LOW COST ASPHALT PAVEMENTS AND BASES EMPLOYING LIQUID ASPHALTS

by

Iftikhar Ahmed Khan

B.Sc., University of Peshawar,
Peshawar, Pakistan, 1974

A MASTER'S REPORT

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Civil Engineering

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1976

Approved by:

Wayne W. Williams
Major Professor

309

TABLE OF CONTENTS

THIS BOOK CONTAINS NUMEROUS PAGES WITH DIAGRAMS THAT ARE CROOKED COMPARED TO THE REST OF THE INFORMATION ON THE PAGE.

THIS IS AS RECEIVED FROM CUSTOMER.

INTRODUCTION

STATEMENT OF THE STUDY

The construction or improvement of the road network is rightly regarded as one of the most effective ways of promoting economic development of a country. The state of a road network in a country and its economic development are therefore closely linked, and it is correct to say that the former is one of the conditions for the latter. The road must be designed to meet the needs in order to ensure the best return for the efforts made. Therefore, the road engineers have to discover how they can make the best use of their available resources, particularly the natural materials which can always be bought at a low price.

Low cost roads can be constructed by employing liquid asphalts, together with the naturally available mineral aggregate. Keeping this point in view, this report deals in how the liquid asphalts and mineral aggregate can be combined to produce economical pavements. The different liquid asphalts are explained, with brief discussions of their manufacture and application. Mineral aggregate is the most important part of an asphalt pavement, therefore it is shown which type of aggregate and how it is used in such flexible pavements. A brief description of the tests and specification of mineral aggregates is also given.

Soil stabilization is frequently used whenever it is necessary to improve the quality of the soil material in use. In this report, soil stabilization with asphalt is discussed, including the laboratory investigations that are in practice. How to make bases from soil treated with asphalt is explained next, that is, granular and cohesive soils. In the end two methods for constructing economical asphalt pavement surfaces are discussed. This report is limited to only rural roads, including, however, certain urban or suburban roads which have a rural character.

PURPOSE OF THE STUDY

With the development of modern road building machinary, it has become a regular affair to construct the less trafficed local rural roads in almost the same manner as the high type flexible pavements. This always results in spending an extra amount of finances, which otherwise can be saved if the methods for constructing low cost pavements were followed. The purpose of this report is to review all the pertinent literature, and put forward the different methods and uses of asphalt treated soil, in order to construct economical pavement bases and surfaces.

SCOPE OF THE STUDY

The scope of this study includes: a fairly intensive review of the pavement materials used in the construction of low cost roads, covering both the asphaltic materials and the mineral aggregates; soil-asphalt stabilization along with the required laboratory investigations; a discussion of asphalt treated pavement bases for cohesive, non-cohesive, and mixed soils; and two methods explaining the construction of economical asphalt pavings, namely, plant-mix and road-mix.

REVIEW OF LITERATURE

ASPHALT PAVEMENT MATERIALS

The materials used in the construction of a road are of intense interest to the highway engineer, who is always very deeply concerned with the properties of the materials being used. All roads have to be founded on the soil, and all require the efficient usage of locally available materials if economically-constructed facilities are to be obtained. This requires not only a thorough understanding of the soil and aggregate properties which affect pavement stability and durability, but also of the properties of the binding materials which may be added to improve these pavement features. Since here we are dealing with low-cost asphalt pavements, therefore we consider only the liquid asphalts. The liquid asphalts used are cutback asphalts, that is, rapid-curing (RC), medium-curing (MC), and slow-curing (SC), and emulsified asphalts, obtained by the combination of asphalt cement and water.

LIQUID ASPHALTS

In low-cost paving work, it is particularly convenient to work with an asphalt that is in liquid form at relatively low temperatures as compared to asphalt cement. Here, such liquid asphalts are discussed, like, the rapid-curing and medium-curing cutback liquid asphalts, the slow-curing cutback asphalts (road oils), and asphalt emulsions. The cutback materials are formed by combining with asphalt cement the volatiles obtained from the first distillation stage in the production of asphalt. Road oils are simply very soft (or liquid) asphalt cements, produced in the same manner as asphalt cement. Asphalt emulsion is obtained by physically combining asphalt cement with water, another method for obtaining a relatively free-flowing, liquid asphalt.

CUTBACK LIQUID ASPHALTS

In the manufacture of cutback liquid asphalts, a solvent is added to asphalt cement, which results in a liquid material that can be handled with equipment without the use of high temperatures. After the material is in place, it can revert to a normal penetration asphalt cement after the volatile component evaporates, that is, by the process of curing. Rapid-curing (RC) cutbacks are made by diluting with a typical naphtha or gasoline a base asphalt having a penetration ranging from 70 to 110 at 77°F. By using a base asphalt of this consistency, the asphalt residue that remains after loss of volatiles will have a penetration ranging from 80 to 120 at 77°F. Careful control of the naphtha or gasoline diluent will keep the flash point of the material above 80°F.

Medium-curing (MC) cutbacks are manufactured by diluting a base asphalt having a penetration of 70 to 250 at 77°F with a kerosene-type diluent. After a distillation test an asphalt residue having a penetration of 120 to 250 must be left. Thus, there are two important differences between RC and MC liquid asphalts. Rapid-curing cutbacks have a hard-base asphalt and a solvent that will evaporate at low temperatures, resulting in a material that will cure rapidly. The medium-curing cutbacks have a softer-base asphalt and a less volatile solvent and thus will cure at a slower rate than RC materials. Either one of these distinguishing characteristics might be the basis of choice of material for a given use. For example, in the construction of a surface treatment in a northern region, one might well choose the medium-curing cutback material because of its softer-base asphalt. The higher penetration-grade asphalt residue that would remain after the material had cured would become less brittle in winter and thus the surface treatment would be less

Table 1 Specifications for rapid-curing (RC) liquid asphalts*

Characteristics	*AASHO test method*	*ASTM test method*	*Grades* RC-70	RC-250	RC-800	RC-3000
Kinematic viscosity at 140°F, cs†	T 201	D 2170	70–140	250–500	800–1,600	3,000–6,000
Flash point (open tag.), °F	T 79	D 1310	......	80+	80+	80+
Distillation						
Distillate (percent of total distillate to 680°F):						
To 374°F	T 78	D 402	10+	......	......	......
To 437°F			50+	35+	15+	......
To 500°F			70+	60+	45+	25+
To 600°F			85+	80+	75+	70+
Residue from distillation to 680°F, percent by volume			55+	65+	75+	80+
Tests on residue from distillation:						
Penetration, 77°F, 100 g, 5 sec	T 49	D 5	80–120	80–120	80–120	80–120
Ductility, 77°F, cm	T 51	D 113	100+	100+	100+	100+
Solubility in carbon tetrachloride, %	T 44‡	D 4‡	99.5+	99.5+	99.5+	99.5+
Water, %	T 55	D 95	0.2−	0.2−	0.2−	0.2−

General requirement: The material shall not foam when heated to application temperature recommended by the Asphalt Institute.

Note: When the heptane-xylene equivalent test is specified by the consumer, a negative test with 35% xylene after 1 hr will be required, AASHO T 102.

* From Asphalt Institute [5].

† As an alternate, comparable Saybolt-Furol viscosities may be specified.

‡ Except that carbon tetrachloride or trichloroethylene is used instead of carbon disulfide as solvent, method 1 in AASHO T 44 or procedure 1 in ASTM D 4.

Table 2 Specifications for medium-curing (MC) liquid asphalts*

Characteristics	AASHO test method	ASTM test method	Grades				
			MC-30	MC-70	MC-250	MC-800	MC-3000
Kinematic viscosity at 140°F, cs‡	T 201	D 2170	30–60	70–140	250–500	800–1,600	3,000–6,000
Flash point (open tag.), °F†	T 79	D 1310	100+	100+	150+	150+	150+
Distillation							
Distillate (% of total distillate to 680°F):							
To 437°F			25−	20−	0–10	....	....
To 500°F	T 78	D 402	40–70	20–60	15–55	35−	15−
To 600°F			75–93	65–90	60–87	45–80	15–75
Residue from distillation to 680°F, % by volume			50+	55+	67+	75+	80+
Tests on residue from distillation							
Penetration, 77°F, 100 g, 5 sec	T 49	D 5	120–250	120–250	120–250	120–250	120–250
Ductility, 77°F, cm§	T 51	D 113	100+	100+	100+	100+	100+
Solubility in carbon tetrachloride, %	T 44¶	D 4¶	99.5+	99.5+	99.5+	99.5+	99.5+
Water, %	T 55	D 95	0.2−	0.2−	0.2−	0.2−	0.2−

General requirement: The material shall not foam when heated to application temperature recommended by the Asphalt Institute.

Note: When the heptane-xylene equivalent test is specified by the consumer, a negative test with 35% xylene after 1 hr will be required, AASHO T 102.

* From Asphalt Institute [5].

† Flash point by Cleveland open cup may be used for products having a flash point greater than 175°F.

‡ As an alternate, comparable Saybolt-Furol viscosities may be specified.

§ 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+.

¶ Except that carbon tetrachloride or trichloroethylene is used instead of carbon disulfide as solvent, method 1 in AASHO T 44 or procedure 1 in ASTM D 4.

subject to cracking. Also when an asphalt deteriorates to a penetration of less than 40, it becomes particularly susceptible of cracking, and the soft base of an MC material would take longer to deteriorate to a penetration of less than 40.

