. 30th	Cool and showery	512	2500	496
Franklin Avenue bridge	8 AM to 10 AM	Thu. Apr. 29th	Cool and sunny	396	3830	*1149
Saginaw at the church	1 PM to 4 PM	Thu. Apr. 29th	Cool and sunny	307	1370	None
N. Wash. north of Lenawee	10AM to 1 PM	Thu. Apr. 29th	Cool and sunny	533	3030	501

Note:- The 24-hour figures were computed by means of the hour ratios obtained at the Mich. Ave. bridge.

*This census was taken on W. Franklin, not at the bridge.

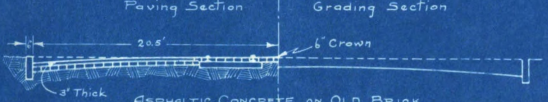
SECTION F.

DISCUSSION IN DETAIL OF EACH OF THE TYPES OF PAVEMENT FOUND IN LANSING.



CEMENT CONCRETE

Section on East Ionia St.



ASPHALTIC CONCRETE ON OLD BRICK

Section on South Washington Ave.

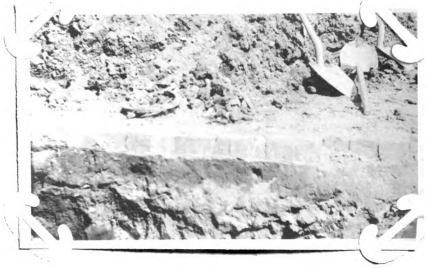
CROSS SECTIONS of PAVEMENTS IN LANSING, MICH.

Section F.

DISCUSSION IN DETAIL OF EACH OF THE TYPES OF PAVEMENT FOUND IN LANSING.

1. Brick on sand.

These were among the first permanent pavements put down in the city. The section of pavement chosen as being typical of brick-on-sand construction is at the west end of the Michigan Avenue bridge. This pavement was laid in 1898, upon no other foundation than the natural sandy soil. This photograph shows a cross section of natural sand foundation. It was taken



farther out on Michigan Avenue, but the construction there is the same. It was due to lack of funds that no better foundation was provided and that no provision was made for underdrainage of the pavement. It may be said here that nowhere in Lansing has it proved ~~to be~~ necessary that any tile pavement drains ~~to~~ be laid. Incidental leakage into

the storm sewers, together with the natural porosity of the soil take care of underdrainage very well. At the time this pavement was laid, however, the truth of the above had not been shown by so many years of experience, and the absence of drains and foundation is due, as has been said, simply to lack of funds. It was thought better to pave several blocks with brick-on-sand than fewer blocks with brick-on-concrete. The traffic over this section of pavement is the heaviest in the city not only because of the bridge, but also because it is part of the Detroit Paved Way and so gets lots of cross-state traffic.

This pavement is now 22 years old, and the bricks are worn off rounding on top and in many places are badly sagged into ruts and waves. (The photograph shows a wave in the Main St. brick-on-sand pavement).

The fact of the extreme long service of this sort of pavement under heavy traffic is without doubt due to the splendid

natural drainage through sand banks to the river.

When it was laid, this pavement cost only 83 cents per sq. yd. It was a contract job. An estimate of the cost of doing a similar job today, based upon current prices and Gillette's Cost Data, shows:

Smoothing up grade ------	per	sq.	yd.	$0.09
52 Pavers at $43/M ------	"	"	"	2.28
Hauling brick (1 Mi.) ---	"	"	"	.16
Laying brick ----------	"	"	"	.12
Total, per sq. yd.------				$2.65

This does not include any grading, as there was none included in the cost of 83 cents in the city engineer's report.

The census taken on this pavement shows the traffic for a bright sunny Saturday, May 1st, as 11233 vehicles for 24 hours. According to our traffic curve (Plate 1.) there have passed over this pavement since it was laid in 1898 about 29,650,000 vehicles.

Being worn and wavey, this pavement is hard to clean, noisy under traffic, uncomfortable to ride over, hard on tires, and presents high resistance to traffic. On the other hand, it was cheap to lay, and has had practically no maintenance. Also it is not slippery.

This pavement was put down against the best engineering judgement and advice, yet it has stood the test of time and traffic marvelously, and though it ought to be replaced with new, it stands today as an example of furtunate bull-headed construction as versus engineering practice.

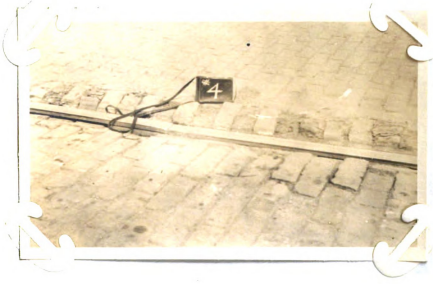
2. Brick on concrete.

The first pavements that were laid of brick in Lansing had a foundation of concrete. A typical section of this construction was chosen at the east end of the Michigan Avenue bridge. By choosing this section, which gets heavier traffic than any other brick-on-concrete pavement in the city, we were enabled to use the Michigan Avenue bridge census for both it and the brick-on-sand just discussed. The bricks for this pavement were placed upon a four-inch layer of concrete. This photograph shows a

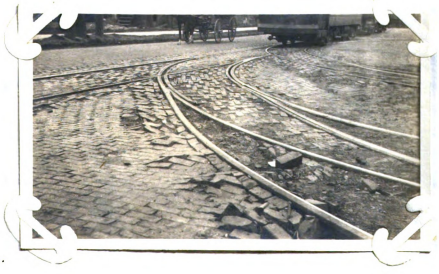
cross section of the construction. We were unable to obtain the exact proportions of the mix, but a sample of the concrete showed many voids and what looked like dirty gravel. It was easily broken with a sledge for excavation. There is no especial provision for underdrainage.

This section was laid in 1895, and is now 25 years old. It is in practically as bad condition as the brick-on-sand. The bricks along the car track are heaved up out of

line with the test; in fact this condition obtains to a greater or less extent on 70% of all the car tracks in the city.



These photographs show the heaved brick on Franklin Avenue



and at the car barns on Shiawassee St.

The cost of laying this pavement was $1.82 per sq. yd., and it was laid by contract. The grading was done by a different contractor under another contract.

The cost of laying a similar pavement today is estimated thus, using current prices for material and labor and time data from Gillette:

Excavation for curb ------	per	sq.	yd.	$0.60
Curb, of concrete --------	"	"	"	0.50
Base, 6" thick of concrete	"	"	"	0.96
Labor on base ----------	"	"	"	0.20
53 Pavers at $43/M -------	"	"	"	2.28
Hauling brick ----------	"	"	"	0.16
Laying brick ----------	"	"	"	0.10
Total per sq. yd.-----				$4.80

This estimate does not include grading, nor does it include anything for cushion or filler. The pavement as laid had no filler at all so far as we could find out, and was cushioned upon an inch of the sand that was right beside the job. Also the base has been increased to 6" in thickness in the estimate since this is the thickness that is more generally laid. For 4" base reduce the third item by a third.

The traffic over this pavement is the same as that over the bridge, namely 11233 vehicles for a maximum day's count, but since this pavement has been in service 25 years its total traffic up to this time has been about 30,300,000 vehicles.

Like the brick-on-sand example this pavement is dirty, noisy, rough, and of high traffic resistance. It lacks the advantage of cheapness, and so far as we can tell

has proved in no way better than the brick-on-sand west of the bridge. The survival of both must be attributed, as has been said, to natural drainage.

There are other examples of brick-on-concrete (South Washington Avenue, for instance) where the grade is still good after 12 years of heavy service, but they have the 6" base that has become standard.

