CONSTRUCTION OF ASPHALT PAVEMENTS

Thesis for the Degree of B. S.

MICHIGAN STATE COLLEGE

C. E. Behrens

1949

Construction of Asphalt Pavements

A Thesis Submitted to

The Faculty of

MICHIGAN STATE COLLEGE

of

AGRICULTURE AND APPLIED SCIENCE

by

C. E. Behrens

Candidate for the Degree of

Bachelor of Science

June 1949

ACKNOWLEDGMENTS

I wish to extend my thanks to Mr. Humphries of the Michigan State Highway Department, the Midland Contracting Company, the Highway Departments of Oregon, North Carolina, Texas and the Asphalt Institute for so kindly furnishing me with the necessary literature required in writing this thesis.

TABLE OF CONTENTS

INTRODUCTION

There are a number of basic types of asphalt surfaces and pavements. Numerous variations in material and certain construction details have been successfully used in the construction of these different types. The selection of type, as well as the material and exact construction details, may, therefore, be governed by a number of local conditions, including climate, volume and weight of traffic, characteristics of locally available mineral aggregate and asphaltic materials, available construction equipment, and lastly cost.

I have become grossly interested in asphalt pavements as during spring vacation I made a contact with the Standard Oil Company with a possibility of becoming employed as an asphalt sales engineer. Although there has been nothing definite mentioned, I thought it would be most advantageous for me to learn about the different asphalt surfaces in regard to both the ingredients used and methods of construction.

This is not meant to be a highly technical report but rather one which deals more generally with the different type surfaces and their specifications. So as to get an over-all picture, I have combined the specifications of Michigan, North Carolina, Oregon, Texas and the Asphalt Institute using what in my mind would ultimately give the best reads.

HISTORY

Asphalt is indeed not a new substance. There are instances which date back some 200,000 years where prehistoric animals have been found with their bones well saturated with asphalt, this best known of all preservatives. In brief, the process of the making of natural asphalt will be discussed.

Prehistoric history tells us that the ocean was once universal, covering the earth in its entirety. The first stirring of organic life was seaweed and one celled diatom. The cycle of life and death slowly built up a deep sedimentary bed through accumulation of these organic remains on the ocean's floor. Sometime later came either an uplift, upheaval, or a decending of ocean level leaving much of the earth's rock barren of water. Accompanying this change in datum were incredible heat and pressure and the organic settlement was partially changed to petroleum. Held in solution in petroleum was the non-volatile hydrocarbons called asphalt. Most of the petroleum was trapped underground but some was left exposed to the air and sunlight which evaporated the light volatile gases and left the heavy non-volatile residue.

As early as 3200 years B. C. temples and protection walls around cities were made of brick laid in asphalt mortar. These structures were still intact some 3000 years hence. Races in the Euphrates valley used asphalt in the construction of their highways. Residents in the valley of the Indies were found to have lined their bathing pools and irrigation canals with asphalt to prevent the loss of valuable water through seepage.

Nabopolassar, King of Babylon, first used asphalt as a mortar for brick pavements. His son, Nebuchadnezzar, was so impressed with this own genius as a roadbuilder that he left the following inscription on one of

the paving bricks: "Nebuchadnezzar, King of Babylon, he who made Esaglia and Ezida glorious, son of Nabopolassar, King of Babylon. The streets of Babylon, the procession Street of Nabu and Marduk, my lords, which Nabopolassar, King of Babylon, the father who begot me, has made a road glistening with asphalt and burnt brick; I, the wise suppliant who fears their lordships, placed above the bitumen and burnt bricks, a mighty superstructure of shining dust, made them strong within with bitumen and burnt bricks as a highlying road. Nabu and Marduk, when you traverse these streets in joy, may benefits for me rest upon your lips; life for distant days, and wellbeing for the body. Before you I will advance upon them. May I attain eternal age!" To prevent motar from flushing out, the joints were widened at the base by bevelling the bricks.

The effect of the dark ages left its mark on the progress of developing uses for asphalt. During these years all research had ceased. It has been said that had it not been for the dark ages asphalt would have contributed largely to the material development of Europe. Petroleum was not mentioned in European chronicles until about 1200 A.D. This situation was the result of the Dark Ages combined with the lack of petroleum in Europe. Asphalt only occurred in those countries where petroleum was obtainable so for thousands of years asphalt remained unknown to the white race.

It was not until early in the Eighteenth Century that deposits of limestone impregnated with asphalt were found in France, Switzerland and Germany and men began to discern the possibilities of the material. In 1802 this impregnated rock was used in a mastic form to lay bridge floors, sidewalks and for floors in buildings. These constructions were so satisfactory that in 1838 asphalt impregnated rock was brought to

America to pave a sidewalk in the portico of the Merchant's Exchange in Philadelphia. Paris used it in compressed form for paving streets in 1854 and fifteen years later London paved Threadneedle street also with rock asphalt. In 1870 and 1876 it was used in New Jersey and Washington respectively as experimental pavements.

It took several years for man to gain sight of a very important fact, namely that it wasn't the limestone but rather the asphalt which was the important material. For several years ton upon ton of limestone impregnated with asphalt were shipped to the different parts of the world void of such material. Finally, after some thought, research began to discover that it was not the limestone but rather the asphalt which contained the important properties. They also concluded further that the aggregate need not be limestone but could be such durable materials as stone, gravel or sand. Now with this problem solved, the next step was to find a source from which asphalt could be secured.

The source was a remarkable asphalt lake located in Trinidad being discovered by Sir Walter Raliegh. It was not until 1836, however, that a small part of this mastic material was first used for paving in England. Then in 1876 asphalt from this lake was brought to Washington to lay the first asphalt pavement of a modern type which is now called sheet asphalt. It was constructed by first melting the asphalt and mixing it with dried sand and a dust filler. The mixture was then laid on a suitable foundation and compressed by a roller. The asphalt supply was increased by the discovery of another lake in Bermudez, Venezuela in 1891.

Within a very short time the demand for asphalt was far greater than the supply so another source had to be found. For some time the oil producers were complaining that they didn't know what to do with the black

sticky residue which remained after the cracking process. There seemed to be some difference, however, in the per cent of asphalt present. The asphalt based oil was found to be most valuable with contents sometimes as high as 50 per cent asphalt. Although the source was an answer to a prayer, it took some time before it was realized what an important item asphalt residue was. In fact, for a few years asphalt was considered the "ugly duckling" of the petroleum industry. However, since 1900 the production of asphalt from crude petroleum has been growing by leaps and bounds.