Conversely in the deep South, the choice might well be a rapid-curing cutback in order to obtain a harder-base asphalt. The harder-base asphalt should provide a more stable surface treatment under high summer temperatures. Thus, in these examples, the differences in curing rate were ignored. However, there can be circumstances when the choice would be made on the basis of curing rate, depending upon the particular circumstances of the job. It might be important that the material cure very rapidly so that traffic could proceed quickly on the new surface treatment or so that the damaging effects of a rainstorm could be avoided. On the other hand, owing to the nature of the project, it may be important to delay curing in order to allow time for sufficient rolling of the stone in the surface-treatment application; thus, a medium-curing cutback might be selected.

Cutback liquid asphalts are graded by viscosity. For many years it has been questioned whether so many grades of cutback liquid asphalts are needed. Also it has been felt that there would be less confusion if the grading viscosities were based upon a single temperature. As a result, the majority of state specifications now base the cutback liquid asphalt grading system on the kinematic viscosity test. This viscosity test is run at $140^{\circ}F$ for all grades of cutbacks. In this grading system, both RC and MC asphalt cutbacks are in the following grades: 70, 250, 800, and 3000. In addition, the MC is often specified for a grade 30. These numbers refer to the minimum of an allowable range of viscosity as determined by the kinematic viscosity test, in the units of centistokes. The grade 70, for example, has a kinematic viscosity range of 70 to 140 cs at 140°F. In each grade the top viscosity limit is double the minimum grade designation. For example, grade 3000 has a range of 3,000 to 6,000 cs. A cutback asphalt provides a means of using an asphalt of the desired viscosity, curing rate, and, at the end of the curing process, having residual asphalt of the desired penetration. The specifications for these materials are well standardized, obtaining similar materials from different manufacturers is not difficult.

SLOW CURING LIQUID ASPHALTS

Road oils, or the slow-curing liquid asphalts originally were manufactured by straight-run distillation and in every sense of the word were liquid-asphalt cements; that is they were manufactured in the same manner as asphalt cements except that the distillation process was cut off earlier so that many of the lubricating oil fractions remained in the asphalt residue. In more recent years, the slow-curing road oils (SC) are actually cutback asphalts, but instead of being asphalt cements cut back with a highly volatile solvent such as naphtha or kerosene, they are merely asphalt cements fluxed with some of the nonvolatile oils that are taken off in the second stage of the distillation process.

The same grades of SC liquid asphalts exist as for RC and MC materials; thus an SC-70 will have the same viscosity as an MC-70 or an RC-70. However, as can be seen from the method of manufacture, the SC road oil material differs from the other cutback liquid asphalts. The road oils are used primarily in the upper Midwest and Far Western regions of the United States. Principal uses are in road-mixing and dust-laying applications. They are also used in stockpile patching mixes, plant mixing with graded aggregates, and occasionally for priming. They are particularly useful in the type of road work where construction involves seasonal tearing and relaying of the existing SC oil mat.

Table 3 Specifications for slow-curing (SC) liquid asphalts*

Characteristics	AASHO test method	ASTM test method	Grades SC-70	SC-250	SC-800	SC-3000
Kinematic viscosity at 140°F, cs†	T 201	D 2170	70–140	250–500	800–1,600	3,000–6,000
Flash point (Cleveland open cup), °F	T 48	D 92	150+	175+	200+	225+
Distillation:						
Total distillate to 680°F, % by volume	T 78	D 402	10–30	4–20	2–12	5–
Float test on distillation residue at 122°F, sec.	T 50	D 139	20–100	25–110	50–140	75–200
Asphalt residue of 100 penetration, %	T 56	D 243	50+	60+	70+	80+
Ductility of 100 penetration asphalt residue at 77°F, cm	T 51	D 113	100+	100+	100+	100+
Solubility in carbon tetrachloride, %	T 44‡	D 4‡	99.5+	99.5+	99.5+	99.5+
Water, %	T 55	D 95	0.5–	0.5–	0.5–	0.5–

General requirement: The material shall not foam when heated to application temperature recommended by the Asphalt Institute.

Note: When the heptane-xylene equivalent test is specified by the consumer, a negative test with 35% xylene after 1 hr will be required, AASHO T 102.

* From Asphalt Institute [5].

† As an alternate, comparable Saybolt-Furol viscosities may be specified.

‡ Except that carbon tetrachloride or trichloroethylene is used instead of carbon disulfide as solvent, method 1 in AASHO T 44 or procedure 1 in ASTM D 4.

EMULSIFIED ASPHALTS

An asphalt emulsion is a mixture of asphalt and water where asphalt is usually the dispersed phase and water the continuous phase. Asphalt emulsification is merely another means of liquefying an asphalt for use. There are many advantages in the use of asphalt emulsions, such as: can be used with cold as well as hot aggregate, can be used with aggregate that is dry, damp, or wet. It also eliminates the fire and toxicity hazards that attend the use of cutback asphalts. Emulsions also have disadvantages, one of which is that they are easily subject to washing by rain. Also, their manufacture is not as standardized as that of other liquid asphalts.

Emulsions are made by mechanically dispersing a hot asphalt cement in water that has been treated with an emulsifying agent. This is usually accomplished by a colloid mill, which in principle consists of a high-velocity rotating element within a stationary cylinder. Emulsifying agent can be any one of a variety of soaps that are introduced along with water and asphalt in the mill, which breaks the asphalt into colloid-size particles. Usually the emulsifying agent is polar in nature, resulting in an emulsion with certain electrical surface characteristics. For normal asphalt emulsions the penetration-grade asphalts ranging from 50 to 300 penetration are used.

The two most commonly used types of emulsified asphalts are anionic and cationic. The type of asphalt emulsion is determined by the kind of emulsifying agent or soap used. The organic part of the emulsifier, adheres to the asphalt particle and imparts a positive or negative charge to the surface of the asphalt-emulsifier complex. With an anionic emulsion this asphalt surface charge is negative and for a cationic emulsion it is positive. There are three general grades for each of the two common types of emulsions. These

Table 4 Specifications for anionic emulsified asphalts*

Characteristics	AASHO test method	ASTM test method	Grades: Rapid setting RS-1	Rapid setting RS-2	Medium setting MS-2	Slow setting SS-1	Slow setting SS-1h
Tests on emulsion							
Furol viscosity at 77°F, sec			20–100	....	100+	20–100	20–100
Furol viscosity at 122°F, sec			....	75–400	....	....	......
Residue from distillation, % by weight			57+	62+	62+	57+	57+
Settlement, 5 days, % difference	T 59	D 244	3−	3−	3−	3−	3−
Demulsibility:							
35 ml of 0.02 N $CaCl_2$, %			60+	50+	....	....	......
50 ml of 0.10 N $CaCl_2$, %			....	....	30−	....	......
Sieve test (retained on No. 20), %			0.10−	0.10−	0.10−	0.10−	0.10−
Cement-mixing test, %			....	....	....	2.0−	2.0−
Tests on residue							
Penetration, 77°F, 100 g, 5 sec	T 49	D 5	100–200	100–200	100–200	100–200	40–90
Solubility in carbon tetrachloride, %	T 44†	D 4†	97.5+	97.5+	97.5+	97.5+	97.5+
Ductility, 77°F, cm	T 51	D 113	40+	40+	40+	40+	40+

* From Asphalt Institute [5].

† Except that carbon tetrachloride is used instead of carbon disulfide as solvent. Method 1 in AASHO T 44 or procedure 1 in ASTM D 4.

Table 5 Specifications for cationic emulsified asphalts*

Characteristics	*AASHO test method*	*ASTM test method*	Grades					
			Rapid setting		*Medium setting*		*Slow setting*	
			RS-2K	*RS-3K*	*SM-K*	*CM-K*	*SS-K*	*SS-Kh*
Tests on emulsion								
Furol viscosity at 77°F, sec	T 59	D 244	....	....	....	....	20–100	20–100
Furol viscosity at 122°F, sec	T 59	D 244	20–100	100–400	50–500	50–500	....	......
Residue from distillation:								
Residue, % by weight	T 59	D 244	60+	65+	60+	65+	57+	57+
Oil distillate, % by volume of emulsion	T 59	D 244	5−	5−	20−	12−	....	......
Settlement, 7 days, % difference	T 59	D 244	3−	3−	3−	3−	3−	3−
Sieve test (retained on No. 20), %	T 59†	D 244†	0.10−	0.10−	0.10−	0.10−	0.10−	0.10−
Aggregate coating—water resistance test	.....	D 244						
Dry aggregate (job), % coated			....	....	80+	80+	....	......
Wet aggregate (job), % coated			....	....	60+	60+	....	......
Cement-mixing test, %	T 59	D 244	....	....	....	....	2−	2−
Particle charge test	T 59A	D 244	Positive	Positive	Positive	Positive	....	......
pH	T 200	E 70	....	....	....	....	6.7−	6.7−
Tests on residue								
Penetration, 77°F, 100 g, 5 sec	T 49	D 5	100–250	100–250	100–250	100–250	100–200	40–90
Solubility in carbon tetrachloride, %	T 44‡	D 4‡	97.0+	97.0+	97.0+	97.0+	97.0+	97.0+
Ductility, 77°F, cm	T 51	D 113	40+	40+	40+	40+	40+	40+

* From Asphalt Institute [5].
† Except that distilled water is used instead of sodium oleate solution.
‡ Except that carbon tetrachloride is used instead of carbon disulfide as solvent, method 1 in AASHO T 44 or procedure 1 in ASTM D 4.
Note: (1) "K" in grade designations signifies cationic type.
(2) In medium setting grades:
"SM" indicates sand mixing grade.
"CM" indicates coarse-aggregate mixing grade.

grades are, rapid-setting (RS), medium-setting (MS), and slow-setting (SS). The rate of setting is controlled by the amount and type of emulsifying agent used.