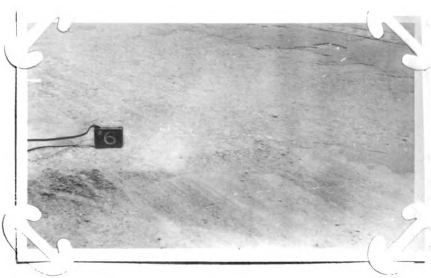
This photograph shows brick starting to fail by crushing in the 10 year old monolithic brick-on-concrete pavement on Turner St.

3. Cement Concrete.

There is not very much of this kind of pavement in the city. In 1911-12 the authorities thought they saw in cement concrete the solution of the paving problem ---- a cheap, permanent, satisfactory pavement. Events, however,

failed to bear out these expectations, and this type of construction was abandoned in favor of the asphaltic concrete. The typical section selected was St. Joseph Street, and a census was taken there between Pine and Division Streets. This pavement, like the rest in Lansing, has no particular provision made for underdrainage, except the crown of the subgrade, which amounts to 6" on a 40 ft. Street.

The St. Joseph Street pavement was placed in 1912, and hence is 8 years old at present. Part of it was laid late in the fall, so that much damage resulted from frost. When frozen, green concrete does not set up properly but peels off in flakes 1/4" thick and soon develops holds 4" or so in depth. This photograph was



taken on St. Joseph Street, and shows one of these holes. There are many such on this piece of pavement.

The city engineer's report shows $1.60 per sq. yd.

as the original cost of this pavement in 1912. An estimate of the cost of the same construction today, figured on a cubic yard basis is:

0.95 bbl cement at $2.80/bbl-----	per cu. yd.	$2.66
0.45 cu.yd. sand at $1.20/cu.yd--	" " "	0.54
0.91 " " stone at $3.00/cu.yd-	" " "	2.73
Labor and management ----------	" " "	2.63
Mixer, repairs, depr. etc. ------	" " "	0.50
Total	per cu. yd.	$9.06

This pavement is 6" thick with no curbs at all, and the cost per sq. yd. would therefore be one sixth of the above figure, or $1.51. Like the rest of the estimates, this does not include grading. The original cost of $1.60 must have included this item, or else the lateness of the season must have hindered the work, for it ought to have been done cheaper than it was. Perhaps the fact that this pavement was in the nature of an experiment tended to make the job more expensive.

The traffic over St. Joseph Street, as computed from a 3-hour census taken on a rainy Friday morning, is 3830 vehicles per 24 hours. We believe that 4500 would better represent a normal day's traffic. Using this figure, our traffic curve gives a total of about 7,380,000 vehicles using the street since 1912.

This pavement, it should be said, is in much worse condition than the one on South Cedar, owing no doubt to the late fall work as mentioned above. In general this

pavement is of fairly low first cost, is smooth to travel over, has low traffic resistance, and if laid under ideal conditions will stand the heaviest kind of traffic. It is also fairly easy to clean, and is a sanitary kind of surface, being practically impervious to water. On the other hand, concrete pavements are noisy, slippery, very difficult to repair satisfactorily, and require about a month to set before traffic can be admitted over them. Another trouble with concrete pavements is that expansion and contraction, due to heat and cold, are very liable to cause cracks. The edges of these cracks soon ship off and crumble and a rough unsightly spot, if not an actual failure, is the result. Various arrangements of expansion joints have been tried on pavements all over the country, but our inquiry or reading has not shown a really satisfactory and uniformly successful solution for this trouble.

4. Bituminous Macadam.

As there are only five blocks of bituminous macadam pavement in Lansing, and none of these is on a street which gets even medium traffic, we did not take a census on any of them. They were laid more as an experiment than anything else, and as such they have not been repeated. The older section on Shiawassee street was originally laid in 1895. We found no record of its having been resurfaced, but attribute the fact that it

is still fairly smooth to the lightness of the traffic over it. Part of it has indeed been torn up and replaced with brick-on-concrete. The other section, laid on Division street in 1907 has been worn out for some time past. These sections of pavement cost the city $1.19 and $0.90 per sq. yd. respectively to build. There are no curbs or gutters on these pavements, with the exception of a few yards of low curb on the part between Grand Avenue and the bridge on Shiawassee.

5. Asphaltic Concrete.

The asphaltic concrete pavement chosen as a typical example is on Grand Avenue north from Michigan Avenue. It was laid in 1911, 9 years ago, and the exact specifications are not known at the city engineer's office. The pavement, however, is about 6" thick, and no especial provision was made for underdrainage. The pavement is in good shape today, except for a few wrinkles or small ruts just where it joins the brick of Michigan Avenue. The cost of laying this pavement is given as $1.29 per sq. yd., which agrees very well with costs given by Blanchard for that year. Without specifications it is impossible to estimate costs today, but it would doubtless be at least twice as much as it was in 1911, since labor has increased in cost from $1.50 to $5.40 per day, and teams with drivers from $5.00 to $9.00 per day since then.

The cost of the asphaltic concrete pavements laid by the city of Battle Creek in 1918 averaged $2.20 per sq. yd. The advance in price of asphaltic materials since then is about 66%. Allowing that $1.20 of the above cost was for materials for the asphaltic concrete, and applying the 66%, an estimate results of $2.60 per sq.yd. today. This Battle Creek pavement did not include curbs, which were already in place, but the result checks in a general way our estimate above of twice $1.29 or $2.58.

The census of this section indicates 4600 vehicles per 24 hours, and from our traffic curve the total number of vehicles since 1911 would be 9,420,000.

The asphaltic concrete pavement has stood up very well under traffic and most of those in Lansing are in

good condition today. This photograph, taken on Hosmer street is typical of an asphaltic concrete pavement with car tracks, expect that the bricks along the track are not heaved up out of line as they are along most of the tracks.

Asphaltic concrete pavement is rather expensive to lay, and when moist is slippery, but it is pleasing in appearance, smooth to ride over, presents little resistance to traffic, is easy to clean, silent under traffic, and may be cheaply patched when holes do appear.

6. Sheet Asphalt.

For the past two years only sheet ashpalt pavements have been laid in Lansing. Most of the paving has been done in residence districts, and a uniform cross section 30 feet wide with a 6" crown and parabolic shape has been chosen. The curb is of monolithic concrete construction with 18" gutter 6" deep. A 6" slab of concrete is laid as a foundation for the asphalt. Next is laid a binder course and on top of that a wearing course which just comes to the top of the gutter floor. Following this section will be found a set of specifications for the sheet asphalt pavements of Saginaw, Michigan. As corrected they are as descriptive of the pavements of Lansing as of Saginaw, as the construction is practically identical. Specifications for paving in Lansing are not printed at all, because the work is done by men working for the city under the direction of the city engineer, and is not let out to contractors at all. There being no contractor in the case, there is no necessity for a set of iron-bound specifications to make a contract crook-proof.

As a typical example of sheet asphalt pavement,

West Allegan street was chosen, and a census was taken there. This pavement was laid last year, (1919) and like all the other pavements in Lansing it depends upon natural drainage entirely. Being new, it is in perfect condition.

This photograph and the one on the following page were taken on Sparrow Avenue where a similar pavement is now under construction. The first shows the grade being smoothed up. The curbs are already finished and cured. The other picture shows the foundation course in place. It is seen that the manholes project just enough above the concrete to come flush with the top of the asphalt.

Plate 2, at the beginning of this Section shows the completed cross section of a sheet asphalt pavement taken on East Main street. The curb is divided into sections about 5 feet long. Thin steel partitions are inserted in the form before the concrete is poured. They serve as spreaders for the form boards, and are withdrawn before the concrete is set firmly enough to grip them.

