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A STUDY OF BITUMINOUS EXPANSION
MATERIALS FOR CONCRETE PAVEMENTS

THESIS FOR THE DEGREE OF B. S.

K. W. Thompson

1930

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A Study of Bituminous Expansion Materials for
Concrete Pavements

A Thesis Submitted to
The Faculty of
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By

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I wish to express my appreciation in behalf of Mr. E. A. Finney for the fine cooperation and untiring effort on his part in helping me formulate and devise my work.

I also wish to express my appreciation to the officials of the W. R. Meadows, Inc., of the Philip Carey Co., of the Serviced Products Corporation, of the Johns - Manville Co., and of the Riker Lumber Co. of Lansing, Michigan, for their hearty cooperation in furnishing the material for my use. The literature which the three former companies sent me was also of valuable benefit.

A great deal of the success of this thesis has been due to the finest kind of cooperation from those named above.

OBJECT OF THIS THESIS

The object of this thesis may be divided into three parts:

1. To determine the percent of bitumen and fibrous material in each of the six samples which I have at hand. Also to determine the percent of organic and mineral matter in the fibrous material and to identify the bitumen.
2. To determine the amount of expansion of each sample after being compressed under various pressures.
3. To formulate a mastic compound consisting of asphalt and sawdust plus some sort of mineral matter such as sand, which would make a satisfactory expansion material with the desired resiliency and permeability.

SHORT HISTORY OF EXPANSION MATERIAL

For centuries concrete has been used in some form for the construction of huge engineering projects. Take for example, the early Roman roads. Although these roads were constructed of stone blocks, the blocks were bound together by a mortar consisting of hot lime and sand. It is true that today the word concrete does not designate a mixture of hot lime and sand, but such a mixture was a fore-runner of the present material which we call concrete and which is used extensively throughout the entire world.

In the construction of the early concrete pavements, there was little or no knowledge of the physical characteristics of the pavement after it had once been laid. Drainage was known to be an important factor, but the expansion and contraction of the material were factors which were not dealt with at first. Consequently, trouble arose in construction due to the cracking and heaving of the pavement resulting from the continual contraction and expansion. As a result, there was much costly construction which was ruined or made very unsightly and large financial losses were sustained.

Engineers began to realize that there had to be an insertion of some elastic material at certain intervals between the slabs in order to counteract the change in volume. A pavement laid without adequate provision for expansion and contraction was a waste of time as well as a waste of money.

The first material to be used for expansion material was wooden

boards. These boards were spaced transversely at short intervals along the roadway. In some measure this material was successful, but it lacked resiliency and permeability and due to decay was very short-lived. These defects were not the only factors which made the wooden material unfit for expansion joint purposes, but they were the principal ones. Since these characteristics, which were and are very essential to good expansion material, were lacking, wooden boards were rendered impractical.

The wooden material did not last long, however, because asphalt was found to be the logical material for expansion joint purposes, due to its ability to retain its elasticity under varying climatic conditions. After actual experiments had been made pure asphalt was found to be too soft in the summer and too hard and brittle in the winter. Due to the intense summer heat, the asphalt would melt and be forced out of the gaps, and be carried away by the traffic. When the contraction of the concrete occurred there was no material left to fill the gap. In winter the asphalt became brittle and was shattered and broken up by the shocks and impacts caused by the traffic. In both cases water and dirt settled in the gap and became an inert material. This caused considerable damage to the construction.

There is today, highly developed expansion materials which have resulted from the necessity to provide for the continual contraction and expansion which occurs in our modern concrete pavements. This material is not pure asphalt, but a mixture of fluxed asphalt and fibrous material.

The fibrous material acts as a binder and because of its inertness is not affected by temperature and moisture variations.

There are various companies throughout the United States that manufacture different types of material for expansion joint purposes. These companies have fully equipped laboratories which possess adequate research and development facilities. All of these companies extend the finest kind of cooperation toward research developments and are always willing to aid in any experiments conducted outside of their own premises.

WHY IS EXPANSION MATERIAL NECESSARY?

Expansion joints are placed in rigid pavements for three general purposes:

1. To prevent so-called blow-ups or heaving of pavement.
2. To control cracks.
3. To prevent spalling due to unrelieved compressive stresses.

Due to experiments conducted by various companies and experiment stations throughout the United States, it has been found that concrete expands or contracts .0000055 to .0000065 or an average of .000006 times its length in inches per degree change in temperature. The modulus of elasticity of concrete is taken as 3,000,000. On this basis the unit stress $= 3,000,000 \times .000006 = 18$ pounds per square inch. This means that one degree change in temperature is capable of producing a tensile or compressive stress of 18 pounds per square inch.

A good daily average temperature change may be taken as 10 degrees. $.000006 \times 10 \times 5280 \times 12 = 3.801$ inches per mile.

This is the amount of contraction or expansion which takes place due to a daily variation of 10 degrees in one mile of pavement.

A good annual average temperature change may be taken as 130 degrees.

$.000006 \times 130 \times 5280 \times 12 = 49.413$ inches per mile. This is the amount of contraction and expansion which takes place due to an annual variation of 130 degrees in one mile of pavement.

Maximum temperature stresses also vary over the cross-section of

the slab. The variation in temperature is 10 to 20 degrees. Only at short intervals in the morning and evening is the temperature constant throughout the cross-section of the slab. This variation would tend to expand the upper part of the cross-section of the slab when the lower part was contracting and vice-versa.