At first petroleum asphalt was considered as solely a highway material and as largely a city paving constituent. With the inauguration of the great Federal Highway program in 1916, asphalt proved itself so adaptable to the requirements of lower costs pavements that it soon dominated the field wherever a mudless, dustless macadam or gravel surface was desired, while low cost modification of the standard sheet asphalt and asphaltic concrete pavements permitted these superlative types to be extended to the less important thoroughfares. Today 80 per cent of city streets and 40 per cent of modern state highways are of asphalt.

PETROLEUM ASPHALT

Asphalts are black or dark brown solid or semi solid cementitious materials which gradually liquefy when heated with the predominating constituents being bitumens. Bitumen is an organic material of very complex structure. It is defined by the American Society for Testing Materials as "A mixture of native or pyrogenous hydrocarbons and their non-metallic derivatives which may be gases, liquids, viscous liquids, or solids which are soluable in carbon disulphide."

Asphalt products consist of materials of various consistencies. There are the liquid materials that are so soft or even fluid at normal temperature (77° F) and their consistency cannot be determined by the penetration test. Next there are the semi solid materials or asphalt cements which have a penetration varying from 40 to 300. The final classification is termed solid or hard asphalts which have a normal penetration of 10 or less.

Most of the products used in the United States are produced from the refining of petroleum. There are several processes through which asphalts are recovered but distillation is the principle method. The distillation process consists of mechanical separation of the various products in the original material, petroleum, without chemical change. Two products are formed in the process: distillates which are first vaporized and then collected by condensation; and residues, the heavier products, which remain in the still. A large percentage of this residue is asphalt when asphalt-bearing petroleum is being refined.

In all cases before asphalt products are used in paving mixtures they must be soft enough so they may be compacted and the mineral aggregate may become well coated with the bituminous material. At present

all asphalt pavement, with the exception of rock asphalt, contain liquid asphalt or asphalts made into liquids. Liquid asphalt products include residual products, mixtures of residual products and distillates, and emulsions.

Residual oils produced by straight fractional distillation are non-volatile compounds commonly called "slow curing," which indicates that the lighter or gaseous material present evaporate very slowly. Also some liquid asphalts which are produced by mixing residual products with heavy distillates such as deisel oil are termed "slow curing" or road oils. Another type is known as "cut back" asphalt. These are produced by fluxing the heavy residue with the lighter and more volatile distillates. "Rapid Curing" cut back asphalts are produced by fluxing with gasoline or naptha and "Medium-curing" by fluxing a semi solid asphalt with kerosine. Fluxing consists of softening a heavy product by the addition of a lighter and more volatile material. The function of the distillate is temporary, using it to enable application to road surfaces or the mixing of the asphalt with the aggregate in plant mixing. After placing, the distillate evaporates leaving the residual asphalt in place.

ASPHALT PENETRATION MACADUM

Asphalt Penetration Macadum is a type of pavement where broken stone aggregate of relatively coarse and uniform size fragments is spread over a base to a thickness greater than 1½ inches, key aggregate applied, and the two interlocked by compaction. Hot asphalt is then applied covering each individual stone, binding them together. The asphalt is applied at the surface but penetrates the layer of stone before cooling. Finally the surface is covered with a course of stone chips which seals the surface. This pavement may be laid on any base which is adequate to meet the traffic conditions. However, it is desirable that asphalt macadum be placed on an asphalt macadum base course.

Specifications state that the mineral aggregate must consist of broken stone or broken slag of uniform quality throughout. The chips must be clean, free from excess dust, soft clay and flat or elongated. Per cent wear in accordance with the Los Angeles Abrasion Test must not be less than 40. If slag is to be used it must be electric or air-cooled blast furnace slag uniform in density, free from glassy pieces and must weigh 70 pounds per cubic foot.

Aggregate	Coarse	Intermediate	Fine
Simplified Practice No.	3	67	78
Total Passing	Per Cent by Weight	Per Cent by Weight	Per Cent by Weight
2 1/2" sieve	100	--	--
2" sieve	90-100	--	--
1 1/2" sieve	35-70	--	--
1" sieve	0-15	100	--
3/4" sieve	--	90-100	100
1/2" sieve	0-5	--	90-100
3/8" sieve	--	20-55	40-75
No. 4 sieve	--	0-10	5-25
No. 8 sieve	--	0-5	0-5

For the surface course it is required that asphalt cement prepared by the refining of petroleum be used. It must be free from mineral matter, water, tar and tar products. Also, it shall be uniform in character and must not foam when heated to 350° Fahrenheit. In the initial and seal coat an R.C.-3 asphalt cut back is used.

Penetration of Original Sample at 77°F., 100 g., 5 sec.	85 to 100	100 to 120 120 to 150
Flash Point, (Cleveland Open Cup) °F. .	450f	425f
Loss on Heating at 325°F., 5 hrs. Per Cent	1-	2-
Penetration after Loss on Heating, % of Original	70f	70f
Ductility at 77°F.	100f	60f
Per cent Soluble in Carbon Tetrachloride	99.5f	99.5f

Before any aggregate is placed the base must be free from all loose and foreign matter. Some method to hold aggregate in place must also be devised. One of these is the use of side forms set on a firm compacted base. They must be securely staked for back support 200 feet ahead of point where aggregate is being spread, must have a back fill two feet in width and a height to conform with profile grade of shoulder. The second method is to form the shoulder with a vertical face for the full depth of surface course 200 feet in advance of the spreading. Both cases when completed must allow roller to pass over the aggregate abutting either with half of the roller overlapping.

When applying the aggregate it must be done in such a fashion to prevent segregation. If trucks are used it is suggested that they dump their load and let it be distributed by some other means. If a mechanical spreader is doing the job it must be so designed so to spread the aggregate in such a manner to obtain uniform compaction. The finished product is

checked for uniform crown by the use of a template. In regard to preventing segregation, power graders should not be used for spreading purposes.

Following the spreading is the dry rolling operation. This operation is done with either a three wheeled or tandem roller weighing not less than 10 tons and capable of compacting from 300 to 330 pounds per inch width of rear roller. Rolling begins at the sides and proceeds toward the center overlapping by one half the width of rear roller on each successive trip. For each 20 ton or fraction of aggregate deposited in an hour, there should be a minimum of one roller in operation. To check for proper texture three test holes are made at intervals of 200 feet and test specimens taken from them. Irregularities are than checked for an if there are any sections which vary one-fourth an inch in a ten foot stretch parallel to the center-line proper corrections are made. Rolling is then continued until aggregate no longer creeps or waves ahead of roller.