The cost of sheet asphalt pavement (not including grading, which is let by contract) to the city during the

season of 1919, together with an estimate of the same items for the present season of 1920, was obtained from the city engineer and are tabulated below:

	1919 per sq.yd.	1920 per sq.yd.
Drainage, changes in catch basins, new catch basins, etc. --	$0.20	$0.32
Curb, incl. material, labor, etc.--	0.40	0.60
Base, Gravel and cement ----------	0.80	0.96
Asphalt, delivered hot at plant ---	0.75	1.10
Street work on asphalt, incl. hauling from plant to street ----------	0.25	0.33
Repairs and depreciation on plant, trucks, and equipment ---	0.15	0.20
Totals per sq. yd. ------	$3.13	$4.25

A three-hour census of traffic was taken on the selected typical section on Allegan street. The day was a rainy Friday, in fact the first hour of the census was taken in a drizzle. The computed traffic for 24 hours was 2500 vehicles, but it is probable that 2800 would better represent an average day's traffic.

The slipperiness of sheet asphalt pavement is about the worst objection to it. In this connection, Blanchard points out the fact that asphalt is not so slippery during a downpour as it is during a drizzle. Sheet asphalt is as rather expensive pavement, but it is cleanest and smoothest of all, very easy to clean, and presents little resistance to the passage of vehicles. Also it can be very readily, cheaply, and satisfactorily patched.

There is very little trucking on this street. The census showed scarcely 2% of horsedrawn traffic; most of the vehicles coming under the heading of "Pleasure cars and Ford deliveries".

SECTION C.

CONCLUSIONS AND COMPARISONS

Section G.

COMPARISONS AND CONCLUSIONS.

As a good means of comparison of the various types of pavement that we have investigated in Lansing, we have prepared in graphical form the material given in Blanchard's Highway Engineers Handbook (p.p. 1362-3) under the heading "Tabulation of Valuated Properties of Roads and Pavements". The "eleven characteristics" as we have them tabulated are given the weights that Blanchard assigns to them, but we have in some cases modified the ratings of the various pavements as regards some one or the other of the characteristics. For instance, as regards cost Blanchard rates sheet asphalt and brick-on-concrete at 3 and 5 respectively as against an ideally cheap pavement rated at 10. Now our own estimates, and those of Mr. Eckert, the Lansing City Engineer, convince us that at present sheet asphalt is the cheaper of the two, and we have rated sheet asphalt and brick-on-concrete at 8 and 5 respectively, as against an ideal rate of 15.

Having thus checked up the table to show, as well as may be, conditions in Lansing today, rather than general average conditions, we plotted the accompanying graph. The "Ideal Pavement" curve is an arbitrarily drawn straight line. Under each of the characteristics respectively we plotted ordinates proportional to the ratings of the various pavements as regards that characteristic. The several

TABLE
of
UATED PROPERTIES OF PAVEMENTS

UALITIES	IDEAL	BRICK	CEMENT CONCRETE	BITUMINOUS MACADAM	BITUMINOUS CONCRETE	SHEET ASPHALT
st Cost	15	5	9	10	10	8
tenance Cost	25	25	20	20	18	18
ubility	7	7	5	5	4	4
of Maintenance	10	7	8	8	7	7
nliness	5	3	3	5	5	5
Tractive Resistance	5	5	4	4	5	5
tfulness	5	3	4	4	5	5
elessness	5	3	3	5	5	4
ofitability	5	2	3	4	3	4
ableness to Travel	8	6	5	6	6	8
Slipperiness	10	4	7	5	7	3

CURVE

Showing the Characteristics
of
The Pavements of Lansing
and
Comparison to an Ideal
Pavement

points representing each kind of pavement were then connected by straight lines, and the result is a graphical representation of the comparative excellence of the several types of pavements in each of eleven respects. The data is not original with us (except several modifications like the one noted above) nor is the idea of the graph a new one. We merely present it here because we think it to be a rather lucid comparison of pavement characteristics.

In concluding our study of the pavements of Lansing, several facts are obvious --- others less so. It is clear from the inspection tables that a great many of the older pavements of the city should be replaced at once. It is less obvious to the casual observer, however, that, poor as the old brick-on-sand pavements are, they have given exceptionally splendid service in proportion to their cost.

The census figures show that traffic has assumed such proportions as to forbid the use in the future of any but slab foundations or concrete construction, and a comparison of the cost estimates would seem to point to either cement concrete or sheet asphalt as the logical type to use. It is less easy to understand why sheet asphalt, the more expensive of the two, has been chosen. The Characteristics Graph does not give a satisfactory answer to the question. We believe that it is because the concrete pavement has been, in a sense, the victim of circumstances. It has been laid late in the fall in several cases, and the damage resulting from frost has prejudiced many people against it. It is

our opinion that cement concrete could very profitably be used in replacing the old brick-on-sand pavements. After some years of use as a concrete pavement it could still be used as a base for sheet asphalt. The cost of the wearing surface of asphalt is not excessive. Nearly a mile of resurfacing with sheet asphalt over old brick pavement was done in Battle Creek, Michigan, in 1919, at an average cost of $1.53 per sq. yd., and the resulting pavement is a satisfaction both to the engineer and to the townspeople. It is needless to say, of course, that green concrete must not be allowed to freeze, as a failure under traffic is sure to be the result.

Another thing peculiar to Lansing's paving conditions is this: There seems to be no necessity of any underdrainage works at all. The leakage into the storm sewers and the seepage into the soil seem amply adequate to keep the water table well below the pavement. So long as this condition obtains it would be a waste of money to place tile drains under the curbs, since they are very liable to stoppage and breakage due to excavation for house connections for sewers and the like. Tile drains seldom function properly for more than a few years at the best, and when broken or plugged they are worse than useless because the water table near the break is often actually raised by the head of water in the drain.

As was stated in Section F, the present accepted type of pavement construction in Lansing is sheet asphalt. It is thought by the City Engineer to be cheaper than brick-on-concrete, and the advantages of smoothness, ease of maintenance, noiselessness, etc, as before enumerated, have helped to win it ascendency, (It should be said here that Mr. Kelley, the Battle Creek City Engineer, is of the opinion that brick-on-concrete and sheet asphalt would cost very nearly the same amounts per sq. yd. to lay at present. His estimates are: Brick $4.20, Asphalt $4.26).

We believe that sheet asphalt is the logical pavement for Lansing's requirements, but as a modification we would suggest the use of the foundation course of concrete alone as a pavement for several years before laying the asphalt wearing course. A pavement life of 7 to 10 years could thus be saved, the base would become well settled, and any heaving from frost or other causes could be compensated for in the thickness of asphalt wearing course. This plan would furnish a solution to one of the worst objections to concrete pavement, namely, difficulty of repair. The asphalt course would be supported exactly as well by concrete which was beginning to need repair as by new concrete, and the necessity of concrete repairs would be obviated. An objection to the plan might be claimed in the adjustment of manholes, catch-basins, and gutter lines to the concrete and asphalt grades. There are on the market at present adjustable

manhole covers of various types, and some cities (as Cleveland, for example) follow the practise of setting manhole covers in asphalt instead of in concrete, so that future adjustments may be more readily made. The use of horizontal discharge catch-basins might be advisable in connection with the plan.

It is not our purpose to work out a design for future pavements in this thesis, but in offering the above suggestion we are convinced that the details would not present any but readily solvable difficulties.

SAMPLE SPECIFICATIONS
FOR
SHEET ASPHALT PAVEMENTS
in the city of
SAGINAW, MICHIGAN.

Owing to the fact that the city of Lansing does its own paving work under the direction of the city engineer, no contracts are let and hence no printed specifications are to be had. The following specifications, for which we are indebted to Mr. Alfred Eckert, Assistant City Engineer of Saginaw, are for a pavement practically identical with that which is at present being laid in Lansing. We have expunged such passages as refer to the contractor specifically, and as they stand the specifications would be simply in the nature of instructions to the executive or foreman directly in charge of the work.

GENERAL SPECIFICATIONS

EXCAVATION AND GRADING.