Although all three grades of emulsions are produced in at least two viscosity ranges, the choice of grade depends upon the use to which the emulsion is put. Occasionally RS emulsions are used for very light seal coats. Basically RS emulsions are rather unstable, that is they contain relatively little emulsifying agent and slight disturbance will cause them to break or set. Thus, this emulsion cannot be used where it would be exposed to a large amount of aggregate surface area. Medium-setting grades of asphalt emulsions are used for mixing with fairly open-graded aggregates and can be used for penetration work in which the liquid asphalt is permitted to penetrate through a layer of aggregate, for seal coats and for surface treatments. These emulsions are more stable than those of the RS type; they contain more emulsifying agent and will not set up before mixing and compacting operations are completed when open-graded aggregates are used.

Slow-setting emulsions are used whenever high mixing stability is required. A common use of SS emulsions is in road mixes where the emulsion is mixed with existing roadbed material that may be granular but that may have many fines. The large amount of surface area presented to the emulsion by the fines would cause either an RS or an MS emulsion to break or set before construction could be completed. Only an emulsion with the amount and type of emulsifying agent to produce great stability is capable of this kind of work.

TESTS FOR LIQUID ASPHALTS

There are many tests used to control the quality of liquid asphalts. The kinematic viscosity test (ASTM D 2170) is used on liquid asphalts to test their viscosity. This viscosity test is essentially the same for liquid asphalts as for asphalt cements, the major difference being the temperature, which is 140°F instead of 275°F.

The test for distillation of cut-back asphaltic products, ASTM D 402-67, is a test that is performed to determine the type and quantity of both the volatile distillate and the asphalt residue of cutback asphalts and slow-curing road oils. Approximately 200 ml of material to be tested is placed in a distillation flask and a distillation process is carried out by heating the material according to a prescribed procedure. In the case of RC and MC materials, quantities of distillate are recorded for temperatures of 374°F, 437°F, 500°F, 600°F, and 680°F, at which time the test is terminated. For SC road oils, the only measurement made is at the 680°F level. For emulsified asphalt the 200 gm sample of emulsion is distilled in an iron still to a temperature of 500°F.

The Float test for asphalt materials, ASTM D 139-49, is a consistancy test that is used for materials that are too soft for the standard penetration test and generally too hard for use with the Saybolt-Furol viscosity test. The Cleveland open-cup flash-point test (ASTM D 92-66) is normally specified for slow-curing road oils and occasionally for the higher-viscosity medium-curing cutbacks. These flash-point tests are used to determine the temperature to which asphalt materials may be safely heated. Water content of asphalt materials is determined by the test for water in petroleum and other asphalt materials, ASMT D 95-62. As far as liquid asphalts are concerned, the purpose of the test is to determine the purity of the product. In the water content test for emulsified asphalt, a smaller sample is taken because of the large amount of water present in an asphalt emulsion.

MINERAL AGGREGATES

Mineral aggregates are the basic materials of highway pavement construction. In asphalt pavements they constitute 88-96% by weight, or something more than 75% by volume. Therefore, their influence on the properties and performance of asphalt mixes is great. There are many types of asphalt mixtures; still, it is possible to formulate a concept of an ideal aggregate for most uses. The ideal aggregate would have proper particle size and gradation, be strong and tough, and consist of angular, nearly equidimensional or "chunky" particles with moderatley low porosity and surfaces that are clean, rough, and "hydrophobic". Aggregate size, gradation, strength, toughness, and shape are primarily for stability, as with base-course materials. However, porosity and nature of the aggregate surface are important to aggregate-asphalt interaction. The asphalt must adequately cover the aggregate and adhere to the aggregate surface. Coverage without the use of excessive asphalt material may be difficult for highly porous aggregates, or, with adequate coverage, an excessive amount of volatiles in the asphalt may be absorbed by the aggregate.

A lack of proper asphalt-aggregate adhesion may occur with smooth aggregate surfaces of very low porosity or those that do not bond well to asphalt because of surface chemistry. Adhesion is particularly important during periods when the mix is exposed to water. If the aggregate is of a type that wets easily with water, water may successfully compete with the asphalt for adsorption onto the aggregate surface and aggregate-asphalt separation, known as stripping, results.

It is known that, as control over quality and gradation of mineral aggregate is decreased, the overall cost of the pavement is decreased too. Therefore, it depends upon the type of pavement; a cheap pavement would not require strict control over quality and gradation of aggregate, while a high type would definitely require. Certain general requirements should be met by all mineral aggregates for pavements. For example, those given by AASHO for dense-graded asphalt plant-mix surface course (AASHO designation M62-64) are representative:

> Aggregates shall be of uniform quality, crushed to size as necessary, and shall be composed of sound, tough, durable pebbles or fragments of rock or slag with or without sand or other inert finely divided mineral aggregate. All material shall be free from clay balls, vegetable matter and other deleterious substances, and an excess of flat or elongated pieces. Slag shall be air-cooled blast-furnace slag of reasonably uniform density and quality. Excess of fine material shall be wasted before crushing.

A typical specification for mineral aggregates for road mix is that of the Illinois Division of Highways. It requires that 100% pass the 1½ inch sieve, 90-100% pass the 1 inch, 60-90% pass the ½ inch, 35-55% pass the No. 4, 10-40% pass the No. 16, and 4-12% pass the No. 200. From this example we can see, how fairly broad the range is set for mineral aggregates, or in other words how less stringent controls are applied.

SIZE AND GRADATION

Depending upon the use or purpose of the mix, a wide variety of sizes and gradations of aggregate may be used. Asphalt mix used for the surface of heavily traveled roads generally contains densely graded aggregate, that is, materials that are well graded from coarse to fine. In actual practice the specifying engineer should be acquainted with the gradation that the local aggregate producers are capable of economically producing and should select a gradation that will show satisfactory results in the laboratory and the field.

STRENGTH AND TOUGHNESS

Since the aggregate in an asphalt mixture supplies most of the mechanical stability, it must have a certain amount of strength and toughness to prevent breakdown under traffic and subsequent loss of stability. Open-graded mixes, for a given load, are probably subject to greater forces of breakdown than aggregate in dense-graded mixes. Thus, when working with a material with minimal strength or crushing resistance, a denser gradation perhaps would be more desirable than one which is open graded. The most commonly used test for measuring the strength and toughness of an aggregate, is the Los Angeles Rattler Test (AASHO designation T96-731). This test is both an impact and an abrasion test.

PARTICLE SHAPE

Particle shape is another very important property. Angular aggregate characteristics give aggregate interlock properties that increase the stability of open-graded materials. In fact, it is very difficult to use well-rounded gravels in an open-graded asphalt mixture because of the lack of stability of the resulting mix. Additions of crushed angular fine aggregate have produced marked increases in stability in all types of mixes.

When rounded gravels must be used to produce highly stable surface mixtures, generally the specification will require that a certain percentage of the coarse aggregate be crushed. A typical specification might require a minimum of 40% of the particles retained on the No. 4 sieve to have at least one fractured face. It is known that crushing rounded gravels adds significantly only to the stability of one-sized aggregate mixes, to open-graded mixes a very little, and to mixes that are dense graded, not at all. Thus gradation control would seem to be most important in the production of a highly stable gravel surface mixture. In most cases, thin and elongated aggregate pieces are also potentially troublesome.

POROSITY

Porosity is of less importance than other properties of aggregates in asphalt mixtures, but it strongly affects the economics of a mix. Except for the requirements of a certain amount of porosity available in an aggregate so that proper adhesion between the aggregate and asphalt will result, high porosities generally do not affect the quality of a mix. However, the higher the porosities, the more asphalt will be absorbed into the aggregate, thus causing a higher percent asphalt required in the mix design.

SURFACE TEXTURE

A rough finish on an aggregate surface makes it more difficult for forces imposed by the pavement loadings to cause the displacement of one particle upon another. Surface texture is also important to adhesion between the aggregate and asphalt material. A smooth glossy aggregate is easy to coat with an asphalt film but offers little adhesion to hold the film in place. Thus, the rougher the surface texture, generally the higher the stability and durability of the asphalt mixture. The crushing of rounded gravels not only produces a more desirable particle shape but also produces a rougher surface texture.

SURFACE CHEMISTRY

The surface chemistry of aggregate particles plays an important role in the design of asphalt mixtures. One of the problems involving aggregates in asphalt mixtures is the stripping of the aggregate from the asphalt during service. The greater the attraction the asphalt has for the aggregate, the less likely that water will get between the film of asphalt material and the aggregate particle, thus permitting the aggregate particle to be whipped out from the surface by the action of traffic.

The term hydrophobic is generally applied to aggregates that have great attraction to asphalt. The basic aggregates, such as limestone, are generally more easily wetted by asphalt than water, and these aggregates are called hydrophobic aggregates. Perhaps a better description as revealed by more recent research is to say that these aggregates are electropositive in nature; that is, they have a positive surface charge which tends to repel water. This so-called dislike of water is implied in the term hydrophobic.

Acidic or siliceous aggregates, such as quartz, more often than not are wetted more easily by water than by asphalt. They are termed hydrophyllic or water-liking, and the term electronegative is now being applied to such aggregates.

SPECIFIC GRAVITY

The specific gravity of aggregates is quite important from the standpoint of mixture calculations such as for the determination of void contents in compacted asphalt mixtures.