The first application of asphalt cement is uniformly applied at the rate of 2 gallons per square yard with a tollerance of only .1 gallon either way, and applied only when course is perfectly dry throughout its entire depth. Such close tolerances are required because an excess of asphalt will destroy the interlocking producing a wavy rutted pavement and a deficiency permits water to enter which tends to destroy both bitumen and stone and if freezing occurs the bond is destroyed. There are definite periods of the year during which asphalt macadum may be laid. Oregon and California designate the months included between May 1 and October 1; in Rhode Island it's between May 15 and October 15; in North Carolina only when the temperature is above 50° and the Asphalt Institute specifies temperatures above 45°. The temperature of the asphalt itself must range between 275°and 350° immediately prior to application.

There are several precautions taken during application with standard distributor to prevent lapping. On end junctions the spray is immediately shut off and a pan inserted under nozzles to catch the drippings. When continuing operations building paper is placed some distance ahead of untreated surface so sprayers may be turned on and operating at a specified rate upon reaching this point. Building paper is then destroyed. It is wise to make as few trips as necessary as each additional trip increases the possibility of overlapping at longitudinal joints. Tanks should be cut off before coming completely empty as the loss in head causes ununiform flow as will the nozzles if they become stopped up. Finally, the distributor should be driven along a marked edge to keep treatment in a straight line. To increase the flow and penetration action of asphalt, a soap-water solution may be sprayed onto the road surface a few inches ahead of the asphalt. The amount used is approximately 10 per cent of the volume of asphalt used. Per cent soap used should not be less than 1 per cent of soap and water solution. For spots where distributor was unable to reach or for some reason didn't give uniform spray, a hand sprayer usually run with compressed air is used for touching up.

Immediately after asphaltic cement is placed and the asphalt is still warm, filler stone is added in such quantities so to prevent the roller wheels from sticking.

This standard distributor which was mentioned in the previous paragraph is a pneumatic tired self propelled tank which is capable of distributing a uniform spray without atomization. It is equipped with several pieces of gear to do this. To insure proper application it has a fifth wheel tachometer registering speed in feet per minute and another tachometer reading gallons per minute, both visible to the operator. The asphalt is forced out of the spray bar under pressure furnished by a pump which has its own power unit. There are pressure, volume, and temperature gages

located in such places so they are easily readable by inspector. It is capable of spraying widths of 15 feet with a minimum of 6 feet with special adjustments made for width less than 6 feet. If the width is too large to cover in two 15 foot trips, 6 to 8 foot runs are used until the surface is completely covered. When the machine is equipped with heating facilities the asphalt cement should be circulated continually.

Immediately after asphaltic cement is placed and the asphalt is still warm, filler stone or key stone is added in such quantities to prevent the roller wheels sticking. Simultaneously with the rolling, small quantities (10 to 20 pounds per square yard) are continually added and broomed over the surface. This process is continued until all voids have been filled by filler stone and the stone is thoroughly imbedded, anchored in place and surface is smooth with no perceptible movement under the roller. Care must be taken so not to have the quantity of filler stone sufficient so it covers rather than only fills voids. Such an excess would crush under the roller forming a surplus of dust which would hinder the adherence of the seal coat.

With the rolling operation complete the surface is ready for the seal coat. The seal coat is applied with distributor at a rate of 0.4 gallon per square yard with a tolerance of plus or minus 0.1. Enough fine aggregate is then spread over the surface to take up the asphalt and the final coat is rolled with a 10 ton roller until the proper crown and profile ($\frac{1}{2}$ inch to 10 foot length parallel to center) is reached. Usually two seal coats are required, the second one applied in the same manner with a wait of 3 to 6 days.

There shall be no traffic admitted on the surface between initial compaction and completion of the final seal coat. If, after traffic has been admitted, bleeding occurs it must be corrected by adding new screenings. Sometime within a 10 day period after the final seal coat has been completed

the specifications state that each 100 square yards must be rolled for a period of 1 hour with a 10 ton roller not exceeding 3 miles per hour.

ROAD MIX - OPEN GRADED TYPE

The term "road mix" is understood to designate the type of bituminous surface which is mixed in place on the road being constructed. The mix is supposed to have originated in Pennsylvania several years ago and has been found to be quite successful if properly used.

Before the surface course is laid the base on which it is to be placed must first be prepared. The first step is to scarify the soil to be used for the base. This is done usually with a multi-bladed drag or other pieces of equipment which are capable of cutting up the surface to a depth varying from 6 to 10 inches. After it has been scarified, it is then treated with an asphalt primer of the MC-0 or MC-1 type. However, if the base is rather porous, an MC-2 cut back asphalt is used. Then, to allow for the correcting of any weaknesses, the base is opened to traffic anywhere from four to twelve months before the road mix is applied, after which all necessary patching is done on spots which vary more than one inch from the normal contour. The surface is then rolled and brought to the specified shape. If the surface being prepared has been oil or cement bound all patching of holes, cracks, and breaks must be done by the penetration method which will be discussed later.

The aggregate used on the surface course may consist of crushed or broken stone, crushed gravel or crushed slag but each must meet the specifications required. Much of the stability of wearing course is dependent upon the interlocking or frictional resistance of angular particles. Therefore the specifications state that not less than 70 per cent of fragments of crushed aggregate retained on the number four sieve shall consist of broken angular pieces. The particles must also be clean, uniform quality throughout and free from dust and flat elongated pieces. The per cent wear, as indicated by the Los Angeles Abrasion Test, shall

not be more than 40. If slag is to be used as the mineral aggregate, it must weight 70 pounds per cubic foot independent of the maximum size aggregate used which is dependent on the thickness.

Type	Coarse	Fine
Simiplified Practice No.	5	7
Total Passing	Per Cent by Weight	Per Cent by Weight
1½" sieve	100	--
1" sieve	90-100	--
3/4" sieve	40-75	100
1/2" sieve	15-35	90-100
3/8" sieve	0-15	40-70
No. 4 sieve	0-5	0-15
No. 8 sieve	--	0-5

Asphalts used are either cut-back asphalts or asphalts emulsions free from water. In some cases additives are added to increase adhesiveness.