The street shall be excavated and graded to lines given by the Engineer, which lines must be strictly followed, and according to the plan and cross-section on file in the Engineer's office, together with any drawings herein referred to, or hereafter made to show any details of the work, which are hereby made a part of these specifications. The roadway shall be excavated to the necessary depth below the surface of the completed pavement, as determined by the thickness of the pavement, and to the form shown on the plans and cross-section therefor. The sub-grade surface shall be smoothly graded and shaped to the form shown on the cross-section, trimming to be done with mattock and shovel, after which, if possible to operate it, the sub-grade will be rolled with a steam roller, weighing at least seven (7) tons, until the surface is made compact and smooth. Any depressions caused by rolling or teaming shall be filled with fine earth or gravel, and rolled or tamped in place; or the depressions may be filled with concrete at the ~~Contractor's~~ City's expense at the time of laying the foundation.

LAWN GRADING.

The lawn spaces between the curb line and sidewalk line, shall be excavated or filled with earth from the excavation as required, to conform to the lines and grades as given by the Engineer. The surface shall be graded to the satisfaction of the Engineer. This grading, excavating and filling will be understood as included in the price paid for excavation. Trees standing within the line of the improvement shall not be disturbed, marred or injured.

CROSSWALKS, ETC.

All stone, cement and brick crosswalks, flag-stones, curbstones, cobble stones and castings not required to be replaced, shall be carefully removed, and shall become the property of the City, ~~to be removed by the Contractor to without cost to the city except price paid for excavation.~~ All driveways, walks, bridges, carriage blocks, platforms, hitching posts obstructing the work shall be carefully removed, cared for and replaced in as good condition as found, ~~without cost to the City.~~

ENCUMBRANCES.

All such materials and encumbrances and all surplus excavation found on the work unless retained by the City or claimed by the adjoining property owners, shall be removed and disposed of by ~~the Contractor without expense to the City other than the price paid for excavation.~~ the City

ADJOINING PAVEMENTS.

In connecting with any brick, asphalt or other pavement, the ~~Contractor~~ City will be required to relay so much of the said pavement as is necessary, in the judgment of the Engineer, to join same with the new work, where the grades are the same, and the old pavements are in good condition. Where the new work joins concrete headers now in place, the same shall be trimmed down to the top of the concrete base and the space paved with new material. This work will be done without extra charge.

ADJUSTING MANHOLES, SEWER INLETS, ETC.

The ~~Contractor~~ City must take special care of all manholes and water valve covers, stop-boxes, gas pipe, water pipes, monuments or other public fixtures in the street, and will be held responsible for all damage or injury thereto. The ~~Contractor~~ City will be required to raise, remove, fill up or lower, as the case may require, to the proper grade and line, all manholes, sewer inlets and other fixtures on the line of the improvement. ~~He~~ It will be required to furnish all the necessary materials, of an approved quality, and perform such work with skilled workmen, to the satisfaction of the Engineer. No extra allowance will be made for this work, but it will be understood as included in the price paid for excavation.

EMBANKMENT.

If the earth excavation is not sufficient, or of suitable quality to fill all low places, the deficiencies shall be supplied by the ~~Contractor~~ City, ~~for which he will receive the price bid for embankment or filling.~~ All embankments shall be of good earth, satisfactory to the City Engineer. No perishable material will be used therein, and it will be measured in place by the Engineer, without allowance for shrinkage.

MEASUREMENTS.

The excavation of the roadway on unimproved streets shall be computed on the actual depth from the present contour of the street to the sub-grade surface of the pavement, as determined by the plan and cross-section therefor; the width shall be computed at two (2′) feet more than the width of the completed pavement. The excavation between the curb and sidewalk lines, and the excavation on old pavements and repaved streets, will be computed according to exact dimensions of the work actually done, or as may be specifically hereinafter provided. In measuring the width of the pavement laid, the width of street railway rails will be included therein; all other measurements will be of exact dimension of the work actually done.

PRICE PAID FOR EXCAVATION.

Includes the cost of removing the earth, including old pavements, crosswalks and other encumbrances in roadway, the filling of all low places in the street, the finishing of the sub-grade surface of the pavement, the grading of lawns and such other work as above required.

CATCH BASINS, MANHOLES, ETC.

The work under this head shall be started as soon as the grading is in shape to allow it, and must proceed expeditiously and be completed as soon as possible.

CATCH BASINS SHALL BE CONSTRUCTED.

Catch basins shall be constructed at the places shown on the plans or as located by the Engineer, in accordance with the details drawings on file in the office of the City Engineer. They are to be constructed of Portland cement concrete, of the quality specified herein.

CONCRETE.

The concrete shall be composed of one part cement to three (3) parts sand and five (5) parts stone. The sand shall consist of clean coarse particles, that will pass a sieve with holes one-quarter (¼") inch mesh. The stone shall consist of the best quality of hard limestone, gravel stone, or equally good stone retained by a sieve with mesh one-quarter (¼") inch square, and passing a screen with holes two (2") inches square. The sizes of the particles shall be so proportioned that those passing a sieve with three-quarter (¾") inch mesh will fill the voids of the portion retained by the same without more than ten (10%) percent excess. Six (6) parts of bank gravel may be used with one (1) part Portland cement when the gravel shows by test that it comes within ten (10%) percent of meeting the requirements specified for sand and gravel combined. All stones having their greatest diameter over two (2") inches shall be removed.

The cement shall meet the City's Standard Specifications for Portland cement.

Mixing shall preferably be done by the use of a batch mixer. Materials must be proportioned dry, and then deposited in the mixer all at the same time. The mixer must produce a concrete of uniform consistency and color with the stone thoroughly mixed with the water, sand and cement.

If hand mixing is used the sand and cement shall be thoroughly mixed dry, and then sufficient clean water shall be added to make a paste of proper consistency; the stone and gravel after being thoroughly drenched with water, shall then be added, and the whole mass quickly turned over with shovels, at least three (3) times, so that the stones shall be thoroughly mixed with the water, sand and cement. The mixing shall be done in a tight box or board floor.

The proportions of cement, sand and stone, may be varied by the Engineer, and when the same are fixed, such proportions shall be rigidly adhered to.

In placing the concrete the same shall be spread to fill the forms even full, and be at once thoroughly compacted by ramming, until free mortar appears on the surface. Special pains shall be taken in mixing, placing and tamping the concrete, that a uniform concrete may be secured, and that all surfaces of the structure shall be smooth and well filled. In conveying the concrete from the place of mixing to the place of deposit, the operation must be conducted in such a manner, that no mortar will be lost, and the concrete must be so handled that the same shall be of uniform consistency throughout, showing no excess or lack of mortar in any place.

Retempering, that is re-mixing with additional water, mortar or concrete that has partially hardened will not be permitted, and no concrete shall be used after it has begun to set.

No concrete shall be mixed while the air temperature is below 32 degrees F., and in no case shall any material containing frost be used; and if this temperature is reached, such methods as the Engineer may direct shall be used, to insure good construction and shall be done by the ~~Contractor~~ City ~~without cost to the City.~~

CENTERING AND FORMS.

All centering and forms are to be furnished by the ~~contractor~~ City and are to be made strictly according to the drawings furnished, and must be so constructed as not to yield under any pressure to which they may be subjected. Such forms shall preferably be of steel, collapsible type. No centering shall be re-

moved nor any backfilling done until the concrete has sufficiently set to prevent any injuries to the work. After the forms have been removed, all mortar and rubbish must be removed from the interior of all work, and all work left perfectly clean.

CHUTES.