SOIL ASPHALT STABILIZATION

Natural soil is both a complex and variable material. Since it is available at a low cost, it offers great opportunities for skillful use as an engineering material.

Most of the time, the soil at any particular locality is unsuited, wholly or partially, to the requirements of the construction engineer. A basic decision must therefore be made, whether to accept the site material as it is, and design with restrictions imposed by its existing quality, or, to remove the site material, and replace it with a superior material, or, alter the properties of the existing soil so as to create a new site material capable of better meeting the requirements of the task in hand. The latter choice, the alteration of soil properties to meet specific engineering requirements, is known as "soil stabilization". There are many ways by which the properties of a soil may be altered -- and one such way is asphalt stabilization.

Soil-asphalt stabilization is used by mixing local soil or aggregate with asphaltic material to form a stable and water proofed base course. The aim is to balance the cost of materials, equipment, and labour to give the most economical design. Asphalt stabilized base courses resist deformation through the cementing action of the asphalt which binds the soil particles together. This resistance to deformation is further aided by waterproofing, which is obtained by the thin coating of asphalt around the soil particle.

Asphalt stabilization proper is used with non-cohesive granular materials, where asphalt adds cohesive strength; and with cohesive materials, where asphalt waterproofs the soil thus reducing loss of strength with increase in moisture content. Both effects stem partly from the formation of films around the soil particles, which stick them together and prevent the absorption of water, and partly from simple blocking of the pores, preventing water from entering the soil mass.

Many engineers have successfully used asphalt materials to waterproof mixtures of both granular materials and troublesome fines. This procedure takes advantage of the fact that the strength of a soil aggregate increases as its moisture content decreases. It follows that, if a base can be placed at a low moisture content and subsequent moisture penetration prevented, the base will maintain high strength. The grading of the soil components of a waterproofed stabilized base is about the same as that for granular bases.

LABORATORY INVESTIGATIONS

In order to determine the type, grade, and amount of asphaltic material for a well-balanced mix design, laboratory investigations are needed, which consists of soil analysis and tests. Soil analysis, showing the grain sizes, and silt and clay content, gives the answer whether or not that particular soil is suitable for asphalt stabilization. Such soils are usually rejected, which contains more than 45% passing No. 200 sieve.

The grade and amount of asphaltic material most suitable for a particular soil can be determined. To perform this a number of mixes are prepared in the laboratory and tested for stability and moisture absorption. The strength reaches a maximum value as the asphalt content is raised, but then strength decreases as the asphalt films become thicker. The higher asphalt content, however, imparts greater waterproofing, and thus it is usual to adopt a compromise between maximum waterproofing and maximum strength. Figure 1, shows a typical variation in strength; and figure 2, shows the change in water absorption against volatiles content.

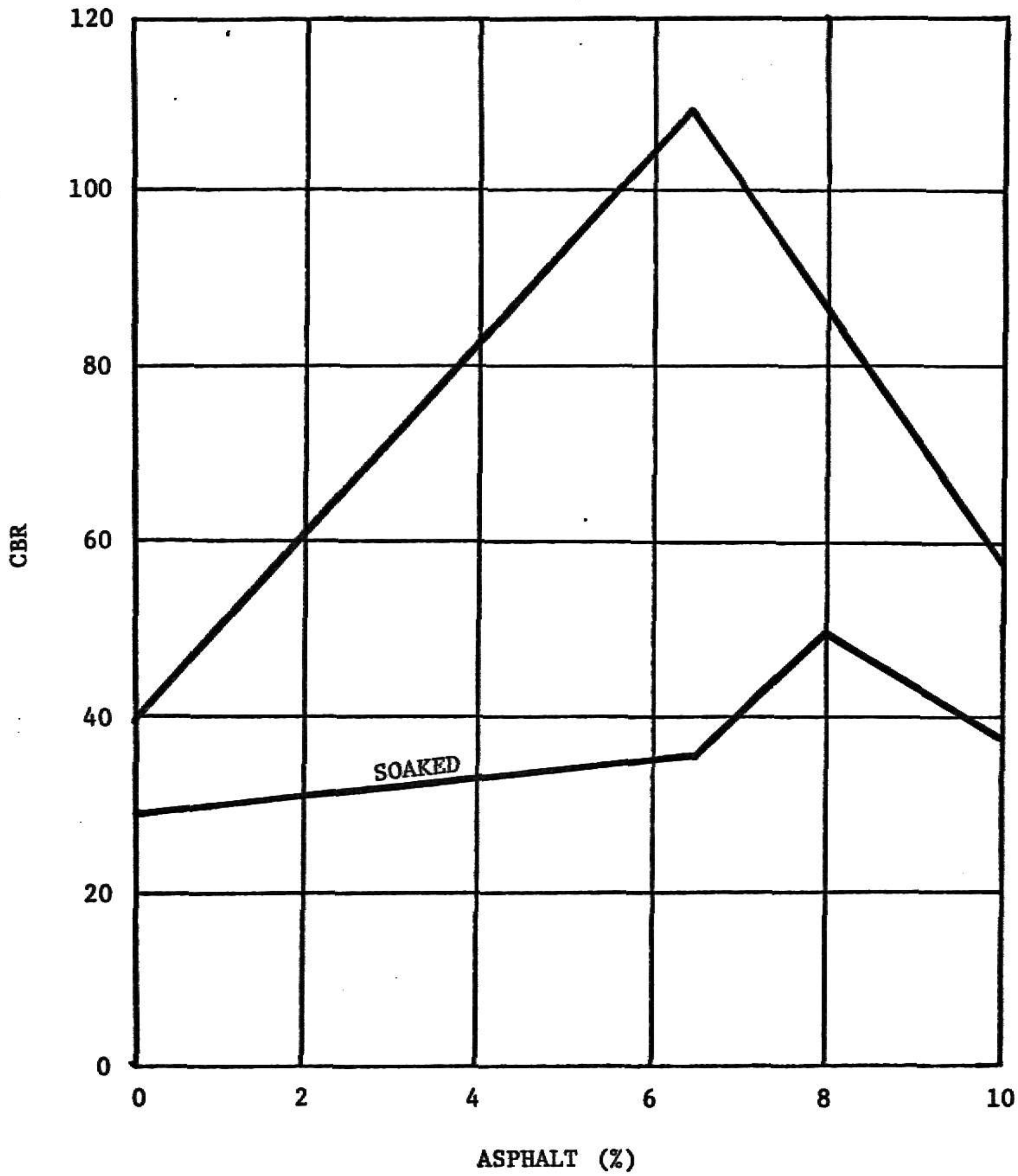

Figure 1. Variation in bearing capacity (CBR) of a gravelly sand stabilized with cutback asphalt (Ingles and Metcalf; Australia, 1972).

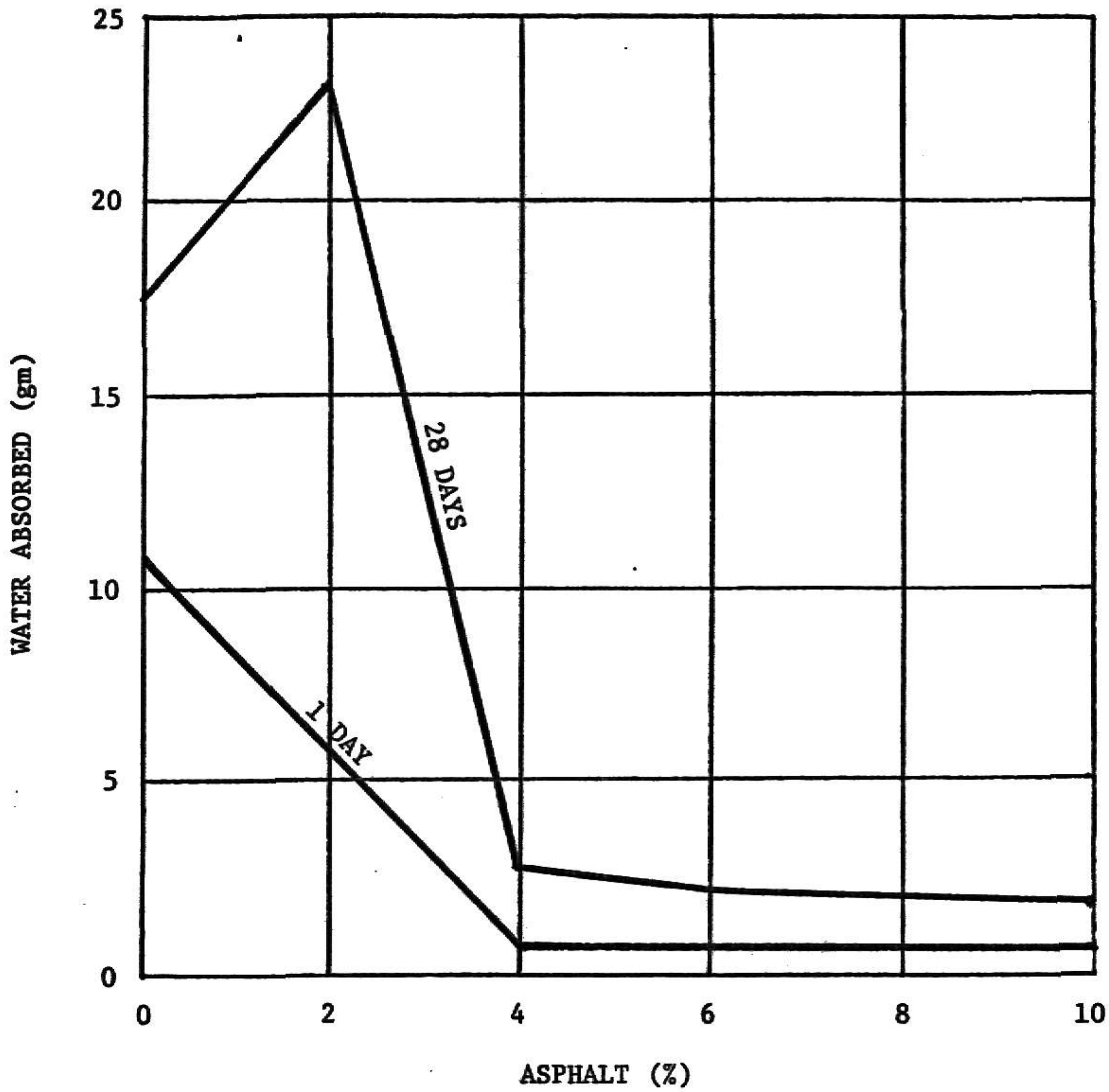

Figure 2. Water absorption of sandy clay stabilized with a cutback asphalt (from Soil Mechanics for Road Engineers, H.M.S.O. London, 1961).