For	Primer		Binder
Designation	MC-0	MC-1	RC-3
Flash Point (Open Tag.) °F.	100+	100+	80+
Furol Viscosity at 77°F.	75-150	--	--
Furol Viscosity at 122°F.	--	75-150	--
Furol Viscosity at 140°F.	--	--	250-500

	Primer		Binder
Distillation Distillate (per cent of total distillate to 680°F.) To 437°F. To 500°F. To 600°F.	 25-- 40-70 75-93	 20-- 25-65 70-90	 25% 55% 83%
Residue from Distillation to 680°F. Volume Per Cent, by Difference	50%	60%	73%
Tests on Residue from Distillation Penetration 77°F., 100 g., 5 sec. Ductility 77°F. Per Cent Soluble in Carbon Tetrachloride	 120-300 *100% 99.5%	 120-300 *100% 99.5%	 80-120 100% 99.5%
Application Temperature °F.	50-120	80-150	150-200

*Note- If penetration of residue is more than 200, and its ductility at 77°F. is less than 100, the material will be acceptable if its ductility at 60°F. is 100 %

Thicknesses of road mix surfaces vary from one to three inches and any thickness in excess of two inches is applied in two courses. As was previously mentioned, if the base is a scarified course a primer coat must be applied by a standard pressure distributor. Before the prime coat is applied the base course must be completely dry or only slightly damp and the atmospheric temperature must not be below 50 degrees Fahrenheit. The bituminous material is applied over the full width of roadway extending from curb to curb or ditch to ditch at a uniform rate of 0.3 to 0.5 gallons per square yard. All traffic is kept off until material is dry enough so the wheels will not displace the primer. In the event that the prime coat fails due to disintegration of the underlying surface, the area in question is filled with selected materials similar to the surrounding soil so the surface at this spot will conform with the crown of the road as a whole. The primer then applied with a hand spray. Any other failures are also

repaired at this time. In some instances, after applying the primer, it is immediately covered with a small quantity (2 to 4 yd^3 per 100 foot station) of material similar to the base material. The primer and base course are then thoroughly mixed by being bladed into windrows. Upon being thoroughly mixed it is bladed and rolled until compaction is complete after which it is left setting for fourteen days before being covered with aggregate.

When the surface to be covered is an old bituminous road, no primer is necessary, however, a preparation called "Tack Coat" is usually applied. The bituminous material used is of the same type used in the surface course being applied at rates of 0.1 - 0.15 gallons per square yard. Its purpose is to aid in waterproofing the base and it also provides adhesion between the road mix and the base.

With the preparation of the base course completed and the surface thoroughly cleaned and dried, the course aggregate may be distributed uniformily over the entire surface. This operation is performed either with trucks or a mechanical spreader leaving a loose layer that is 20 per cent deeper than the specification road. Following the spreading operation the aggregate should be leveled to a higher degree by a grader followed by harrowing with a disk harrow so to distribute the various particles uniformly and also aid in drying off the aggregate should there be some moisture present.

The surface is now ready for its first application of asphalt provided that the aggregate is completely dry. The amount of asphalt to be applied is dependent on the thickness of the surface with the thinner surfaces requiring a greater proportion of asphalt. Although there is no set rule, the following table indicates the approximate quantities:

Thickness in inches	Gallons per Yard
1½	0.2 - 0.3
2	0.3 - 0.4
2½	0.5 - 0.7

Certain types slag require 0.1 gallon more than shown above. Once again the atmospheric temperature must not be below 50° Fahrenheit.

Very necessary precautions must be taken to prevent overlapping. To prevent lapping at the end junctions the distributer must be immediately shut off and a pan inserted under the nozzles to catch the drippings. When continuing operation, building paper is placed some distance in advance so sprayers may be turned on and operating at their specified rate upon reaching the untreated surface. The building paper is then removed and destroyed. When the tank is approaching the empty mark it should be shut off before coming completely empty thereby avoiding non-uniform application caused by a non-uniform flow. Nozzles in the spray bar must be kept clean and unplugged as the plugging of merely one noggle hole will lead to uneven distribution. Also, as few trips as necessary should be made to eliminate the possibility of overlapping, and each trip being guided or steered along a marked edge to insure no overlapping.

Immediately after application of asphalt, the coarse aggregate and binder are thoroughly mixed with such equipment as blade grader, multiple-blade drags or pin mixes for a period long enough to distribute the asphalt well but not long enough to allow the mixture to become tacky. Blade graders should be avoided wherever possible and the multi-bladed drag employed as the later is much faster. Speed is of great importance for no time should be lost in mixing as the light constituent used in road mixes evaporate rather quickly and the mixture becomes tacky. Multi-bladed

drags are mounted on four wheels. The blade is 10 inches high and is capable of mixing surfaces with thicknesses of one and a half inch or less. Anything in excess of one and a half inch is mixed by means of a machine called "Retread". It is operated by two men, one operating the mixing blade and the other the leveling blade at the rear of the machine. The machine is capable of taking widths up to 10 feet with the leveling blade leaving a surface planed to a uniform cross-section and smooth longitudinal profile. If a second application of asphalt is required, the same procedure is followed.

Another method of mixing used extensively is the traveling plant mixer. The coarse aggregate is first spread in one or more windrows best adapted for the type plant to be used. Its rated capacity should be sufficient to produce the required compacted thickness given in the specifications. Some plants are designed with tanks and measuring devices that the asphaltic binder is added during the mixing process. In such cases the tank must be equipped with steam coils so designed to secure uniform heat throughout its contents and a thermometer to determine the temperature of the asphalt before being combined with the aggregate. Other plants are not built with asphalt tanks and so with these mixers the binder must be applied by pressure distributers while the aggregate is laying in windrows. With either type plant the following quantities of asphalt are needed for the stated thickness in each case.

Thickness in Inches	Gallons per square Yard
1½	.45 - .6
2	.6 - .8
2½	.7 - .9

The aggregate is then picked up from the windrows and mixed until all the aggregate has been coated with binder. The mixture is then deposited either in back of the plant in a windrow and spread over the entire surface with a blade grader or long wheel base spreader, or if the plant is equipped with a spreader the mixture is placed and spread in one operation. In each case the results must produce a smooth even profile and cross-section.

After the mixture has become "Tacky", two to five hours depending on the bituminous material and the air temperature, compaction begins. Both tandem and three wheeled rollers are used in this process, the weight depending on the thickness to be compacted. A six ton roller is satisfactory for thicknesses less than 1½ inches but surfaces in excess of this dimension must have an 8 to 10 ton rated roller with a minimum of 300 pounds per inch width of rear roller. To avoid ragged edges a small gang of men is placed ahead of the roller building up the edges with shovels and tamps giving support when being rolled.

A seal coat is necessary on an open-graded road mix as the mixture leaves quite a porous surface and placing of a seal coat will prevent raveling under traffic in addition to making surface waterproof. It should not be applied in less than a week after surface course has been compacted and is usually deferred from two weeks to several months, thus allowing all volatile constituents to evaporate and leaving the course in a perfectly hardened condition. The first step in applying the seal coat is to spread a small portion of fine aggregate (at the rate of 15 to 18 pounds per square yard) by means of hand or machine. This cover coat is then lightly broomed by means of a broom drag filling in all the surface voids. A bituminous material, the same as was used on the surface course, is then applied at

a rate varying from .2 to .3 gallons per square yard. Brooming is continued simultaneously with rolling, with the possibility of adding fine aggregate if necessary until a smooth well bonded surface results. Usually the complete filling of the void is not practiced as a semi nonskid surface is the result of not filling the voids in their entirety. Within a period of ten days the surface should be back rolled in accordance with the engineer's discretion.