There are bending stresses which are set up due to traffic loads which may cause both tension and compression. These stresses are taken into consideration in the design of the pavement, but due to fatigue, impact, and excess traffic loads, additional bending stresses may take place.

Moisture and dryness are two more factors which bring about contraction and expansion of pavements. The general tendency among engineers is to disregard entirely the effect of moisture and its relation to the changes in volume of the concrete. Concrete expands when wet and contracts when dry, the amount of change varying with the proportions of the cement and its age. The greater the proportions of cement, the greater the change in volume due to moisture. The change in volume due to the variation in moisture content is equally as great as the change due to a variation from summer to winter temperature. Laboratory measurements have been made which indicate that under ideal conditions moisture can cause a change in length equivalent to that change caused by a variation in temperature of 109 degrees.

The statements made above are statements which are true in every detail. I have set forth four very important reasons for the use of ex-

pansion joint material. Proper provisions must be made to take care of the variations in volume if success is to be had in the construction of modern pavements.

TYPES OF EXPANSION JOINT MATERIAL

In general there are two different types of joints used in the construction of pavements; the premoulded joint and the poured joint. These joints consist of two materials as a basis; asphalt and tar. There are three advantages in using these materials; 1. Price; 2. General availability; 3. Ease of handling.

The premoulded joints are more popular among contractors due to the ease with which they can be installed and the lack of tools which are necessary in installing poured joints. These premoulded joints are used in two ways: as a joint which cuts the entire cross-section of the slab and as a dummy joint which cuts only a part of the cross-section. The joint which cuts the entire cross-section is used throughout the United States on all of the large high-ways. However, the dummy joint has proven satisfactory in various parts of the country.

For example, the city of Seattle has had unusual success in the use of dummy joints. The amount of cracks was decreased by 96% by their use and the durability and continuity of the concrete was also increased. The joint was constructed by means of making the gap with a two inch T-bar and filling it with the premoulded material only two inches deep. Each side of the joint was edged and finished.

The complete separation of adjacent slabs through joints is in marked contrast to conditions at the dummy joint. Even after cracking below the dummy joint, has occurred, the adjacent slabs are keyed and interlocked by the irregular nature of the crack, and any change in

surface elevation is common and mutual to the two abutting slabs. A slight change in direction may occur, but abrupt discontinuity in the surface is impossible.

There is a decided advantage in the use of dummy joints as compared with through joints, as I have shown above, provided there is no large variation in moisture content and temperature of the concrete. The joints are easily installed and are very economical. However, such joints would not be suitable in Michigan due to the large variation in temperature and moisture content.

The poured joints are constructed by means of first placing some sort of a form between adjacent slabs and then removing the form as soon as the concrete is set and pouring the joint material into the gap. There are various methods of making the gap. The most common methods are using a board slightly tapered and using a wedged shaped shell of steel which may be easily removed after the concrete becomes set by removing the wedges which keeps the shell spread apart. These are only two of the many methods which are used. The material used in the poured joints can be and is used for crack fillers also.

The one big advantage of the poured joint is that it has a tendency to cling to the concrete with which it comes in contact and this results in a much more stable expansion material. There is less chance of the material being separated from the concrete and the gap becoming filled with dirt and water.

Of the two types of joints, the poured and premoulded, the later is

used much more extensively than the former. However, I can see no reason why the poured joint cannot be used more in the future. The big item is an economical means of installing such a joint.

CHEMICAL ANALYSIS OF SIX SAMPLES OF EXPANSION MATERIAL

I had six samples of $\frac{1}{2}$ inch expansion material with which to work in making my analysis.

Approximately 100 grams of each sample were broken up and placed in individual beakers filled with 200 to 300 cc. of carbon disulphide, and left for 24 hours. Each sample was completely disintegrated as a result of the bitumen being dissolved by the carbon disulphide.

The fibrous material was removed by means of the centrifugal method. Each sample after being dissolved was placed in the iron bowl of the centrifugal extractor, properly called the "Rotorex". A round piece of felt paper was placed on the bowl with the center cut out to allow air to escape during the process after the cover had been fastened on by means of a milled nut. An empty beaker was placed at the spout before starting the machine. The machine was started and run slowly at first to allow for an even distribution of the fibrous material. The speed was then increased by means of the regulator until the dissolved bitumen was drained off.

When the first charge was drained off the motor was stopped and a fresh amount of carbon disulphide was added. This operation was repeated four to six times using 150cc. of disulphide with each addition.

When the last addition of disulphide had been drained off the cover and felt paper were removed and the fibrous material was removed from the bowl and felt paper to a metal container and placed in the hot air oven at 87 degrees C. for one hour. The material was placed in the

oven in order to remove any carbon disulphide present. The fibrous material was then weighed.

The dissolved bitumen was then placed in a distilling flask and distilled at a temperature of 45.5 degrees C., the heat being supplied by means of an electric light bulb. (Figure I shows the set-up of the distilling apparatus.) After all carbon disulphide had been distilled off the bitumen in the flask was heated by means of a gas flame and poured into a small metal container. In removing the bitumen it was found that all disulphide had not been thoroughly distilled off.

When the bitumen was heated, the intense heat caused a blue flame to appear and the bitumen showed the presence of gas due to the bubbling effect. There was also a strong odor of burning disulphide.