Each basin shall be connected with the sewer by a chute of nine (9") inch pipe, with joints thoroughly cemented with mortar, consisting of one (1) part Portland cement to two (2) parts sand, and all pipes thoroughly cleaned as the work progresses. Basin chutes shall have the ends built firmly into the walls of the basin, manhole or sewer. The chute at the basin end shall be at the bottom of basin as shown on plan therefor, and shall be laid from sewer to basin before the connection is concreted into the basin. The pipe shall be laid true to line and grade in straight lines from end to end as far as possible, and when changes in the line or grade must be made they shall be made with the proper bends or Y branches. No underground work must be covered until the inspector has examined it and found it to be in proper condition. All old chutes, if used, shall be in good condition, and shall be relaid, as far as necessary, to secure proper drainage before connecting new basins to them. All pipes shall be cleaned of mortar and dirt as the work progresses. The trench must be kept free from water while the pipe is being laid, and until the mortar has set. Soft or insecure bottom must be made secure in such manner as the Engineer may direct before laying the pipe thereon.

BACKFILLING TRENCHES.

When backfilling trenches or excavations the earth shall be mixed with said one to one, and shall be tamped solid in uniform layers not exceeding six (6") inches in depth. Special care must be taken in ramming immediately around and over the sewer to make the filling as compact as possible, and at the same time, not to injure or disturb the masonry or pipe.

CASTINGS.

All castings will be furnished by the City along the line of work, and such castings shall be fully bedded in cement mortar and set to true line and grade.

Where a steam roller is used on the street any and all castings likely to be damaged during the process of rolling shall be removed and the masonry work covered with plank and fine gravel until the rolling is finished. ~~All castings that are broken during the time of construction of the improvement, shall be carefully removed and replaced by the Contractor at his own expense, including the cost of castings.~~

CASTINGS TO GRADE.

The ~~Contractor,~~ City shall at ~~his~~ its own expense, bring to the surface of the pavement all manholes, sewer, and other fixtures, and adjust any basin inlets along or adjoining his work, and shall connect old work with the new in a workmanlike manner to the satisfaction of the Engineer. Any castings found broken before commencement of work will be furnished and replaced by the City. Where sewers, water pipe or conduits are laid after the contract is awarded, the castings will be brought practically to grade, ~~after which time, the Contractor for this improvement shall consider and treat them as though in place previous to his taking the contract.~~

CHANGES IN MANHOLES.

The upper three (3) feet of such manholes shall be rebuilt when so directed by the Engineer ~~and the Contractor will be paid therefor at the price bid per foot.~~ Said work shall be done as provided hereinbefore under "Concrete," and as per detailed drawing.

ROLLING TRENCHES.

The backfilling and all excavation shall be brought above the sub-grade foundation, as directed, to permit compression by the steam roller, and more sand or earth shall be added as the filling settles. It shall afterwards be taken out, as is necessary, preparatory to laying the concrete foundation, ~~which extra excavation and work shall be included under the price bid for basins.~~

TILE DRAINS.

Tile shall be laid on each side of the street under the curb stone, when ordered. The tile shall be sewer pipe of such internal diameter as shown on the plan. Each pipe is to be laid on a firm bed and in conformity to lines and levels given by the Engineer. All irregularities in the trench shall be filled with suitable material to procure a solid foundation. When the ground does not present a sufficiently firm foundation for the pipe, the ~~Contractor~~ City shall excavate to such increased depth as may be necessary, filling to the required form and line, or such other course may be taken to secure a good foundation as the City Engineer may direct. The pipe shall be carefully laid so that the bottom of the inside of the pipe will conform to the true grade and line, and they shall be turned and placed so that there will be no shoulder or unevenness on the bottom of the inside of the pipe, and, after inspection, covered with clean, coarse gravel, or stone, and gravel with excelsior covering over joints only. Connections of the tile drain with manholes and basins shall be made in places where, and in the manner as directed by the Engineer.

~~The price bid for the drain includes the digging of the pipe trench, laying of pipe, and backfilling with stone and gravel.~~

DITCH DRAINS.

Six (6") inch sewer pipe drains shall be laid on each side of the intersecting streets, back of the curb, when ordered. The sewer pipe is to be laid on a firm bed three (3') feet below the grade of the curb; all pipe shall be carefully laid to conform to the true grade and line given by the Engineer. Connections of the tile drain with the catch basins shall be made in places where, and in a manner as directed by the Engineer. The ditch end of the tile drain shall be raised at the street line to the grade of the bottom of the ditch. All joints shall be thoroughly cemented with mortar, and the backfilling shall be done with fine earth, compactly rammed into place.

~~The price bid for six (6") inch ditch drains includes digging of pipe trench, laying of pipe and backfilling with earth.~~

STREET CAR TRACKS.

Where electric street railway tracks are in the street, the tracks, including switches, turn-outs, etc., will be rebuilt by the street railway company, and any excavation below the foundation of the pavement shall be done by the street railway company. The ties shall rest upon a continuous strip of concrete, and the rails, securely spiked thereto, placed to the proper grade and line, and the spaces under and between the ties filled with concrete, rammed and tamped solid to the proper height for the sub-foundation. All of said work to be done by street railway company. No cars will be permitted to run over the tracks until the concrete is thoroughly set, at least ten (10) days after it is put in place.

The street railway may complete the pavement included in the width of space to be paved by it, including all excavation, otherwise the ~~Contractor~~ City will be required to place concrete thereon and complete the pavement in the said space. Care must be taken to fit the pavement close against the head of the rails and to leave the surface to the exact height of the rails, the space below the head of the rails to be filled with Portland cement mortar and the surface material placed against it. If the street railway company lays only the concrete paving base in connection with the foundation for its track, the ~~Contractor~~ City will be required to furnish the necessary materials, and lay the wearing surface of the pavement, as required by the plans and specifications, between the rails, and one (1) foot each side, for the price bid for pavement in street car space, exclusive of concrete foundation; and if a T rail section is used, the ~~Contractor~~ City will provide and furnish a proper grooved block, providing for a flange way on the inner side of each rail, which will be understood as included in the cost paid square yard of the pavement in street car space.

OLD BASINS ABANDONED.

All basins to be abandoned shall be cleaned and filled with good material, thoroughly rammed in place. The iron castings, all sewer traps and upper two feet of basin shall be removed and the outlet shall be thoroughly sealed with brick and mortar or concrete. ~~This work shall be done by the Contractor without expense to the City, and it will be understood as included in price paid for new catch basins.~~

OLD BASINS REBUILT.

Where old basins can be used and adjusted to the lines and grades for the new improvement, the same shall be used. The upper part shall be rebuilt and adjusted and fitted with new castings in the same manner as provided under new basins. The old basins shall be thoroughly cleaned, and all brick work, where brick are crumbling or disintegrating shall be rebuilt with new brick of same quality. All joints of the brick work on the inner side shall be scraped, refilled, and repointed with mortar; the mortar to be used in brickwork. unless otherwise specified, shall consist of one (1) part of Portland cement and three (3) parts clean, sharp sand, screened through a one-eighth (⅛") inch mesh. The cement and sand shall be thoroughly mixed to a uniform color before wetting, and then brought to a uniform consistency. All traps and basin end of connections shall be relaid and readjusted as directed and such other incidental work shall be done as is required to be performed to make such basins a neat and workmanlike job satisfactory to the Engineer, and will be paid for at the price bid for rebuilding old basins.

CLEANING.

All basins shall be thoroughly cleaned and left in good condition on completion of the improvement.

PRICE PAID FOR NEW BASIN.

The price paid for new catch basins includes the digging of the pit for basin and the pipe trench, the laying of the pipe, the backfilling of the trench with sand, the placing of the castings, and the work of stripping and filling abandoned basins.

Specifications for Concrete Curb and Combined Curb and Gutter

EXCAVATION AND GRAVEL BASE.

The ~~Contractor~~ City shall excavate on each side of the proposed pavement a trench of sufficient depth that the curbstone can be set on six (6") inches of gravel and of such width as shown on detail plans therefor. The gravel shall be placed in the work, and thoroughly saturated with water before the curb is set, and the concrete curbstone placed thereon and the gravel thoroughly and compactly rammed around to firmly set and hold the curb to true line and grade. The curb, or combined curb and gutter shall be built to conform to the detail plans therefor.