ROAD MIX - DENSE GRADED AGGREGATE TYPE

Dense aggregate road mix was developed in the western part of the United States. The purpose of this type of road is to reduce the cost of construction by employing aggregates which are available in the particular location in question. It consists of aggregate from coarse to fine mixed with a bituminous material. Thicknesses range from 1 inch to 4 inches with 2 or 2½ inch surface commonly used. Dense graded aggregate is most frequently placed on old gravel roads or newly graveled base course and is sometimes called "Oil gravel road mix".

Briefly, the construction procedure of such a surface is as follows: First the base is treated with asphalt primer. A layer of graded aggregate is then spread over in sufficient quantity to produce a compacted surface course of specified thickness. Spreading is followed by grading, applying binder, mixing mixture, compaction by traffic during blading, dragging and rolling. The last operation is the application of the seal coat which consists of a bituminous coat covered with sand.

Aggregate to be used may come from either of two sources. If agreed to by the engineer, the old gravel road to be surfaced might be scarified and used with possibly an addition of graded aggregate if the quantity isn't sufficient. In some cases, however, this is not allowed and all the aggregate must be applied. Under these conditions the aggregate must be a mixture of broken stone, crushed or uncrushed gravel, sand and stone screenings or mineral dust with wide limitation specified as to grading. The limit on sizes is a minimum of two; anything less than a number four sieve is considered coarse and greater than number four is considered fine.

When tested by means of laboratory sieves, the mixed aggregate shall meet the following requirements:

Total Passing	Per Cent by Weight
1" sieve	100
No. 4 sieve	50-70
No. 10 sieve	35-60
No. 200 sieve	0-14

The asphaltic materials for the primer and binder shall meet the following requirements:

Per	Primer		Binder
Designation	MC-0	MC-1	MC-3
Flash Point (Open Tag.) °F.	100+	100+	150+
Furol Viscosity at 77°F.	75-150	--	--
Furol Viscosity at 122°F.	--	75-150	--
Furol Viscosity at 140°F.	--	--	250-500
Distillation			
Distillate (per cent of total distillate to 680°F.)			
To 437°F.	25--	20--	5--
to 500°F.	40-70	25-65	5-40
to 600°F.	75-93	70-90	55-85
Residue from Distillation to 680°F. Volume Per Cent, by Difference	50+	60+	73+
Tests on Residue from Distillation			
Penetration 77°F., 100 g., 5 sec.	120-300	120-300	120-300
*Ductility 77°F.	100+	100+	100+
Per Cent Soluble in Carbon Tetrachloride	99.5+	99.5+	99.5+
Application Temperature °F.	50-120	80-150	175-250

*Note - If penetration of residue is more than 200, and its ductility at 77°F. is less than 100, the material will be acceptable if its ductility at 60°F. is 100+.

As in the Open Grade mix, the first step in construction is the application of the prime coat providing the total amount of aggregate to be used is brought to the job. However, if all or any fraction of the total is to be supplied from the road bed, it is first scarified, harrowed and all loose material bladed in windrows at the side of the road. The remaining soil is then graded to a smooth well shaped crown with perhaps a slight wetting to aid operations. All excess soil is removed and disposed of on the shoulders.

A pneumatic tired distributer is used to place the prime coat with a capacity of 800 gallons. It is capable of maintaining a temperature of 325° Fahrenheit and is equipped with a spray bar which is adjustable in length from 8 to 21 feet. The prime coat is applied at rates of .25 to .5 gallons per square yard over the full width of roadway with the temperature not below 50 degrees. Traffic must be kept off for a period of twelve hours and the curing period (time elapsed before aggregate is applied) not less than 48 hours. There should be no pools on the surface after the curing period is complete. When the aggregate to be used is dumped in the roadway, the uncovered half is first primed and after it has completely dried the aggregate is bladed into it and the second half primed. However, this situation should be avoided if possible.by placing aggregate outside of the area to be surfaced.

Whether the aggregate in total or in part is taken from the original surface or the entire amount is from some outside source its first move is to be placed in triangular windrows either in the center or at the side of the road. At this point it is sampled by the engineer to check for proper proportioning and in some cases it is wise to weigh a square yard to check quantity. The quantity must be sufficient to furnish the surface with pre-

per thickness. After proportions and weights are checked it is thoroughly mixed by a combination of blading back and forth across the roadway and disc harrowing. Once again it is bladed in windrows where again it is examined for measurement and possible adjustments. Then immediately before application of asphalt binder the aggregate is bladed into a uniform cross-section across the full width of road only after the mixing has decreased the moisture content to a maximum of 1½ per cent.

The first application of asphalt is then applied at a rate of ½ gallon per square yard. Immediately after this, the mixture is disc harrowed which continues until all aggregate is covered with asphalt. Successive treatments identical with the one just described are necessary as they make it possible to prevent an excessive amount of asphalt from being applied. The exact number is dependent upon the thickness being laid but they run somewhere between two to five not exceeding ½ gallon per square yard on any treatment. The final mixture should contain 7 to 10 per cent of bituminous material.

As soon as a full width section of mineral aggregate has received its total application of binder and has been thoroughly disced, mixing is continued with either a blade grader, multiple blade drage, pin mixer or re-tread mixer. Care should be taken so no untreated base or shoulder material is brought into the mix and also precaution taken so mixing does not cause segregation or loss of materials. If mixture is toowet, mixing is continued until moisture has been removed. The finished mix should produce a homogeneous mass free from fat spots, balls and uncoated particles placed in a single windrow waiting spreading and compaction.

A second method of mixing is accomplished with a travel plant as was described in the mixing of the Open Aggregate Road Mix. It also picks up the mixture of aggregate and binder from the windrow or in other cases aggregate, depending upon the plant, mixes the mixture and deposits it behind in windrows. The plant heats the mix to a maximum of 250° Fahrenheit

for proper fluidity but anything over this temperature is injurious to the asphalt and causes it to be rejected.