The above mentioned mixes should be made with a broad range of asphaltic contents in increments of 0.5 percent. Mixes prepared in the laboratory with the following amounts in percent, 3.5, 4.0, 4.5, 5.0, 5.5, 6.0, 6.5, 7.0, of asphaltic material will locate the optimum asphaltic content. Laboratory tests may be reduced to only three or four different asphalt contents for a particular soil with which experience has been gained.

Both in laboratory and on the project if a homogeneous mass is needed with a minimum of mixing effort, the soil should contain some moisture for cutback asphalt mixes, and 10% or more moisture for emulsified asphalt mixes. The reason for moisture is that it acts as a carrier for the asphalt and is an aid to mixing.

Addition of the asphalt stabilizer reduces the need for water to be added for compaction, and this may be a considerable advantage in very dry conditions although the maximum density will be reduced, as shown in figure 3. Because for any compacted density, the higher the asphalt content the less the absorption and loss of strength on soaking compared to the untreated material. And because, beyond a certain level the strength decreases and the material may be impossible to compact, the total volatiles content is important. For any given soil, however, the combined volume of asphalt and water must not completely fill the pore space of the soil system at the desired compacted density, otherwise the particle interlock will be prevented. If it does so, the mixture will lack stability even though its resistance to deterioration under the influence of water is comparitively high.

After the laboratory mixes have been moulded and cured, they are tested for dry and wet stabilities and moisture absorption and then plotted on a graph as shown in figure 4. For testing stabilities many tests are in use,

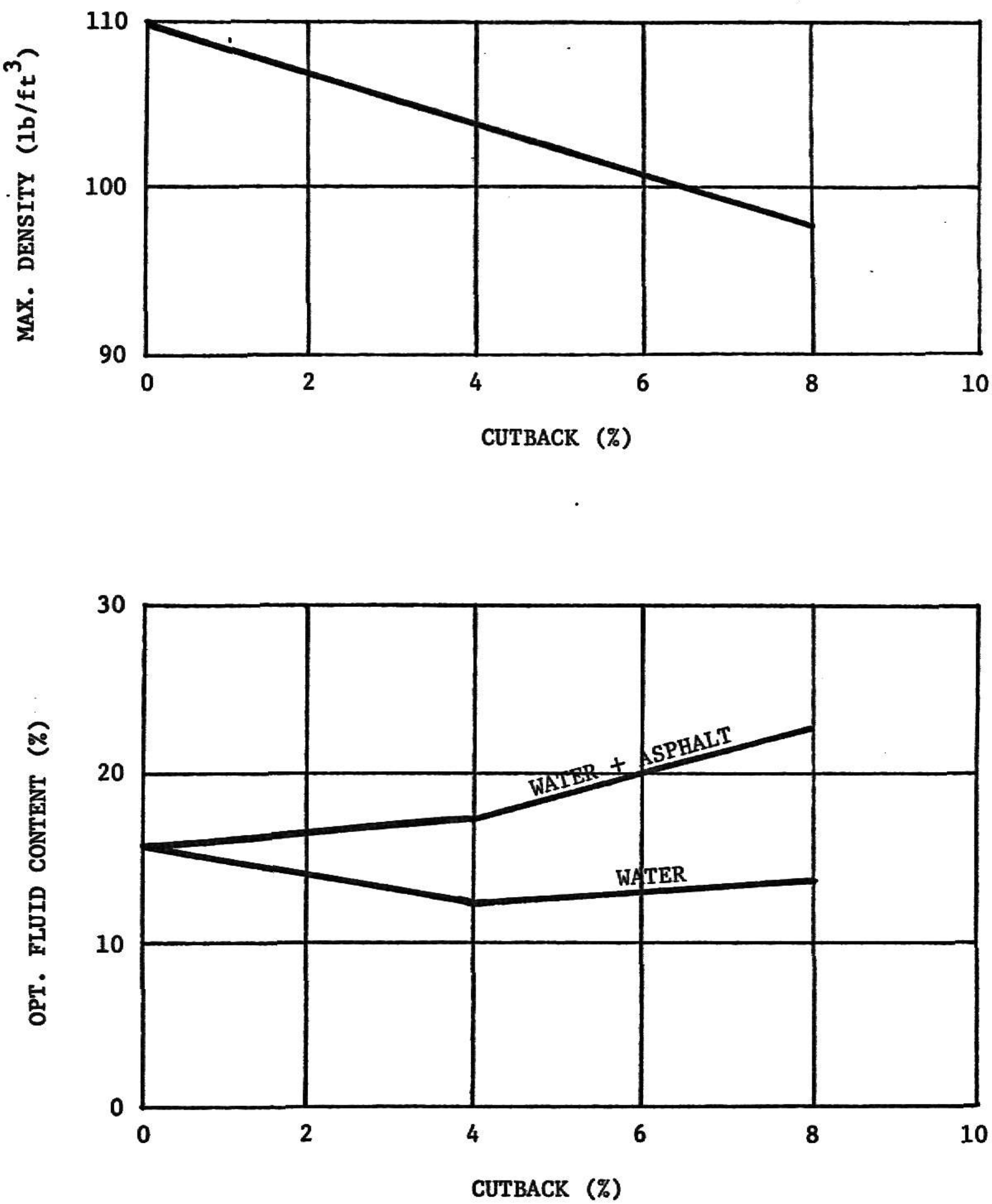

Figure 3. Effect of asphalt stabilizer on masimum compacted density and optimum moisture content (from Soil Mechanics for Road Engineers, H.M.S.O. London, 1961).

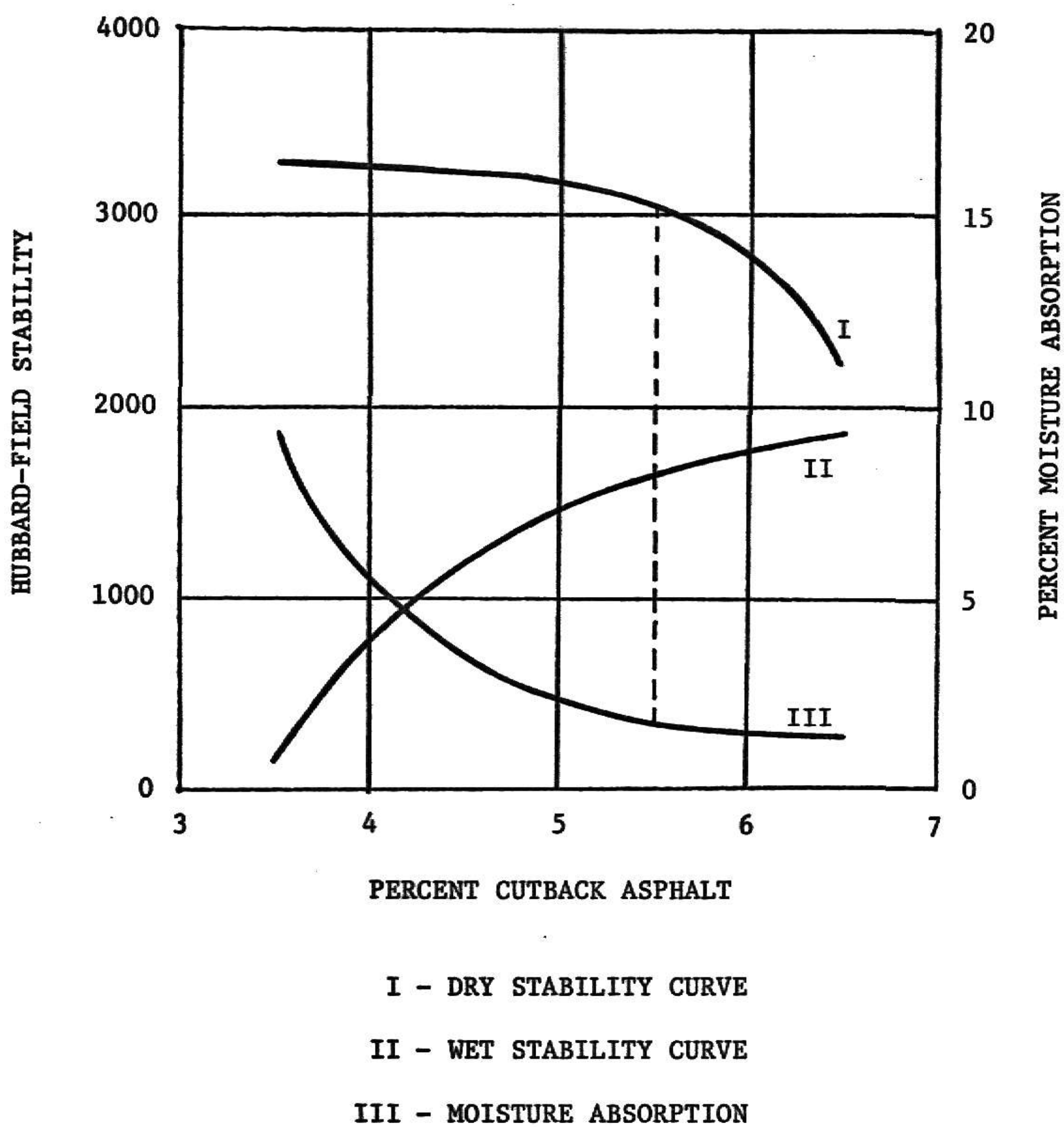

Figure 4. Typical curves of results of preliminary laboratory investigations of soil to be stabilized with an asphaltic material (Wallace and Martin, 1967).