The metal containers containing the bitumen were then placed in the hot air oven at a temperature of 87 degrees C. for 18 hours to remove all disulphide. This proved very satisfactory. The removal of all disulphide was absolutely necessary because of the specific gravity of the bitumen. I made a specific gravity test on one sample before the bitumen was placed in the hot air oven and after it had been heated for 18 hours and I found there was a slight variation in the two specific gravities.

At the end of the 18 hour heating period the bitumen was taken from the oven and each sample was heated to a temperature of 300 degrees C. and thoroughly mixed and then allowed to cool. The specific gravity was then determined.

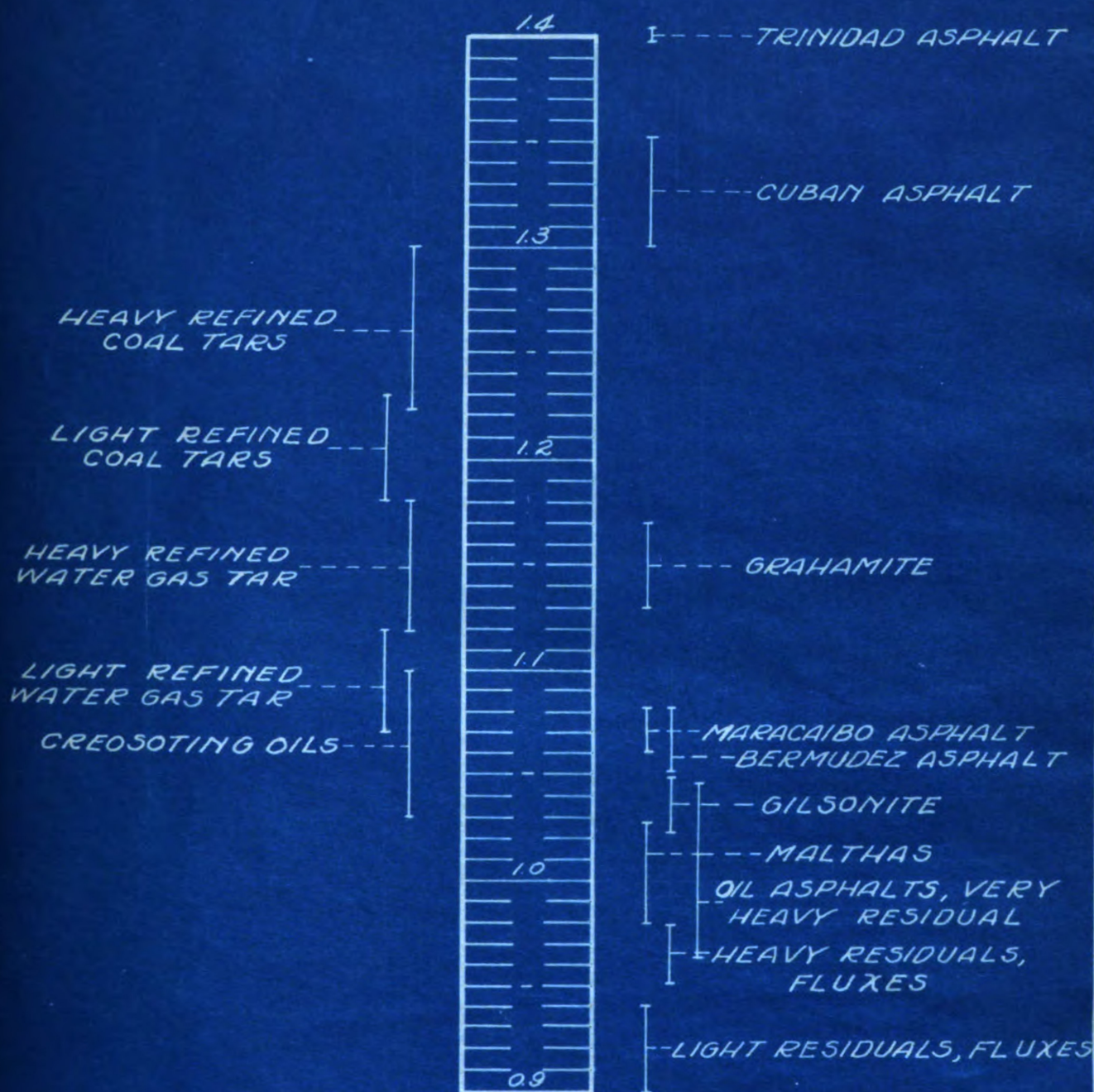
The specific gravity of four of the samples was determined by means of the displacement method. A small specimen of the bitumen was suspended by means of a waxed string from the end of the balance and the weight recorded. This weight was called "a". The specimen was then weighed completely immersed in pure distilled water at 25 degrees C., adhering air bubbles being first removed by means of a wire. This weight was called "b". The specific gravity was determined from the formula:-