Before the finished mixer is finally spread for compaction on traffic bound base, triangular cuts are made at the edge with a blader. These cuts are 2 inches deep at the outer edge and slope to zero 2 feet in toward the center. The excavated material is placed in windrows on the shoulder lending support to the spreaded mixture. Then in succession of thin layers, the mixture is removed from the windrows and deposited to uniform cross section and correct thickness. Care is taken to make a smooth joint between each separate application. At this point, if mixture shows an excess or deficiency of bituminous material or perhaps uneven distribution, each should be corrected by scarifying, adding either aggregate or asphalt depending on the case, and remixing.

Initial compaction begins at edges and progresses toward center parallel to centerline, overlapping on each successive trip by one half width of roller. This procedure is usually done with a pneumatic tired roller weighing 3 tons and so designed that the weight might be increased to 7 ton Tires must be of same size and inflated to the same pressure so producing uniform compaction by the wheels. Final compaction is completed with a 5 to 10 ton steel wheeled roller of either a tandem or 3 wheel type. All rolling is preferably done in the cool part of the day when surface is being maintained. During the rolling operation the surface is simultaneously bladed until a smooth, compact, true crown is the result. After compaction is completed the surface is opened to traffic to aid in further compaction. During this further compaction rolling and blading is continued off and on and the operation continued until traffic no longer grooves the surface. This process usually is completed in 3 to 10 days depending on the weather and the aggregate.

With a dense graded mix the application of a seal coat is optional but generally is considered wise to use as it aids in wear and ease in maintenance. When used it is applied in quantities ranging from .2 to .3 gallons per square yard at a temperature specified by the engineer and is of the same type used in the road mix. It is then lightly covered with sand or some other similar fine material and dragged until it blends with the underlying surface. The completed surface, especially when a slow cure cut back is used, hardens very slowly. Therefore, it should be kept free from any steel tired impliments or the like for a period of at least ten weeks.

PLANT MIXED ASPHALT

The building of a plant-mixed asphalt surface is essentially a manufacturing process. It is very important that the steps taken in the manufacture of an asphalt pavement are such so the final product is uniform. To accomplish this there are several mechanical devices available to aid in the construction of plant mixes.

DRIER:

Before any steps can be taken in the manfucture of a plant mix the aggregate which has been stock piled, must be rid of its moisture before being screened. Each plant is equipped with a retary drier which in many cases is considered the "Bottleneck" of an asphalt plant. It is shaped as a drum and is mounted on a slight angle from the horizontal to assist the aggregate in passing through. The unheated and wet mineral aggregate is fed into the higher end of the drum. As it rotates steel angles, fastened to the inside, pick the material up and agitate it as it is being carried through. The drier is also equipped with hot gases which are supplied to an oil burner capable of heating the aggregate to a temperature of 550 degrees Fahrenheit as it is cascaded through the drum. Just before the dried aggregate is discharged to the chutes leading to the screens, the temperature of the aggregate is registered by means of a pyrometer. This, of course, is a check to see that the aggregate is completely dry. To keep "bottlenecking" at a minimum the drier's capacity should be in excess to the mixer's. According to specifications here in Michigan for a rated mixer of 2,000 pounds the minimum size of the drier should be 22 feet long with a volume of 432 cubic feet. The drying unit must also be equipped with a power driven mechanism which is capable of adjusting flow of at least two separate aggregates. It

also must have a fan of sufficient capacity to remove all moisture from the heated aggregate and also a dust collector which is 75 per cent efficient. A final point which is very important is that the drum must be properly sealed to prevent loss of fines upon rotation.

SCREENS:

From the drier the aggregate is placed on chutes taking it to the screens which are located directly above the hot storage bins. The screens are of two types, either rotating or vibratory. They must be capable of segregating the aggregate into two extremes namely fine and coarse. The State of Oregon specified that they must be capable of separating anything from number 10 to 3/4 inch. In Michigan the specifications read that the sand screens shall have square openings not less than 0.0937 inches (no. 8 screen) or greater than 0.132 inches (no. 6 screen) and for binder mixes they must also have square openings not less than 1¼ inches or greater than 1½ inches. The tolerance allowed in either case is 10 per cent. Like the drier, the screen should also have a capacity in excess of the mixer.

BINS:

The next step after the aggregate has been properly screened is for it to be placed in their proper bins. The minimum number of bins should be three, each bin containing only one sized aggregate with a combined capacity large enough to keep the plant at a maximum rated capacity. So the size in each bin will remain constant, the bins are equipped with an overflow vent which prevents the overflowing of one bin into another. They are also equipped with a very accurate working mechanism operating a discharge gate at the bottom of the bin directly over the weigh hopper. In addition to the bins mentioned, there is a special constructed bin holding the mineral filler. It is constructed dust tight and has a

mechanical device for accurately depositing the required amount of mineral filler into the weigh box. All of the bins are inspected at regular intervals to check against the forming of pockets in the corners and segregation.

DEVICES

PROPORTIONING:

Perhaps the most intricate built devices in a mixing plant are the proportioning mechanisms. They must be very accurate to obtain a mixture which is uniform. The devices proportioning the aggregate may operate either by the weight or volume system. If the weight system is used the hopper, or sometimes called weigh box, is mounted directly over the mixer on knife edges in such a manner that all parts of the box are free to move. Through a system of knife edges and levers either a dial or beam scale sensitive to one half of one per cent of maximum load with minimum gradnations of five pounds is operated. When the scale is of the beam type, it should be equipped with a tare beam which would eliminate the error of the weight of the weigh hopper. The box is open at the top and equipped with a gate opening across the full width of the hopper thus eliminating any possibility of some aggregate remaining inside after it is dumped. When the proportioning is done by volume, the scales, of course, are eliminated but it should be made clear that the high degree of accuracy is still retained. Each bin is equipped with an 8 by 9 inch rectangular orifice with one of the two dimensions adjustable. The proportioning is done by the operator merely opening and closing these orifices by a system of compressed air or some other approved mechanical means. For inspection purposes there must be a way of by-passing a complete or fractional portion of a batch to check for proper

porportions. To insure that all the aggregate is out of the box, a vibrator is used. Also the slides leading from the weigh box and bins must be kept smooth and on correct minimum angle so the fines won't have a tendency to remain in their respective container.

Another important proportioning device is the weigh bucket used to weigh and distribute the molten asphalt. Its rated capacity shall be within the limits of 12 to 20 per cent of the weight of the aggregate used in one batch. The bucket is suspended from either a dial or beam scale whose accuracy is within plus or minus two per cent of the weight required for the batch. To prevent the accumulation of chilled asphalt from building up and changing the tare of the bucket, a heating unit either of a steam jacketed or electric type is installed to continuously drain the accumulated condensate. However, even with all the preceding precautions taken, the tare of the bucket is determined for each batch. The design of the bucket is such as to allow the molten asphalt to be distributed in thin uniform sheets over the full width of the mixer. This device usually consists of a spray bar which is also steam jacketed to prevent the orifices from clogging up. For the convenience of the inspector the line feeding the asphalt to the bucket is equipped with a thermometer close to its outlet reading in the range from 200° to 400° Fahrenheit.