like the following, Hubbard-Field, Hveem, triaxial, and Marshall. Moisture-absorption tests may be made by placing the moulded specimen in a capillary tank for 7 days or by complete emersion for 24 hours.

From the laboratory tests a well-balanced mix design should be selected, one which does not exceed the maximum moisture absorption allowed and does not fall below the minimum stability requirements. In case a soil considered for use borders any of the cohesionless or cohesive soils classifications, preliminary laboratory investigations should include two types of asphaltic materials.

ASPHALT-TREATED BASES

Before 1940, base courses consisted only of mineral aggregates, the most common types were the granular base courses. A granular base course is a mixture of soil particles ranging in size from coarse to fine. In order to secure the desired grading, oversize particles were crushed and screening was done where necessary. Macadam type bases involving successive layers of crushed stone bound with rock dust were also used. Since about 1940, "treated bases" composed of mineral aggregates and additives to make them stronger or more resistant to moisture have become increasingly common. One way of making treated base courses which is gaining popularity day by day, is, combining soil-aggregate base-course materials with asphalt.

In the northern states, there are areas of deep frost penetration, where subbases of clean non-capillary materials often underlie the regular base course. These seldom, if ever, are treated, otherwise whenever subbases are treated with asphalt, they are treated in order to gain extra strength. Materials such as clean sands or even clays, which alone would be unsatisfactory as base, may furnish the soil portions of these mixtures. These treatments are adopted when, in the judgement of the roadway designer, a satisfactory result can be obtained at a lower overall cost.

ASPHALT TREATED SANDY SOILS

When the soil is extremely sandy or those containing a minimum of silt and clay particles, rapid curing cutback or emulsified asphalts produce best results. Soils having a plasticity index 5 or less are included in this range. Soils having little or no plasticity are cohesionless and depend upon the cementing value of the asphaltic material for stability. Sand-asphalt bases have a particular application in the southern, Gulf, and certain midwestern states where aggregates from streams or quarries are costly, but deposits of clean sand are available within reasonable distances. According to "HRB special report 117, as of 1971", 14 state highway departments are employing them.

Sands, to be suitable for sand-asphalt bases, must be relatively clean. Grading is not critical, but the sand must be stable; that is, the surface properties and grain shape must be such that they will resist displacement under load. The Hubbard-Field, Marshall, or Hveem stabilometer tests are commonly used to determine stability of sands for sand-asphalt mixes. If the sand is not satisfactory, it may be blended with sharp angular particles such as crushed aggregates, stone or slag screenings, stone dust, loess, or other substantially non-cohesive mineral matter to produce a stable mixture.

For sandy soils, the following are used: rapid-curing (RC) or medium-curing (MC) asphalts, or slow setting emulsified asphalts. The asphalt material by weight used in these mixes, ranges from 4-10% for cutbacks, and from 5-10% for emulsified asphalts. Whenever such mixes are made, an optimum binder (asphalt) content must be used, so that overall stability is increased. According to the American practice, liquid rapid-curing cutbacks are commonly used. But the exact grade selected in any particular instance depends on climate and mixing conditions prevailing. In the British practice, the most commonly used asphaltic material is the medium curing cutbacks.

ASPHALT TREATED COHESIVE SOILS

Only liquid asphalts are suitable for stabilizing cohesive soils. For soils having a plasticity index range of 6 to 10, medium-curing cutback asphalts having a kerosene-type liquifier give good results. As the plasticity of a soil increases, cohesion also increases, therefore, the stability of a mixture of this classification of soil depends upon both the cementing value of the asphaltic material and the cohesion of the clay particles in the soil. Emulsified asphalts are also satisfactory with some soils within this plasticity range.

When there are clay soils of a high plasticity-index range, slow-curing cutback asphalts made liquid by the addition of gas oil or heavy residuals penetrate these soils more rapidly than do other types of asphaltic materials. That is, these are used to allow time for thorough dispersal of the asphalt waterproofer throughout the soil. For best results such soils should have a plasticity index of more than 10, or silt and clay contents of more than 30%. These highly cohesive soils have greater inherent binding characteristics, and depend less upon the cementing value of the asphaltic material. As a rule cohesive soils have satisfactory bearing capacity at relatively low moisture content. But they loose strength when the moisture content becomes high. By incorporating an asphalt waterproof agent with the soil, it is possible to maintain the low-moisture condition and an adequate load carrying capacity in the base. The amount required to stabilize a cohesive soil usually varies between 4-8%. At the present time there is no satisfactory method to determine what content should be used in a given situation.

The clay mineral present in the soil has quite an effect on the stability of a soil-asphalt mixture. Kaolinitic soils are easy to stabilize but montmorillinites can be difficult due to mixing problems. The greater the silica content of the clay minerals, the greater the amount of stabilizer required. Research has shown, however, that the addition of small amounts of certain antistripping agents and reactive chemicals, such as phosphorus pentoxide (P_2O_5), hold promise for improving and broadening the effectiveness of asphalts as stabilizing agents for cohesive soils. Considerable care must be exercised, however in both the selection of additives and their method of incorporation in a soil, if the maximum benefits are to be realized.

SAND-GRAVEL-ASPHALT MIXTURES

In the construction of pavements, sand-gravel-asphalt mixtures are generally used under similar conditions and circumstances as the sand-asphalt mixtures for treated bases. Sand-gravel material has a fairly good gradation, and the frictional characteristics are okay, but has little or no cohesion. When asphalt is mixed with such a material, both the binding of the soil particles and waterproofing in the base is obtained. For typical gradings of aggregate, more than 50% should pass through a No. 10 U.S. standard sieve. Such a sandy gravel should contain less than 1% of clay content by weight. The moisture content of the aggregate should be 3-8%. The asphalt content is normally between 3.5-6.0% by weight of total mix, depending upon the amount of traffic carried per day.

PLANT-MIX PAVEMENTS

The materials for this type of asphalt surfaces is obtained by plant mixing of local aggregates with some liquid asphalt. However, as the term is commonly used, asphalt concrete, sheet asphalt, and open-graded mixes are excluded, and "plant mix" generally denotes the cheaper and less rigidly controlled products. By mixing the materials at a plant and placing them as soon as they are delivered to the road, many of the delays caused by inclement weather are avoided.

As of today, then, a pavement called plant-mix by one agency may be equal in almost every regard to the asphalt concrete of another. Some have dropped the plant-mix designation completely in favour of asphalt concrete. Still others retain both, with plant mix less rigorously controlled. But, when it comes to designing an economical pavement, then obviously the choice is plant-mix, rather than spending additional amounts on employing asphalt cement, and strict control over aggregate quality and grading.

The cost of producing plant-mix materials increases each time some additional refinement is introduced and as controls over grading and other characteristics are tightened. However, by introducing these refinements and controls, the engineer gains added assurance that the completed surface will give satisfactory service.

HEATED PLANT MIXES

These mixes employ the higher-viscosity liquid asphalts. Types and grades of asphaltic materials suitable for these mixes are RC-800, RC-3000, MC-800, MC-3000, SC-800, and SC-3000. Because the quantity and boiling point range of the solvent used in manufacturing the above types and grades of cutback asphalts vary, the mixing temperature should be regulated accordingly, with lower temperatures for the RC materials and the high temperature for the SC materials. The mixing temperature for liquid asphalt mixes is considerably lower as compared to asphalt cement mixes. The temperature ranges from approximately 175°F to 250°F. In table 5-1, are given the working temperatures of asphalt concrete, and various liquid asphalt materials.

During the mixing period, much of the solvent in the cutback asphalt is evaporated but not always enough to provide a stable pavement; therefore, additional manipulation for further aeration is sometimes necessary before compaction.

Table 6. Suggested spraying and mixing temperatures for asphaltic materials (from Asphalt Institute).