FORMS.

The forms shall be smooth, free from warp and of sufficient strength to resist springing out of shape. Mortar and dirt shall be removed from forms that have been previously used. The forms shall be well staked and thoroughly braced and set to the established lines, their upper edge conforming to the grade of the finished curb. The work shall be blocked out in sections which shall not measure more than six (6) feet in length and not less than four (4) feet. The cross forms shall be of one-eighth (⅛") to one-quarter (¼") inch metal, as the Engineer may direct. The cross forms shall be of a depth to correspond to the depth of the proposed work, and shall extend the full width of the work. They shall be left in place until after the wearing surface has been floated. Wood forms shall be moistened before concrete is placed.

BASE CONCRETE.

The concrete shall be composed of one part cement to three (3) parts sand and five (5) parts stone. The sand shall consist of clean coarse particles, that will pass a sieve with holes one-quarter (¼") inch mesh. The stone shall consist of the best quality of hard limestone, gravel stone, or equally good stone retained by a sieve with mesh one-quarter (¼") inch square, and passing a screen with holes two (2") inches square. The sizes of the particles shall be so proportioned that those passing a sieve with three-quarter (¾") inch mesh will fill the voids of the portion retained by the same without more than ten (10%) percent excess. Six (6) parts of bank gravel may be used with one (1) part Portland cement when the gravel shows by test that it comes within ten (10%) percent of meeting the requirements specified for sand and gravel combined. All stones having their greatest diameter over two (2") inches shall be removed.

The cement shall meet the City's Standard Specifications for Portland cement.

Mixing shall preferably be done by the use of a batch mixer. Materials must be proportioned dry, and then deposited in the mixer all at the same time. The mixer must produce a concrete of uniform consistency and color with the stone thoroughly mixed with the water, sand and cement.

If hand mixing is used the sand and cement shall be thoroughly mixed dry, and then sufficient clean water shall be added to make a paste of proper consistency; the stone and gravel after being thoroughly drenched with water, shall then be added, and the whole mass quickly turned over with shovels, at least three (3) times, so that the stones shall be thoroughly mixed with the water, sand and cement. The mixing shall be done in a tight box or board floor.

The proportions of cement, sand and stone, may be varied by the Engineer, and when the same are fixed, such proportions shall be rigidly adhered to.

In placing the concrete the same shall be spread to fill the forms even full, and be at once thoroughly compacted by ramming, until free mortar appears on the surface. Special pains shall be taken in mixing, placing and tamping the concrete, that a uniform concrete may be secured, and that all surfaces of the structure shall be smooth and well filled. In conveying the concrete from the place of mixing to the

place of deposit, the operation must be conducted in such a manner, that no mortar will be lost, and the concrete must be so handled that the same shall be of uniform consistency throughout, showing no excess or lack of mortar in any place.

Retempering, that is re-mixing with additional water, mortar or concrete that has partially hardened will not be permitted, and no concrete shall be used after it has begun to set.

No concrete shall be mixed while the air temperature is below 32 degrees F., and in no case shall any material containing frost be used; and if this temperature is reached, such methods as the Engineer may direct shall be used, to insure good construction and shall be done by the ~~Contractor~~ City ~~without cost to the City.~~

FACING OR WEARING SURFACE.

The top, or wearing surface, shall be composed of one (1) part Portland cement and two (2) parts sand, mixed with sufficient water to produce a mortar of a consistency which will not require tamping and which can be easily spread into position with a straight edge.

The mortar for the facing shall be mixed in a mortar box, and spread in place immediately after mixing in such a manner as to thoroughly unite with the backing and must be put on before the latter has set. In no case shall more than thirty (30) minutes elapse between the mixing of the concrete for the base and the covering of the same with the wearing surface.

The facing or wearing surface of the curb shall be placed on the inside of the form as the body of the curb is being built up.

The face is understood to be all surface exposed to view in the completed work, as shown on the plan.

The thickness of the facing or wearing surface shall be three-quarter (¾") inches.

After the facing has been worked to an approximately true plane, the surface shall be troweled smooth and then lightly brushed. The application of neat cement to the surface in order to hasten hardening is prohibited. The section marking shall be made directly over the joint of the base, and shall be made with a tool which will cut entirely through and entirely separate the surfaces of adjacent sections.

PROTECTION.

When completed the work shall be kept moist for four (4) days and protected from traffic and the elements for at least ten (10) days.

BROKEN CORNERS.

Curb with broken corners or loose seams or damaged in any way will not be allowed in the work.

STREET CORNERS.

At street corners of paved streets the curb will be cast to a true circle of such radius as is shown on plan, except where there are corner basins, where it shall be fitted as directed by the City Engineer, and paid for at the same price per lineal foot as straight curb.

THE PRICE PAID.

The price paid per lineal foot for the concrete curb or combined curb and gutter, includes the furnishing of all materials (except the cement), the making of the necessary excavation below the sub-grade of the pavement to receive the curb, and the concrete used and all labor and material incident to the full completion of the curb.

RETAINING CURB OR HEADERS.

At street intersections where the paving joins an unimproved street or at such other places as the Engineer may direct, a concrete retaining curb or header shall be constructed in place six (6) by twelve (12) inches in size; the upper surface shall be troweled and shaped to conform to the crown of the pavement. When completed the ~~Contractor~~ City shall protect the same until it has thoroughly hardened.

CONCRETE BASE OR FOUNDATION.

Upon the sub-grade prepared as above specified, there shall be placed a six (6) inch concrete base or foundation proper, to be prepared as follows:

CEMENT.

The cement required in this work will be furnished by the City along the line of work, ~~without expense to the Contractor; the Contractor will be held responsible for all cement and cement sacks which are delivered to him by the City.~~

SAND.

The sand must be clean, coarse, sharp, bank sand, or fine gravel, entirely free from all foreign matter and uniformly graded, ranging in size from one-quarter (¼) inch down.

STONE.

The stone shall be the best quality hard lime stone, field boulders, gravel stone, or equal thereto in the judgment of the Commissioner of Public Works. Stone shall be free from all foreign matter, and properly graded, ranging in size from a quarter (¼) inch up to a size not to exceed two (2) inches.

NATURAL MIXED AGGREGATES.

Natural mixed aggregates shall not be used as they come from deposits, but shall be screened and remixed to agree with the proportions specified. (The remixing to be done on the job.)

CONCRETE.

The concrete base shall be composed of Portland cement, sand and stone, mixed in proportion of 1, 3 and 6; this proportion may be varied, the exact proportion to depend upon the size and character of the stone and sand furnished and will be determined by actual trial, and when the exact proportions are fixed, that proportion shall be rigidly followed.

MIXING.

A power driven batch concrete mixer shall be used. The materials must be proportioned dry, and then deposited in the mixer all at the same time. The mixer must produce a concrete of uniform consistency and color, with the stone thoroughly mixed and covered with the mortar.

CONSISTENCY.

The materials shall be mixed wet enough to produce a concrete of a consistency that will flush readily under light tamping but which can be handled without causing a separation of the coarse aggregate from the mortar.

Retempering, that is, remixing with additional water, mortar or concrete that has partially hardened, will not be permitted.

PLACING CONCRETE.

The concrete shall be deposited in a layer on the sub-grade in such quantities that, after being thoroughly tamped in place, it will be of the required inches in thickness, and the upper surface shall be true, uniform, parallel to and below the grade of the surface of the finished pavement.

In conveying the concrete from the place of mixing to the place of deposit, the operation must be conducted rapidly and in such a manner that no mortar will be lost and the concrete must be so handled that the foundation will be of uniform composition throughout, showing no excess nor lack of mortar in any place.