$$\text{Specific Gravity} = \frac{a}{a - b}$$

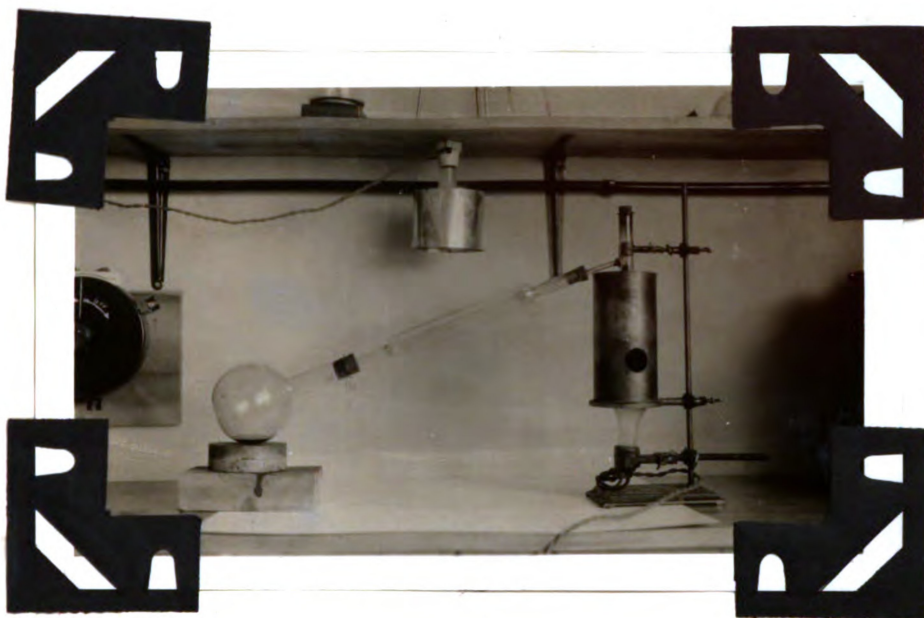
The specific gravity of the last two samples of bitumen was determined by means of the alternate displacement method. A small crucible was weighed suspended from the beam of the balance by means of a waxed thread. This weight was called "a". The crucible was then weighed in pure distilled water at 25 degrees C. This weight was called "b". The crucible was thoroughly dried in the hot air oven and then filled with several grams of the material under examination. The weight of both the bitumen and the crucible was called "c". The crucible and bitumen were then placed in a water bath at 25 degrees C. for one-half hour and then weighed in pure distilled water at the same temperature. This weight was called "d". The specific gravity was determined from the formula:-

$$\text{Specific Gravity} = \frac{c - a}{(c - a) - (d - b)}$$

After finding the specific gravities of the six samples of bitumen, each sample was identified by means of the chart shown on the next page.



SPECIFIC GRAVITY OF BITUMINOUS MATERIALS



SETUP OF DISTILLING APPARATUS



MINERAL MATTER IN THE FIBROUS MATERIAL - From left to
right:- TYPE "B", HOOSIER FIBROUS, MEADOWS FIBROUS, "WEBBED", JOHNS - MAN-
VILLE FIBROUS, and "FELT SIDE"

All samples of bitumen were found to be some grade of asphalt.

After weighing the fibrous material it was placed in shallow pans and heated over a gas flame to a red heat. At the same time a flame was applied directly to the material. This process was continued until there were no incandescent particles remaining. The resulting ash was then weighed, this ash being the mineral matter.

The following is a sample computation for the analysis using the $\frac{1}{2}$ inch type "B" Servicised joint:-

Wt. of sample - - - - -	100.00 g.
Wt. of fibrous material - - - - -	21.84 g.
Percent of fibrous material - - - - -	$\frac{21.84}{100} = 21.84 \%$
Percent of bitumen - - - - -	$100 - 21.84 = 78.16 \%$
Wt. of mineral matter - - - - -	12.69 g.
Percent of mineral matter in fibrous material - - - - -	$\frac{12.69}{21.84} = 58.10 \%$
Percent of organic matter in fibrous material - - - - -	$100 - 58.10 = 41.90 \%$

Specific gravity:-

Wt. of specimen in air - - - - -	3.7420 g.
Wt. of specimen in water - - - - -	0.0920 g.
Difference in wt. - - - - -	3.6500 g.
Specific gravity = $\frac{3.7420}{3.6500}$ =	1.025

Record of analysis:-

- $\frac{1}{2}$ inch type "B" joint manufactured by the Servicised Products Corp.;

Wt. of sample - - - - -	100.00 g.
Wt. of fibrous material - - - - -	21.84 g.

Wt. of bitumen - - - - - 78.16 g.
 Percent of bitumen - - - - - 78.16 %
 Percent of fibrous material - - - - - 21.84 %
 Wt. of mineral matter in fibrous material - - - - - 12.69 g.
 Wt. of organic matter in fibrous material - - - - - 9.15 g.
 Percent of organic matter in fibrous material - - - 41.90 %
 Percent of mineral matter in fibrous material - - - 58.10 %
 Specific gravity of bitumen - - - - - 1.025
 Identification - - - - - oil asphalt or malthas.

2. $\frac{1}{8}$ inch "webbed" joint manufactured by the Servicised Products Corp.;

Wt. of sample - - - - - 91.76 g.
 Wt. of fibrous material - - - - - 22.10 g.
 Wt. of bitumen - - - - - 69.60 g.
 Percent of bitumen - - - - - 76.83 %
 Percent of fibrous material - - - - - 23.12 %
 Wt. of mineral matter in fibrous material - - - - - 11.41 g.
 Wt. of organic matter in fibrous material - - - - - 10.69 g.
 Percent of organic matter in fibrous material - - - -48.39 %
 Percent of mineral matter in fibrous material - - - 51.61 %
 Specific gravity of bitumen - - - - - 0.981
 Identification - - - - - oil asphalt.