Type and Grade of Asphalt	Pugmill Mixing Temperature: Dense-Graded Aggregate	Pugmill Mixing Temperature: Open-Graded Aggregate	Spraying Temperature: Blade Mixing	Spraying Temperature: Surface Treatments
Asphalt Cements				
40- 50	275-350	225-310	———	300-410
60- 70	265-330	225-305	———	295-405
85-100	255-325	225-300	———	290-400
120-150	245-325	225-300	———	285-395
200-300	225-300	225-300	———	275-385
Cutback Asphalts (RC, MC, SC)				
30 (MC)	60-105		35-210	85-190
70	95-140		65-235	120-225
250	135-175		105-260	165-270
800	165-205		135-295	200-305
3000	200-240		165-330	235-345
Emulsified Asphalts				
RS-1 CRS-1	———		———	75-130
RS-2 CRS-2	———		———	110-160
MS-2 CMS-2 CMS-2S	50-170		50-170	100-160
SS-1 CSS-1	50-170		50-170	75-130
SS-1h CSS-1h	50-170		50-170	75-130

COLD PLANT MIXES

For "cold laid" and similar plant mixes having binders of cutbacks or emulsions, aeration before laying may be needed to permit evaporation of some of the solvent or water. Otherwise the pavement may be overlubricated and unstable. Cold-plant mixes are similar in most respects to hot-plant mixes, except that they employ the lower-viscosity cutback asphalts and emulsified asphalts, and are mixed at normal temperatures. Such mixes can be used immediately as they are made, or can be shipped and stockpiled for future use. The type and grade of most suitable asphaltic material is governed by the aggregate gradation and the usage of the pavement by future traffic.

Mixtures made with cutbacks must be thoroughly aerated before compaction, as they contain volatiles. Aeration is usually performed by blading the mixture back and forth on the roadway until a large percentage of the volatiles has evaporated. Evaporation of the volatiles is noted by an increasing stiffness of the mixture during its manipulation. When thoroughly aerated, these mixtures appear to be very stiff, but they still have sufficient workability to be spread smoothly with motorgraders.

Mixes for immediate placement may be made with RC-70 or MC-250 cutback asphalts, or a medium-setting emulsified asphalt. Such surface-course mixes should be dense-graded, that is, these should contain 35-45% of minus-10-mesh aggregate. Drying of the aggregate for cutback-asphalt mixes is necessary only when the aggregate is saturated or has some surface moisture. Emulsified-asphalt mixes may be made with wet aggregate; in fact, the addition of water is necessary, especially when the aggregate contains a high percentage of minus-10-mesh material.

Mixes made with medium-setting emulsified asphalt are placed without aeration and compacted. Low humidity and high atmospheric temperatures cause emulsified-asphalt cold mixes to cure rapidly; however, the reversal of weather conditions retards the curing time.

In a cold-mixed paving material, the amount of minus-10-mesh aggregate has considerable bearing upon the workability of the mixture. Therefore cutback-asphalt cold mixes which are to be stockpiled for future use generally contain 5-10% less of the minus-10-mesh fraction than mixes manufactured for immediate placement. Medium-curing cutback asphalt (MC-70) used as the liquid asphalt for stockpiled paving mixture affords the necessary workability.

ROAD-MIX PAVEMENTS

Road-mixed, or mixed-in-place surface courses are constructed by either travelling mixing plant or by the use of motor graders. Surface-course mixes constructed in this manner are of a lower quality and lower cost than plant mixes, because there is no positive gradation control. Both, processed and natural materials can be used as aggregate for these road-mixed surfaces. If a blend of two or more materials is necessary to provide a satisfactory gradation, the blending is usually performed before the material is transported to the project.

Many variations to the original road-mix process have been developed. One of the most important has been to import mineral aggregate from local pits or quarries instead of using the loosened material from the existing road surface. In this manner it is possible to control more closely its quality and grading, particularly the percentage of dust. Furthermore, a constant amount of mineral aggregate per unit of roadway length can be assured by sizing the aggregate windrow with a spreader box. This results in a more uniform asphalt content and fewer fat and lean spots in the completed roadway.

Road-mix processing is now often performed by a single machine which picks up the aggregate from the roadway and adds and mixes in the asphalt in a specified amount. Spreading of the processed mix is commonly done with blade graders, but may be done with a finishing machine.

Dense-graded and open-graded aggregates, sands and sandy soils have all been successfully road-mixed. Materials high in fines and without fines and with or without coarse aggregate have been used. Sometimes roadside pits, even without screening, offer suitable materials. At times no processing other than the rejection of oversize or of excess fines is needed. Angular, broken particles which produce added stability are to be perferred, but crushing to produce them adds to the costs and is avoided unless it is necessary to produce the desired grading. A typical specification for mineral aggregates for road mix is that of the Illinois Division of Highways. It requires that 100% pass the 1½ inch sieve, 90-100% pass the 1 inch, 60-90% pass ½ inch, 35-55% pass the No. 4, 10-40% pass the No. 16, and 4-12% pass the No. 200. By comparing these grading limits with those given for typical asphalt concrete, it can be seen that less stringent controls are applied to road mix with the aim that the aggregates will be less costly. It is also common to control the character of the fines in road mix. For example, the Arizona Highway Department sets the plasticity index at 5 or less.

Road mixes, like other pavements, must be placed on a sound roadbed of width somewhat greater than the pavement itself. Satisfactory results cannot be obtained over yielding subgrades or those that become unstable when the evaporation of capillary moisture is prevented by the moistureproof asphaltic blanket. Furthermore, the roadbed must be carefuly leveled and consolidated before roadmix operations are begun; otherwise variations in the thickness of the asphaltic blanket or undulations in the finished surface must result. Maintaining constant surface thickness is particularly troublesome on superelevated curves. As would be expected, smoothness requirements for road mix are less stringent than for asphalt concrete. For example, the California Division of

Highways permits a variation of 1/4 inch under a 12 foot straightedge, as contrasted with 1/8 inch for asphalt concrete.

During the rainy season, processing by road-mix method is done under a serious handicap. Mixing in the rain soon soaks the spread-out materials; therefore, if it begins to rain, the mix must be quickly pushed into a windrow. This is sometimes hastened by spreading and blading the mixture. If wet mixtures are laid down, they will probably be unstable. This is commonly controlled in a manner, that in case the moisture content of the mixture exceeds some maximum such as 1 or 1.5% by weight, laying down of the material on the road for construction is not done. Therefore construction is prohibited when weather is severe.

TRAVELING PLANTS

Mechanical mixers are the common traveling plants used for roadmixing the asphalt material and aggregate. These mechanical mixers lift the aggregate from a windrow, and pass it through a pugmill mixer, where it is sprayed with asphalt material at a predetermined rate. This windrow is formed from a uniformly sized aggregate, so that the amount of asphalt sprayed can be controlled according to the requirement for the size of the windrow.

Besides the mechanical mixers, other types of traveling plants are those which take the aggregate from an in-place position or which operate from a flattened windrow having aggregate in a uniform loose depth prior to mixing operations. The plants which take the aggregate from an in-place position loosen the material and pulverize it, introduce the asphalt material at a controlled rate, and thoroughly mix the component parts. The mixture is left in a loose condition ready for aeration.

Aggregates having an approximate maximum size of 1 inch, and not more than 40% of minus-10-mesh material, RC-800 cutback, MC-800 cutback, or medium-setting MS-2, SM-K, or CM-K emulsified asphalt may be used. When the minus-10-mesh fraction exceeds 40%, a more homogeneous mix is obtained with lower-viscosity cutbacks, such as RC-250 and MC-250. A small amount of moisture, 3-4%, which acts as a carrier for the asphalt, aids in obtaining a good mix.

BLADE MIXING

Mixing by blade grader is probably the least costly method in terms of mechanical plant. This type of mix-in-place can be done with the most common pieces of road-building equipment, such as harrows, ploughs and tillers. Windrowed material is spread over the formation and the binder added, in several stages, by spraying machine to give the required total amount. Between each application of binder the mixture is bladed across the road alternately in each direction, the blade turning the material over so that the particles are gradually coated with binder. Care is necessary not to loose uncoated material outside the mixing area. It is equally important not to scrape the foundation with the blade because this will introduce extra aggregate or soil into the mix. The time to obtain a uniform mix by the blade method can sometimes be lengthy, varying with the type of mix, binder consistancy, and air temperature. The work will not be successful, however, unless mixing is continued until all obviously dry and rich patches have been rectified. Since, with blade graders a longer period of time is required to obtain an equal mix, therefore it is more practical to use a lower-viscosity cutback asphalt. Asphaltic materials most suitable for mixing with motor graders are RC-70, RC-250, MC-70, and MC-250 cutback asphalts, and medium-setting MS-2, CM-K, or SM-K emulsified asphalt.

Mixtures which have undesirably high moisture contents must be aerated before they are compacted. Failure to do this will give an unstable pavement. To aerate the mix it should be well turned over by blading, tilling, harrowing or other means, to expose it as much as possible to sun and wind. The time between spreading and rolling is largely governed by the curing rate of the mix and its ability to be compacted without serious deformation. Thus, material mixed by the blade method, in which it is usual to use binders of low viscosity, may have to be left for some time before compaction.

NUMERICAL EXAMPLES

The California Bearing-Ratio curves are used to make the design (pavement thickness) for the example given below. These curves were first developed by O. J. Porter, in conjunction with the U.S. Army Corps of Engineers in 1942, and are still being used. The using of these curves, as shown in figure 5, is straightforward and simple.

In figure 5, the curves in the highway weight range seem to be based on a total of around 700,000 to 8000,000 repetitions of the designated "wheel load". For a 9,000 pound wheel load, for example, this corresponds to around one-hundred 18,000 pounds equivalent single-axle loads per day for a 20-year life.

EXAMPLE 1; UNTREATED BASE

The road subgrade is a clayey soil with a CBR of 3. The wheel load is to be 12,000 pounds. A sandy material with a CBR of 9 is to serve as a subbase. The base is to be crushed stone with a CRB of 80. Asphalt paving is to be used as the surface course.