PROTECTION.

The concrete base or foundation shall be kept moist for not less than two (2) days, and when ordered by the Engineer, the ~~Contractor~~ City shall sprinkle the base between the hours of sunset and sunrise as often as may be deemed necessary. The concrete base shall be protected from traffic until the concrete has thoroughly set and attained sufficient strength for the purpose of laying the wearing surface upon it. In cold weather, or weather unsuitable for concrete work, the ~~Contractor~~ City shall suspend work when so notified by the Commissioner of Public Works. If work is permitted while the air temperature is below 35 degrees F., the ~~Contractor~~ City shall take such additional precautions as the City Engineer directs ~~without any additional expense to the City.~~

In no case shall any materials, containing frost or affected by the weather, be used. Any precaution which the City Engineer may consider necessary to avoid injury to the concrete shall be used by the ~~Contractor~~ City ~~without expense to the City.~~

All boards, templets, stakes, or other appliances, required in laying the concrete or in preparing the sub-foundation, shall be furnished by the ~~Contractor~~ City at ~~his~~ its expense.

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SPECIFICATIONS FOR SHEET ASPHALT PAVEMENT.

FOUNDATION.

Upon the concrete base as hereinbefore specified under specifications for the particular pavement, the wearing surface shall be laid.

SHEET ASPHALT SURFACE — REFINED ASPHALT.

Refined asphalt to be used for paving mixture herein required shall be derived in the following manner:

1. By heating, if requiring refinement, crude, natural, solid asphalt to a temperature of not over 450 degrees F., until all the water has been driven out. Crude, natural, solid asphalt shall be construed to mean any natural mineral bitumen, either pure or mixed with foreign matter, from which, through natural causes in the process of time, the light oils have been driven off until it has a consistency of harder than 100 penetration at 77 degrees F. At least 98½ per cent of the contained bitumen in the refined asphalt which is soluble in cold carbon disulphide, shall be soluble in cold carbon tetra chloride. In no case shall such asphalt be prepared at the refinery with any product not hereinafter provided for.

2. By the careful distillation of asphaltic petroleum ~~with continuous agitation~~ until the resulting bitumen has a consistency not harder than 30 penetration at 77 degrees F.

(a) All shipment of material shall be marked with a lot number and penetration, and ten samples taken at random from each lot shall not vary more than 15 per cent from the average penetration, providing no part of any shipment shall be below 30 penetration at 77 degrees F.

(b) The solid bitumen so obtained shall be soluble in cold carbon tetra chloride to the extent of 98½ per cent. If the solubility in cold carbon tetra chloride is less than ninety-nine (99) per cent the bitumen shall yield upon ignition not more than fifteen (15) per cent of fixed carbon; if the solubility is 99 per cent or more, the bitumen shall yield upon ignition not more than 18 per cent of fixed carbon.

(c) When 20 grams of material are heated for five hours at a temperature of 325 degrees F., in a tin box two and one-half (2½) inches in diameter after the manner officially prescribed, it shall not lose over five (5) per cent by weight, nor shall the penetration at 77 degrees F., after such heating, be less than one-half the original penetration.

(d) The solid bitumen, at a penetration of fifty (50) shall have a ductility of not less than ~~40~~ 60 centimeters, at 77 degrees F. If the penetration varies from 50, an increase of at least two (2) centimeters in ductility will be required for each five (5) points in penetration above 50, and a corresponding allowance will be made below 50 penetration. This test shall be made with a briquette or cross-section of one square centimeter, the material being elongated at the rate of 5 centimeters per minute (Dow moulds).

3. Refined asphalt produced by combining crude, natural asphalt with either of the following:

(a) Residuums obtained by the distillation of petroleum oils, as specified under fluxes.

(b) Asphalts obtained by the distillation of petroleum oils, as specified.

In the use of these mixtures of refined asphalts for asphaltic cement, only asphaltic or semi-asphaltic fluxes shall be used, except in those cases where the solid, natural asphalt is of such character that, when mixed with paraffine flux, without the addition of any other material, it will produce an asphaltic cement complying with the requirements set forth under that head. In such cases, any of the fluxes elsewhere specified may be used.

The preparation and refining of all asphalt admitted under these specifications shall be subject to such inspection at the paving plant and refineries as the City Engineer may direct.

FLUX.

The fluxing material may be of paraffine, a semi-asphaltic or an asphaltic residue, which may be tested with, and found suitable to the asphalt to be used.

The residuums must have a penetration of greater than 350 with a No. 2 needle at 77 degrees F., under 50 grams weight for one second. All residuums shall be soluble in cold carbon tetra chloride to the extent of 99 per cent, and must remain soft after heating for five hours at 400 degrees F.

(a) The paraffine residuum shall have a specific gravity of .92 to .94 at 77 degrees F.

It shall not flash below 350 degrees F., when tested in the New York State closed oil tester, and shall not volatilize more than 5 per cent of material when heated five hours at 325 degrees F., in a tin box 2½ inches in diameter, as officially prescribed. The residue, after heating, shall flow at 77 degrees F., and shall be homogeneous and shall show no coarse crystals.

(b) Semi-asphaltic residuum shall have the same general characteristics as paraffine residuum, except that it shall have a specific gravity of .94 to .98 at 77 degrees F.

(c) Asphaltic residuum shall have the same general characteristics as paraffine residuum, except that the specific gravity shall be not less than .98 nor more than 1.04 at 77 degrees F. The asphaltic residuum, after evaporation, at 500 degrees F., to a solid of 50 penetration, shall have a ductility of not less than 30 centimeters (Dow method).

ASPHALTIC CEMENT.

The asphaltic cement prepared from materials above designated, shall be made up from the refined asphalt, or asphalts, and the flux, where flux must be used, in such proportions as to produce an asphaltic cement of a suitable degree of penetration. The proportion of the refined asphalt comprising the cement, shall, in no case, be less than 40 per cent, by weight.

When the weight of flux in the asphaltic cement prepared from solid, natural asphalt exceeds 25 per cent thereof, asphaltic ~~cement~~ flux, or semi-asphaltic ~~cement~~ flux shall be used.

Refined asphalt and flux comprising the asphaltic cement shall, when required, be weighed separately in the presence of the authorized inspectors or agents of the City Engineer.

Refined asphalt and flux used in preparing the cement shall be melted together in a kettle at a temperature ranging from 250 degrees to not over 375 degrees F., and be thoroughly agitated, when hot, by air, steam or mechanical appliances, until the resulting cement has become thoroughly mixed into a homogeneous mass. The agitation must be continued during the entire period of preparing the mixture. Cement shall always be of uniform consistency, and if any portion should settle in the kettle between intervals of using the same, it must be thoroughly agitated before being drawn for use.

(a) The asphaltic cements shall have a penetration of from 40 to 85, which shall be varied between these limits to adapt it to the particular asphalt used in the paving mixture, and to the traffic and other conditions.

(b) When 20 grams of the asphaltic cement of the penetration to be used in the paving mixture shall be heated for five hours to a temperature of 325 degrees F., in an oven as officially specified, there must not volatilize more than five per cent of the bitumen present, nor shall the penetration at 77 degrees F., after such heating, be less than one-half of the original penetration.

(c) A briquette of the asphaltic cement, when at a penetration of 50, having a cross-section of one square centimeter, shall elongate to the extent of not less than 20 centimeters at 77 degrees F. If the asphaltic cement, as used in the paving mixture varies from 50 penetration, an increase of at least 2 centimeters in ductility will be required for each 5 points in penetration above 50, and a corresponding allowance will be made below 50 penetration (Dow moulds).

SAND.

The sand shall be hard grained and moderately sharp. It shall be so graded as to produce in the finished mixture, the mesh requirements elsewhere specified. It shall contain not to exceed ~~4~~ 5 per cent of sand that will pass a No. 200 mesh sieve.