3. $\frac{1}{8}$ inch "felt side" joint manufactured by the W. R. Meadows, Inc.;

Wt. of sample - - - - - 100.00 g.
 Wt. of fibrous material - - - - - 24.91 g.

Wt. of bitumen - - - - - 75.09 g.
 Percent of bitumen - - - - - 75.09 %
 Percent of fibrous material - - - - - 24.91 %
 Wt. of mineral matter in fibrous material - - - - 14.83 g.
 Wt. of organic matter in fibrous material - - - - 10.08 g.
 Percent of organic matter in fibrous material - - - 40.47 %
 Percent of mineral matter in fibrous material - - - 59.53 %
 Specific gravity of bitumen - - - - - 1.004
 Identification - - - - - oil asphalt.

4. $\frac{1}{2}$ inch fibrous joint manufactured by the Hoosier Co.;

Wt. of sample - - - - - 100.00 g.
 Wt. of fibrous material - - - - - 22.59 g.
 Wt. of bitumen - - - - - 77.41 g.
 Percent of bitumen - - - - - 77.41 %
 Percent of fibrous material - - - - - 22.59 %
 Wt. of mineral matter in fibrous material - - - - 6.99 g.
 Wt. of organic matter in fibrous material - - - - 15.60 g.
 Percent of organic matter in fibrous material - - - 69.06 %
 Percent of mineral matter in fibrous material - - - 30.94 %
 Specific gravity of bitumen - - - - - 0.970
 Identification - - - - - oil asphalt or fluxed heavy residual.

5. $\frac{1}{2}$ inch fibrous joint manufactured by the W. R. Meadows, Inc.;

Wt. of sample - - - - - 100.00 g.
 Wt. of fibrous material - - - - - 27.23 g.

4. The fourth part of the document discusses the implications of the findings. It suggests that the results have significant implications for the field of study and may lead to further research in this area.

5. The fifth part of the document concludes the study. It summarizes the key findings and provides a final statement on the importance of the research.

6. The sixth part of the document provides a detailed description of the experimental setup. It includes a list of the equipment used and a description of the procedures followed during the experiment.

7. The seventh part of the document discusses the limitations of the study. It acknowledges that there are certain factors that may have influenced the results and that further research is needed to confirm the findings.

8. The eighth part of the document provides a list of references. It includes a list of the books, articles, and other sources used in the study.

9. The ninth part of the document provides a list of appendices. It includes a list of the additional materials that are included in the document.

10. The tenth part of the document provides a list of figures. It includes a list of the graphs and tables that are included in the document.

11. The eleventh part of the document provides a list of tables. It includes a list of the tables that are included in the document.

12. The twelfth part of the document provides a list of figures. It includes a list of the graphs and tables that are included in the document.

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15. The fifteenth part of the document provides a list of tables. It includes a list of the tables that are included in the document.

Wt. of bitumen - - - - - 72.77 g.
 Percent of bitumen - - - - - 72.77 %
 Percent of fibrous material - - - - - 27.23 %
 Wt. of mineral matter in fibrous material - - - - - 15.67 g.
 Wt. of organic matter in fibrous material - - - - - 13.56 g.
 Percent of organic matter in fibrous material - - - - - 49.78 %
 Percent of mineral matter in fibrous material - - - - - 50.22 %
 Specific gravity of bitumen - - - - - 1.015
 Identification - - - - - malthas or oil asphalt.

6. $\frac{1}{2}$ inch rubber fibrous joint manufactured by the Johns - Manville Co.;

Wt. of sample - - - - - 98.00 g.
 Wt. of fibrous material - - - - - 50.36 g.
 Wt. of bitumen - - - - - 47.63 g.
 Percent of bitumen - - - - - 48.61 %
 Percent of fibrous material - - - - - 51.39 %
 Wt. of mineral matter in fibrous material - - - - - 25.66 g.
 Wt. of organic matter in fibrous material - - - - - 23.70 g.
 Percent of organic matter in fibrous material - - - - - 47.06 %
 Percent of mineral matter in fibrous material - - - - - 52.94 %
 Specific gravity of bitumen - - - - - 1.038
 Identification - - - - - malthas or oil asphalt.

The following photos show the fibrous or binding material after the bitumen has been removed. The material was divided into three groups. On the outside is shown the thick fibrous material. Next is shown the fine stone. The third group consists of sand passing a number 30 sieve.

These photos show very clearly the proportions of the three groups of material for each sample of expansion material.



LEFT - TYPE "B" RIGHT - MEADOWS FIBROUS



LEFT - JOHNS-MANVILLE FIBROUS RIGHT - "WEBBED"



LEFT - "FELT SIDE" RIGHT - HOOSIER FIBROUS

EXPERIMENTS ON CONTRACTION AND EXTENSION

I had six different samples of $\frac{1}{2}$ inch expansion joint material with which to conduct my tests. There were three samples which were of the "sandwich joint" type, that is the bituminous and fibrous materials were contained between two felt sides. The other three samples were made up of the same material throughout and had no felt sides.

Each sample was cut to a 5" X 4" size before being tested.

At first one sample was placed between two six inch concrete cylinders about two inches thick and compressed in a hand operated machine but the compression was not uniform and could not be accurately measured. Two steel plates $\frac{5}{8}$ inch thick and 9 inches in diameter were then used instead of the concrete cylinders.