MIXER:

Following proportioning comes the mixing process which is accomplished by the use of a twin-pug batch or continuous mixer. It is the bottom most portion of the plant elevation located directly underneath the weigh box at such a height to enable discharging into a truck or into a hopper from which trucks are loaded. The twin-pug batch mixer is a rectangular shaped container enclosed on either end with its semi-circular bottom opening up in its entirety when discharging its load. The mixer is manufactured in three

different sizes: small 750 pounds, medium 2000 pounds and large 4000 pounds. The mixing is accomplished by mixing blades mounted on two rotating shafts rotating at a rate not less than 70 or greater than 90 revolutions per minute. They should rotate in opposite directions and preferably be so constructed so the flow of mix can be rapidly retarded by merely reversing the shafts. The blades are so attached to the shaft so they may be set in the proper run around order at the most efficient angle. They are also attached in such a fashion so they might be removed after showing wear. For such surfaces as sheet asphalt, for example, the maximum clearance should not exceed three-fourths of an inch anywhere in the mixer. In rare cases for coarse mixes the clearance is increased to a maximum of one and a half inches. Anytime these clearances are exceeded either or perhaps both the old lining and blades must be replaced with new parts. Added attachments are the dust hood and automatic timing device. The timing device has an important sequence to follow. It should lock the weigh box after charging of mixer until closing of mixer gate. It must lock the asphalt bucket throughout the dry mix and the mixer gate throughout both wet and dry mix. The device is locked in a glass case by the inspector on the job. It is at this point of the process where the filler is usually added, care taken so it is added to the center of the mixer. A formula for determining the mixing time is dead capacity in pounds divided by output in pounds per second. The general procedure is to set a minimum of 45 seconds and continuing the mixing until a homogeneous mixture is produced. A twin-pug continuous mixer is identical to the batch mixer with the exception that its top end is open and aggregate and asphalt are added at this end while the mixture is being discharged at the other end.

TANKS:

The supply of asphalt is also under constant check to see if it is entering into the bucket at a proper temperature. Asphalt tanks, with a minimum capacity of a ten hour run of plant, control this temperature. The tanks are heated by steam jacketed, steam, electrically heated lines but never by direct fire or any other method giving localized heat. The allowable temperatures vary between 250° and 325° with a pyrometer located just before the orifice leading into the bucket. Continuous circulation is maintained through draw-off tube to maintain a constant temperature throughout the mass. The engineer should see that the pipe leading from the tank to the bucket is properly heated and insulated.

Once the mixture has been transported by truck to the job there must be equipment available to spread, shape and compact the mix in as short of time as possible to prevent the mixture from becoming tacky. There are several commercial spreader finishing machines on the market but they all come under either one of three classes and must be capable spreading the mixer true to line, grade, and crown. Although spreaders and finishers are mounted on one frame they still may be considered as individual units. The spreader usually consists of a hopper located in the front end of the mechanism. In the bottom of the hopper there is a horizontal opening through which the mixture is applied in thicknesses adjustable from 3/4 to 3 inches and in widths varying from 6 to 10 feet. To insure that the mixture is carried across the full width of the opening, a revolving screw is included in the design thereby making certain the application is uniform.

The older type pavers (combination spreader and finisher) run on side forms of wood, steel or curbing if it is available. If forms are used they must meet specifications set by the engineer. They are in the neighborhood of six inches in width and 10 to 15 feet long and must be free from warps, bends and any other possible defects. The forms must be placed on firm soil true to line and grade and should be placed at a minimum distance of 500 feet ahead of the spreader but not further than 2 miles in advance. Forms must be left in place until initial compaction is completed or, when possible, left until the entire rolling and compaction operation is finished. Immediately after removal, approved material is to be placed against the finished edges and compacted to form a shoulder of specified width. The newer machines do not require forms or curbings to operate on. They are either supported on runners which move along with

the machine, by wheels or rollers.

All types are equipped with a striking-off device called a screed which is adjustable to any size or shape and does its job without the least bit of tearing, gauging or shoving. For best operation the screed should have a heating attachment to prevent the accumulation of bituminous material but care must be taken not to overheat and cause blistering and bleeding. The machine should produce a finished surface which has uniform thickness, contour and density. Best results are obtained when the machine is either self propelled or pulled at a speed ranging from 10 to 20 feet per minute, being equipped with a sensitive enough steering mechanism to enable quick and efficient steering at these speeds.

Although the paver does the greatest portion of spreading and finishing there are some spots such as intersections, turnouts, driveways, etc. where manual labor is a necessity. Also any spot either after finishing or rolling which is in need of repair due to its ununiformity is removed, replaced, spread, finished and tamped by hand. The usual procedure is to dump the paving material outside the area where the work is being done. It is then distributed by means of hot shovels to the area being worked where it is immediately raked to uniform thickness, contour and density. Both the speed of the trucks and shovelers is dependent upon the speed of the rakers. Specifications state that the tines of the rake shall not be less than one half inch longer than the loose depth of the surface and the distance between tines is not less than the maximum diameter of the aggregate. As a safety precaution, the rakers should never stand in the hot mix unless it is to correct an error and then he must wear stilt sandals.

Another hand operation is the making of joints between old and new

pavements on successive days. The edge of the previous course is first cut to its full depth. The hot mix is then placed in the cut and raked to proper depth and grade. Hot tampers heated to a temperature sufficient to insure proper bond between aggregate and asphalt but not to a point where tamper might cause asphalt to burn are used to compact the mixture. Before placing mix against longitudinal joints such as curbs or gutters, all contact surfaces must first be painted with hot asphalt cement or a rapid-cure cut back asphalt. After the surface has been coated with liquid asphalt the joint is properly "set up" with the back of the rack to a proper height and bevel so the joint will receive maximum compression under rolling. Such joints should be made by competent experienced workers as joint construction is considered a skilled job.