BINDER STONE.

Stone to be used for asphaltic concrete binder shall be hard and durable, free from all foreign substances and of uniformly varying sizes. The largest passing a ¼-inch screen to the finest.

ASPHALTIC CONCRETE BINDER.

Asphaltic concrete binder shall be made as follows: The binder, stone and sand, as above specified, shall be heated to from ~~200~~ 250 to ~~325~~ 375 degrees F., in suitable appliances. Stone and sand shall be measured off separately, and then be mixed with sufficient asphaltic cement, prepared as heretofore specified, in such proportions that the resulting aggregate will contain, by weight, material passed through a No. 10 mesh screen, between 25 and 35 per cent, and bitumen in quantity from 5 to 8 per cent of the entire mixture. Binder thus prepared shall be a compact mass containing a minimum of voids.

NOTE.—Inasmuch as the percentage of bitumen in the binder will depend upon the grading of the aggregate, proportion of the materials used in the above may be varied by the City Engineer, but only within the limits designated.

LAYING ASPHALTIC CONCRETE BINDER.

The asphaltic concrete binder shall be brought to the work in ~~wagons~~ conveyances covered with canvas or other suitable material, and upon reaching the street, shall have a temperature of ~~300~~ 250 to 325 degrees F. It shall be placed upon the street and raked to a uniform surface, to such depth that, after being rolled and thoroughly compacted, it shall have an average thickness of one inch.

The surface after compression shall show at no place an excess of asphaltic cement, and any spot covering an area of one square foot or more, showing an excess of asphaltic cement, shall be cut out and replaced with other material. Smaller spots may be dried by the use of stone dust and smoothers. Any asphaltic concrete binder broken up during the process of laying, must be removed and replaced with new materials. No more binder shall be laid at any one time than can be covered by two days' run of the paving plant on surface mixture.

No binder shall be laid when in the opinion of the City Engineer the weather conditions are unsuitable or unless the base on which it is to be laid is thoroughly dry, clean and free from leaves and other foreign matter.

ASPHALTIC SURFACE MIXTURE OR WEARING COURSE.

The surface mixture shall consist of asphaltic cement, stone dust, and sand, proportioned by weight, so that the resulting mixture will contain average proportions of the whole mixture, as follows:

Bitumen, soluble in cold carbon disulphide	10	to	13.5	per cent
Stone dust passing a No. 200 sieve	10	to	15	"
Sand passing a No. 80 sieve	18	to	36	"
Sand passing a No. 40 sieve	20	to	50	"
Sand passing a No. 10 sieve	8	to	25	"
Sand passing a No. 4 sieve	up	to	10	"

The item designated (as stone dust passing a No. 200 sieve) within the limits herein named, includes in addition to the stone dust, fine sand passing a No. 200 sieve, not exceeding four and one-half (4½) per cent of the total mixture, and such 200 mesh mineral dust naturally self-contained in the refined asphalt.

Sand and asphaltic cement shall be heated separately to about 300 degrees F. The maximum temperature of the sand at the mixers shall in no case be in excess of 375 degrees F., and the maximum temperature of the asphaltic cement shall not exceed ~~325~~ 350 degrees F. at the discharge pipe. The stone dust shall be mixed with the hot sand, in the required proportions, and then these shall be mixed for at least one (1) minute with the asphaltic cement at the required temperature and in the proper proportions, and in a suitable apparatus so as to effect a thoroughly homogeneous mixture.

The proportion of asphaltic cement shall, at all times be determined by actual weighing with scales attached to the asphaltic cement bucket.

The stone dust and sand must also be weighed unless a method of gauging approved by the City Engineer shall be used.

The ~~Contractor~~ City shall furnish ~~every facility~~ all necessary equipment for the verification of ~~all scales or measures~~ the work.

The sand gradings and bitumen may be varied within the limits designated, in the discretion of the City Engineer.

LAYING THE WEARING SURFACE.

The asphaltic wearing surface shall be hauled to the work in ~~wagons~~ conveyances provided with a canvas or other suitable covering. As placed in the street, it shall have a ~~minimum~~ temperature of 250 to ~~300~~ 350 degrees F., as suitable for the asphalt used.

It shall be dumped at such distance from the work that all the mixture must be turned and distributed to the place where it is to be raked, and shall be spread while hot, to such depth upon the asphaltic concrete binder, which must be thoroughly dry, free from leaves or other foreign matter, that after receiving its ultimate compression by rolling, it shall have an average thickness of one and one-half (1½) inches.

Before the surface mixture is placed, all contact surfaces of curbs, manholes, etc., must be well painted with hot asphaltic cement. After raking, the surface mixture shall at once be compressed by rolling and tamping after which a small amount of cement shall be swept over it and it shall then be thoroughly compressed by a steam roller, weighing not less than ~~200~~ 250 pounds to the inch width of tread, the rolling being continued until a compression is obtained which is satisfactory to the City Engineer. Such portions of completed pavement as are defective in finish, compression or composition, or that do not comply in all respects with the requirements of these specifications, shall be taken up, removed and replaced with suitable material, properly laid, in accordance with these specifications, at the expense of the ~~Contractor~~ City. Whenever so ordered by the City Engineer, a space of twelve inches next to the curb shall be coated with hot asphaltic cement which shall be ironed into the pavement with hot smoothing irons.

No wearing surface shall be laid when in the opinion of the City Engineer the weather conditions are unsuitable, or unless the binder on which it is to be placed is dry. The finished pavement must be well protected from all traffic by suitable barricades until it is in proper condition for use.

NOTE.—All tests herein provided must be conducted according to official methods on file in the office of the City Engineer.

All penetration indicated herein, unless otherwise specified, refers to the depth of penetration in hundredths centimeters, of a No. 2 Standardized cambric needle, weighted with one hundred grams at 77 degrees F., acting for five seconds.

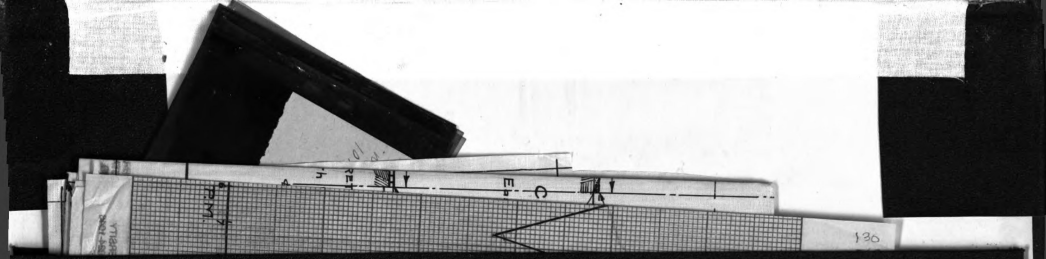
STANDARD METHODS FOR CARBON TETRA CHLORIDE TESTS.

Weigh off one (1) gram of material. Cover with 200 c.c. of carbon tetra chloride in Erlenmeyer flask, about four o'clock in the afternoon. Allow to stand overnight in dark cupboard. Next morning at ten o'clock, Gooch crucible with felt is weighed and solution poured therein. Wash with carbon tetra chloride; dry at 100 degrees Centigrade, and weigh.

Parlet has: no. 2 – no. 5
no 6 = 10 negatives

(no. 1 missing as of 5/24/2011)

[redacted]



CONTENTS OF THE POCKET

Not Here (1.) Map of the City of Lansing. *Missing as of 5/24/2011.*

(2.) Tracing. Curve Showing the Hourly Variation of Traffic.

(3.) Tracing. Curve Showing the Increase in Traffic.

(4.) Tracing. Cross Sections of Pavements.

(5.) Tracing. Curve Showing the Characteristics of Pavements.

(6.) Ten Photographic Negatives. (Clipped together)