The sample to be tested was placed between the two plates and compressed in the hand operated machine. The first compression was only 4,000 pounds. As soon as the specimen had been compressed, it was removed from the machine and its thickness measured. The measurement was made by placing two steel straight edges on each side of the sample and measuring the distance between the two straight edges with a steel scale calibrated to .01 of an inch. The straight edges were extended over the entire length of the sample and held firmly to it. Four measurements were made on the four edges respectively and an average taken as the final result.

Each of the six samples was compressed in this manner. As soon as all samples had been compressed they were allowed to remain undisturbed for 24 hours. At the end of the 24 hours, each sample was measured as I have

have described before. This thickness subtracted from the first thickness represented the amount of expansion.

Each sample was then compressed under a pressure of 8,000 pounds and the contraction measured, the amount being the total contraction due to both the 4,000 pounds and 8,000 pounds pressure minus the amount of expansion resulting from the 24 hour rest period. The same sample of each commercial type was used throughout the entire test in order to make the test fit the practical use of the material. That is the same piece of material when used in practice is not compressed once under only one pressure, but it is compressed a number of times under varying pressures. So it is that the test was made with only one specimen of each type.

The compression test was carried on in the manner described using 12,000 pounds, 16,000 pounds, and 20,000 pounds pressure respectively. After each compression, each sample was allowed to remain undisturbed for 24 hours with one exception. After the 12,000 pound compression, each sample remained undisturbed for 72 hours. All of these tests were carried on under a temperature varying from 80 degrees F. to 81 degrees F.

The following results were obtained:-

I. Type "B" joint - fibrous joint;

Pressure	Total Contraction	Expansion
4,000 lbs.	.015"	.015"
8,000 lbs.	.030"	.018"
12,000 lbs.	.087"	.027"
16,000 lbs.	.105"	.021"
20,000 lbs.	.151"	.018"

2. Hoosier joint - fibrous joint;

Pressure	Total Contraction	Expansion
4,000 lbs.	.010"	.010"
8,000 lbs.	.020"	.006"
12,000 lbs.	.062"	.016"
16,000 lbs.	.107"	.006"
20,000 lbs.	.148"	.017"

3. Meadows' joint - fibrous joint;

Pressure	Total Contraction	Expansion
4,000 lbs.	.010"	.010"
8,000 lbs.	.050"	.030"
12,000 lbs.	.129"	.020"
16,000 lbs.	.157"	.022"
20,000 lbs.	.190"	.014"

4. "Felt side" joint - felt side joint;

Pressure	Total Contraction	Expansion
4,000 lbs.	.025"	.015"
8,000 lbs.	.051"	.022"
12,000 lbs.	.140"	.018"
16,000 lbs.	.176"	.021"
20,000 lbs.	.209"	.009"

5. "Webbed" joint - felt side joint

Pressure	Total Contraction	Expansion
4,000 lbs.	.020"	.010"

8,000 lbs.	.076"	.005"
12,000 lbs.	.144"	.027"
16,000 lbs.	.193"	.013"
20,000 lbs.	.223"	.009"

6. "Elastite" joint - felt side joint - manufactured by the Philip Carey Co.;

Pressure	Total Contraction	Expansion
4,000 lbs.	.005"	.005"
8,000 lbs.	.050"	.015"
12,000 lbs.	.104"	.024"
16,000 lbs.	.189"	.013"
20,000 lbs.	.226"	.017"

There were several very interesting results noted from the compression tests.

In the first place it was found that there is practically no expansion to the commercial joints after once being compressed sufficiently to change their shapes. The greatest amount of expansion at any time during the tests was only .03 of an inch. This is a very small amount in comparison to the amount of contraction of a slab due to a falling temperature or large decrease in moisture content. For example if a pavement had expansion joints placed every 25 feet there would be 211 joints to the mile. $211 \times .03" = 6.33"$ of expansion of the joint material which would be insufficient to take care of the contraction of the slabs of the pavement. Of course the continual traffic would help to push the joint material

back into the gap after it had once been forced out due to the expansion of the two adjacent slabs, but the joint would lose its efficiency because there would be space between the lower part of the cross section of each of the adjacent slabs and the joint material. In case of water and frost considerable damage might result from this situation.

In recording the pressures it was found that the material would fatigue when being compressed. It was impossible to keep a constant pressure. As a result all readings had to be taken for an instantaneous pressure. When the pressure was applied to the material, it was constant for only an instant and then steadily decreased. In this case there would be no constant pressure on expansion material between two adjacent slabs.

In the case where the specimens were left undisturbed for 72 hours instead of 24 hours there was no appreciable difference in the amount of expansion for the two periods. Under an approximately constant temperature, the expansion of the joint material reached a maximum during the first 24 hour period.

The three felt side or "sandwich" joints were less resistant to pressure and more easily compressed. The bituminous and fibrous material within the felt sides was squeezed out when compression took place. This is a disadvantage from a practical viewpoint when this condition occurs in a concrete pavement, the bituminous and fibrous material would be forced above the surface of the slab. The wheels of traffic would then carry the material away and leave an insufficient amount to fill the gap

in case of contraction.

The fibrous joints seem to be the best type of joint for practical purposes. This type is one which holds its shape much better and does not squeeze out like the "sandwich" joint. This type is also more resistant to compression and binds itself more easily to the cross section of the slab. The binding quality was demonstrated by the way in which the fibrous joints adhered to the steel plates when compression took place. For the reasons stated above fibrous joints should prove more satisfactory than the so-called "sandwich" joints.