The final step in the construction of an asphalt surfaced roadway is compaction accomplished by mechanical steel faced rollers. These rollers are of three types: three wheel, tandem or three axle ranging from 5 to 10 tons. They are equipped with either gasoline or deisel engines driving at speeds not to exceed three miles per hour and always slow enough to avoid the displacement of any of the hot mix. Generally, the three wheeled roller is used for initial rolling as it has more compaction per inch width of roller. However, the rollers should not be so heavy so as to crush the aggregate during rolling. Initial rolling is begun as soon as the newly applied surface will allow the weight of the roller. The rolling is begun on the outside edge traversing parallel to the center line of the pavement and gradually working into the center. Each successive trip should overlap the preceding rolled strip by one half the width of the rear roller. Alternate trips shall be of slightly different lengths so to prevent a slightly weakening effect. During the process of rolling, the rollers are kept moist

with either oil or water aiding in preventing the displacement of the hot mix. On superelevated curves the rolling begins on the lower edges and progresses toward the upper edges in the same manner as was previously stated. Finished rolling is usually done with a tandem roller and progresses also in like manner until further compaction is impossible. The finished surface shall be free from depressions exceeding one-eighth inch measured with a ten foot straight edge running parallel to the center line with a crown varying from one-eighth to one-fourth inch per foot width. Density shall not be less than 95 per cent of the laboratory's specimen and traffic shall not be permitted to drive on surface until it has cooled to atmospheric temperature.

ASPHALTIC CONCRETE

Asphalt concrete is a plant mix of asphalt cement with coarse graded mineral aggregate. Most common mineral constituents are a combination of broken stone, broken slag or gravel, sand and mineral filler. They should be accurately proportioned and designed to have a high degree of stability when compacted and be sufficiently waterproof to require no seal coat. A number 10 sieve serves as a convenient division between coarse and fine and a number 200 dividing the fine and filler. Asphalt concrete may be laid to any desired thickness in one or more courses, varying in thicknesses from one to three and a half inches.

The coarse aggregate must consist of broken stone, broken slag, or gravel crushed or if uncrushed it must have a rough surface. It must be free from excess dust, dirt, sand and flat elongated pieces. Per cent wear must be somewhere between 30 and 50 when given the Los Angeles Abrasion test.

All material used as fine aggregate must pass the number 10 sieve and not more than 4 per cent passing the 200 sieve. The particles might consist of sand and/or stone screenings with a per cent wear of 65, clean tough and rough surfaced grains. Any mineral that passes the 200 sieve and is free from lumps and loosely bonded aggregations may be used for mineral filler. Some examples are Portland cement, dolomite, dust and dry limestone dust.

Coarse Aggregate

Sec. 2.5 (a) Mix No.	I	II	III	IV	V
Simp. Practice Size No.	357	467	57	67	78
	Per Cent by Weight				
Total passing					
2 1/2" sieve	100	--	--	--	--
2" sieve	95-100	100	--	--	--
1 1/2" sieve	--	95-100	100	--	--
1" sieve	35-70	--	90-100	100	--
3/4" sieve	--	35-70	--	90-100	100
1/2" sieve	10-30	--	25-60	--	90-100
3/8" sieve	--	10-30	--	20-55	40-75
No. 4 sieve	0-15	0-15	0-15	0-15	5-25
No. 10 sieve	0-5	0-5	0-5	0-5	0-5

Fine Aggregate

Passing	Retained on	Per Cent by Weight
No. 4 sieve	--	95-100
No. 4 sieve	No. 10 sieve	0-15
No. 10 sieve	No. 40 sieve	15-30
No. 40 sieve	No. 80 sieve	30-60
No. 80 sieve	No. 200 sieve	15-40
No. 200 sieve	--	0-5

Mineral Filler

	Per Cent by Weight
Passing No. 30 sieve	100
Passing No. 100 sieve, not less than . .	85
Passing No. 200 sieve, not less than . .	65

When choosing the asphalt cement to be used, the present tendency is to use the softest grade which will still provide a stable mixture. The cement must be prepared by refining of petroleum and must be void of all mineral matter other than those contained in asphalt. It also should be free from water and not foam when heated to 350° Fahrenheit.

Penetration of Original Sample at 77 °F., 100 g., 5 sec.	60 to 70 70 to 85 85 to 100	100 to 120 120 to 150 150 to 200
Flash Point, (Cleveland Open Cup) °F. . .	450+	425+
Loss on Heating at 325°F., 5 hrs., Per cent	1-	2-
Penetration after Loss on Heating, % of Original	70+	70+
Ductility at 77°F.	100+	60+
Per cent Soluble in Carbon Tetrachloride .	99.5+	99.5+

CONCLUSION

Although this thesis does not include all of the possible asphalt surfaces, I have endeavored to consider the more important constructions. I definitely feel satisfied that I have succeeded in my original goal of learning what materials are used and how each type is constructed.

It was very interesting for me to compare the specifications used in states located in various parts of these United States and to learn how each agree and disagree on the subject of constructing asphalt surfaces. Where one might be lax another would be very particular but then again, just the reverse might be true. From all indication, however, all states are in rather close agreement with the specifications suggested by the Asphalt Institute.

By the way of suggestion, I would like to say that I am of the opinion that it would be most beneficial for the writer to not only have his subject matter chosen but also have the necessary material available so he might begin work immediately upon the beginning of his thesis term. In my particular case I was several weeks gathering information both by mail and personal contact. I am now in a position where I have a wealth of material but not sufficient time to use it after having read the literature through and deciding what I wanted to include.

In my introduction I gave as my reason for deciding on this particular subject the fact that there was a possibility of my becoming employed as a Asphalt Sales Engineer with the Standard Oil Company. I am happy to say that although this particular position is not open at the present time, I have been interviewed with very good possibilities

of becoming employed by the Company and later on being transferred into the asphalt field.

BIBLIOGRAPHY

The Asphalt Institute, Asphalt Handbook (Construction Series No. 51)

The Asphalt Institute, Construction Specifications (Construction Series No. 50)

The Association of Asphalt Paving Technologists, Proceedings of The Association of Asphalt Paving Technologists, Technical Sessions Held at Chicago, Illinois January 20 and 21, 1942. Volume 13

The Association of Asphalt Paving Technologists, Proceedings of The Association of Asphalt Paving Technologists, Technical Sessions Held at St. Louis, Missouri November 30 and December 1, 1942. Volume 14

The Association of Asphalt Paving Technologists, Proceedings of The Association of Asphalt Paving Technologists, Technical Sessions Held at Chicago, Illinois December 1 and 2, 1943. Volume 15

J. E. Pennybacker, Asphalt: Nature's Most Versatile Product

John H. Bateman, Introduction To Highway Engineering, Fifth Edition, 1948.

Michigan State Highway Department, 1942 Standard Specifications for Road and Bridge Construction

North Carolina State Highway and Public Works Commission, Standard Specifications for Roads and Structures, January 1, 1946

Oregon State Highway Commission, Specifications and Contract Agreement for State Highway Construction, Issue of September 15, 1940

Texas Highway Department, Construction Bulletin C - 14, October 1947

ROOM USE ONLY