A MASTIC EXPANSION MATERIAL CONSISTING OF ASPHALT,
SAWDUST, SAND, AND SILICA DUST.

There has been little use made of sawdust as a filler or binder in expansion joint material. The only record which I have found concerning its use was in Los Angeles on the Los Angeles harbor truck boulevard. Gaps were made every 200 feet by means of a tapered steel header 1 inch at the top and $\frac{3}{4}$ of an inch at the bottom. The proportions of asphalt and sawdust were 3 : 1 by weight. This proportion represented the maximum amount of sawdust that the asphalt would absorb. The sawdust was also absolutely dry when mixed with the asphalt to avoid steam in the kettles and the exploding of the asphalt.

Sawdust is a rather elastic material due to the peculiar shapes of the various individual particles. If you take a handful of the material and squeeze it in your fist and then open your hand, the expansion is very noticeable. Another test which will show its elasticity is to compress the sawdust after it has been placed in a container. Immediately after the pressure is relieved, the surface of the material will rise.

Before making any use of the sawdust, the bitumen was given several standard tests.

The first test was the specific gravity test by the displacement method as I have described before. The specific gravity was found to be 1.025.

The next test was the penetration test. The asphalt was heated and a sufficient amount was placed in a small metal box and allowed to cool at

room temperature. The sample was then placed in a water bath at 25 degrees C. for one hour. The apparatus used was the one recommended by the A. S. T. M. Standard Method. At the end of the hour period the sample was placed in the transfer dish and completely immersed in water and kept at a constant temperature of 25 degrees C. The needle was loaded with 100 grams and the point made to come in contact with the bitumen. The adjustment of the shaft holding the needle was made so that the reading was zero. The needle was released for 5 seconds and the amount of penetration was recorded. This process was continued until eight readings had been recorded, always keeping the sample at a constant temperature. An average of these eight readings was taken as the true penetration at 25 degrees C.

Record of penetration test;

Test	Penetration
1	49.0
2	46.4
3	47.5
4	50.0
5	46.8
6	49.2
7	<u>48.0</u>
	346.9

$$\text{Average} = \frac{346.9}{7} = 49.5$$

The flash and fire points were next determined by means of the open cup. Standard apparatus was used. The asphalt was heated and placed in

the cup until the meniscus was exactly at the fine line on the inside. A gas flame was placed under the cup and the asphalt was heated at the rate of about 10 degrees F. per minute. At the same time a gas flame protruding from a 1/16 inch orifice was passed back and forth over the surface of the bitumen about $\frac{1}{2}$ inch above it and perpendicular to the diameter of the cup. The time for the passage was about one second. The flash point was found to be approximately 545 degrees F. and the fire point was found to be 606 degrees F. The flash point was the temperature taken when a true flash appeared on the surface of the bitumen. The fire point was the temperature taken when the asphalt ignited and continued to burn for at least 5 seconds.

The last test was the ductility test. The asphalt was heated to a temperature of 170 degrees C. and mixed thoroughly and then poured into the briquette moulds. The moulds were allowed to cool at room temperature. After cooling they were placed in a water bath at 25 degrees C. for one half hour. At the end of this period the moulds were smoothed off by means of a heated spatula. They were then placed in the water bath for one and one-half hours. The moulds were taken from the water bath and the plate and side pieces removed so that each briquette could be placed in the ductility machine, by means of the two remaining clips. The clips were pulled apart at a uniform rate of 5 cm. per minute. During the test the water in the tank of the machine was kept at a constant temperature of 25 degrees C. The reading was recorded when each specimen broke and an average figure was taken for the two highest readings.

Record of ductility test;

Test	Ductility
1	21
2	27
3	<u>29.5</u>
	56.5

$$\text{Average} = \frac{56.5}{2} = 28.25$$

The first three samples of mastic material which were made, consisted of 25 percent, 20 percent, and 15 percent, respectively, of sawdust. The percentage was based on weight. 25 percent of the sawdust was approximately the maximum amount that the asphalt would absorb.

The asphalt was heated to a temperature of 200 degrees C. and mixed thoroughly. The proper amount was then placed in another metal container and the sawdust was added. The mixture was continually stirred as the sawdust was added, and continued to be stirred until the asphalt and sawdust were thoroughly mixed. The mixture was then heated to 140 degrees C. if necessary and placed in a wooden mould.

The wooden mould consisted of a flat piece of board as a base upon which were fastened 4 - $\frac{1}{2}$ inch strips forming a square 5 inches on a side and $\frac{1}{2}$ inch deep. A square piece of fairly heavy paper, 5" X 5", was placed on the base of the mould before the material was placed in it to keep the bitumen from sticking to the wood.

After the mixture had been placed in the mould it was compressed and the surface was smoothed off by means of a heated hand trowel. The edges were cut loose from the $\frac{1}{2}$ inch strips by means of the heated point

of the trowel. The casted material was then removed from the mould and allowed to cool at room temperature.

The next four samples consisted of 20 percent of sawdust and 5 percent of silica dust, 15 percent of sawdust and 5 percent of silica dust, 20 percent of sawdust and 10 percent of silica dust, and 15 percent of sawdust and 10 percent of silica dust, respectively. In making up these samples the silica dust was added to the heated bitumen before the sawdust.

The last two samples consisted of 20 percent of sawdust and 10 percent of sand and 15 percent of sawdust and 10 percent of sand. The sand used was that which passed a number 10 sieve.

In making these nine samples the sawdust, silica dust, and sand were absolutely dry when added to the asphalt to avoid any exploding of the bitumen.

After all of the samples had stood for 24 hours or more they were weighed and placed in a water bath for 24 hours. The water was kept at a constant temperature of 25 degrees C. At the end of the 24 hour period the samples were removed from the bath and the excess water was removed from the sides of each sample. Each sample was then weighed and the amount of water absorbed was computed by subtracting the first weight from the second weight, just found. This difference divided by the second weight was the amount of moisture absorption.

Record of moisture absorption test;

I. 25 percent of sawdust:-

Wt. of sample and absorbed water - - - - - 211.95 g.

Wt. of sample - - - - - 205.85 g.

Difference in wt. - - - - - 6.00 g.

Percent of moisture absorption = $\frac{6.00}{211.85} = 2.83 \%$

2. 20 percent of sawdust:-

Wt. of sample and absorbed water - - - - - 203.90 g.

Wt. of sample - - - - - 200.45 g.

Difference in wt. - - - - - 3.45 g.

Percent of moisture absorption = $\frac{3.45}{203.90} = 1.70 \%$

3. 15 percent of sawdust:-

Wt. of sample and absorbed water - - - - - 190.38 g.

Wt. of sample - - - - - 189.00 g.

Difference in wt. - - - - - 1.38 g.

Percent of moisture absorption = $\frac{1.38}{190.38} = 0.73 \%$

4. 20 percent of sawdust and 5 percent of silica dust:-

Wt. of sample and absorbed water - - - - - 209.01 g.

Wt. of sample - - - - - 199.00 g.

Difference in wt. - - - - - 3.51 g.

Percent of moisture absorption = $\frac{3.51}{209.01} = 1.68 \%$

5. 15 percent of sawdust and 5 percent of silica dust:-

Wt. of sample and absorbed water - - - - - 178.00 g.

Wt. of sample - - - - - 176.50 g.

Difference in wt. - - - - - 1.50 g.

Percent of moisture absorption = $\frac{1.50}{178.00} = 0.84 \%$

6. 20 percent of sawdust and 10 percent of silica dust:-

Wt. of sample and absorbed water - - - - - 212.48 g.

Wt. of sample - - - - - 208.65 g.

Difference in wt. - - - - - 3.83 g.

Percent of moisture absorption = $\frac{3.83}{212.48} = 1.79 \%$

7. 15 percent of sawdust and 10 percent of silica dust:-

Wt. of sample and absorbed water - - - - - 199.70 g.

Wt. of sample - - - - - 198.16 g.

Difference in wt. - - - - - 1.54 g.

Percent of moisture absorption = $\frac{1.54}{199.70} = 0.77 \%$

8. 20 percent of sawdust and 10 percent of sand :-

Wt. of sample and absorbed water - - - - - 225.60 g.

Wt. of sample - - - - - 221.59 g.

Difference in wt. - - - - - 4.01 g.

Percent of moisture absorption = $\frac{4.01}{225.60} = 1.78 \%$

9. 15 percent of sawdust and 10 percent of sand:-

Wt. of sample and absorbed water - - - - - 224.92 g.

Wt. of sample - - - - - 223.80 g.

Difference in wt. - - - - - 1.12 g.

Percent of moisture absorption = $\frac{1.12}{224.92} = 0.49 \%$

After the samples had been weighed the second time, they were allowed to stand under room temperature for 48 hours in order to evaporate all moisture. At the end of this period each sample was given one compression test and allowed to expand for 24 hours. The temperature varied

from 80 degrees F. to 82 degrees F. during this test.

Record of compression test:-

Sample	Pressure	Contraction	Expansion
No. 1	20,000 lbs.	.114"	.019"
No. 2	25,000 lbs.	.198"	.024"
No. 3	20,000 lbs.	.101"	.020"
No. 4	20,000 lbs.	.121"	.019"
No. 5	20,000 lbs.	.104"	.023"
No. 6	18,000 lbs.	.093"	.016"
No. 7	20,000 lbs.	.105"	.015"
No. 8	22,000 lbs.	.144"	.016"
No. 9	20,000 lbs.	.121"	.016"

The last test to be made was a tensile test to determine the binding quality of the mastic material to the concrete.

Two 6 inch concrete cylinders about 8 inches high were bound together by means of the mastic material. The material used consisted of 20 percent sawdust and 10 percent sand. The material after being mixed was heated to 140 degrees C. and placed on the end of the cylinder. The second cylinder was then placed on the first and pressed down firmly. After the mastic material had set for 24 hours the combination was suspended from a supported steel bar by means of a wire wrapped around the top cylinder. Weights were suspended from the lower cylinder until the cylinders were pulled apart. The weight necessary to pull the cylinders apart was found to be 89 pounds. However, very little of the material stuck

to the end of the cylinder which was pulled loose.

CONCLUSION

Asphalt may be classed as an elastic material, but the tests which I have run demonstrate that there is very little elasticity to it when used in expansion joint material. Both the commercial joints and the joints which I made showed very little expansion after once being compressed.

However, there is an advantage in using the mastic material which I have made. If anyone of the nine samples were used as a joint material, the material would bind itself to the concrete and would expand and contract along with the slab due to this binding quality. This seems to be the only way in which bituminous expansion material may be made to expand.

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