1. The 12,000 pound curve intersects the vertical line for a CBR of 3 at 22 inches. This means that the subgrade must be at least 22 inches below the pavement surface.

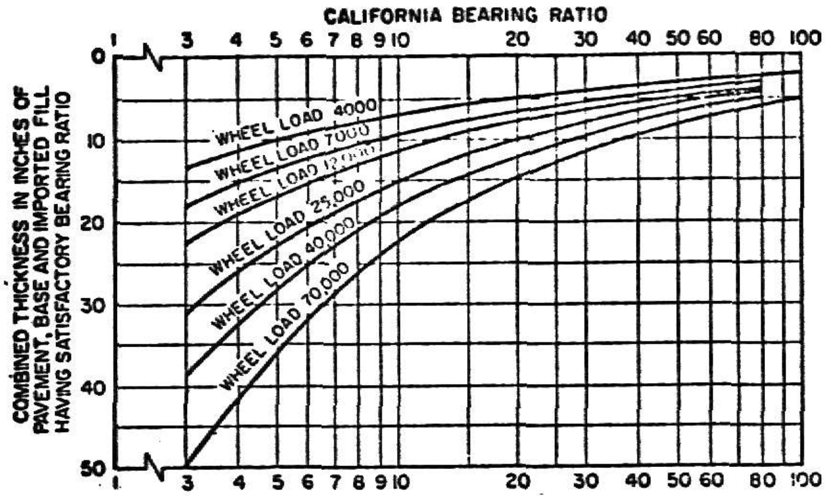

Figure 5. California bearing ratio in percent at 0.1 inch penetration.

2. The subbase material has a CBR of 9. Therefore the 12,000 pound curve intersects the vertical line for a CBR of 9 at 12 inches. This means that the top of the sand layer must be at least 12 inches below the pavement surface.
3. The designer chooses to use 4 inches of asphalt paving as the surface course. This fixes the base thickness at 8 inches.

The design is, as shown in figure 6, 4 inches of paving, 8 inches of crushed stone base, and 10 inches of subbase.

<u>EXAMPLE 2; ASPHALT TREATED BASE</u>

The road subgrade is a clayey soil with a CBR of 3. The wheel load is to be 12,000 pounds. A sandy material with a CBR of 9 is to serve as a subbase. The base is to be asphalt treated soil-aggregate with a CBR of 80. Asphalt paving is to be used as the surface course.

1. The 12,000 pound curve intersects the vertical line for a CBR of 3 at 22 inches. This means that the subgrade must be at least 22 inches below the pavement surface.
2. The 12,000 pound curve intersects the vertical line for a CBR of 9 at 12 inches. This means that the top of the subbase layer must be at least 12 inches below the pavement surface.
3. The designer chooses to use 4 inches of asphalt paving, and 8 inches of asphalt treated soil-aggregate base course.

The design is, as shown in figure 7, 4 inches of paving, 8 inches of asphalt treated soil-aggregate base, and 10 inches of subbase.

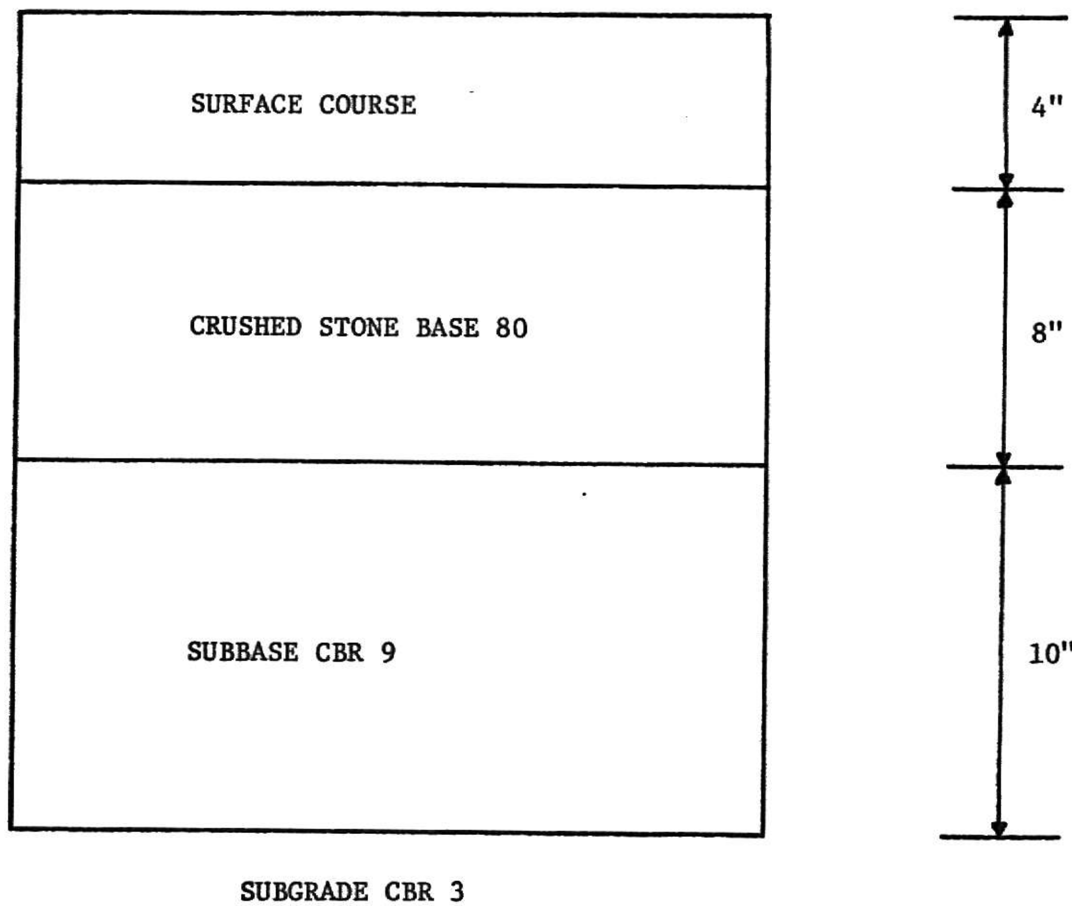

Figure 6. The design is 4 inches of paving, 8 inches of crushed-stone base, and 10 inches of subbase.

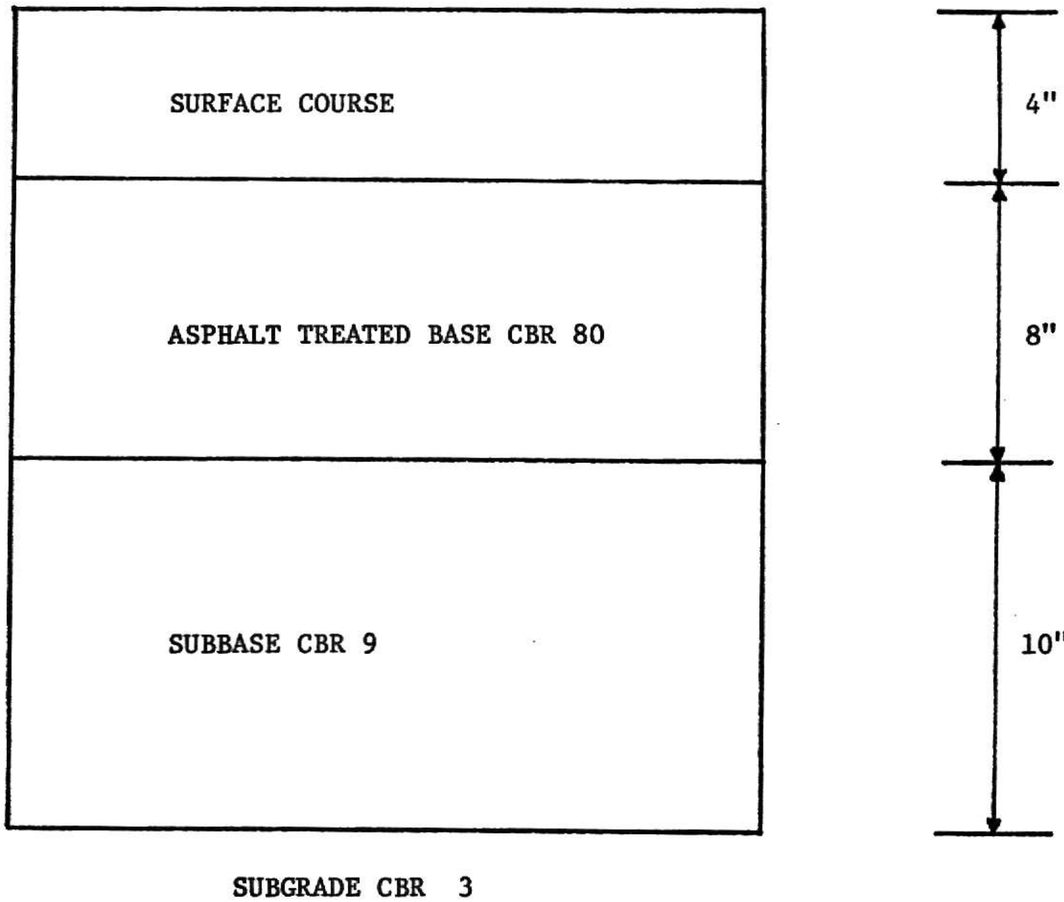

Figure 7. The design is 4 inches of paving, 8 inches of asphalt treated soil-aggregate base, and 10 inches of subbase.

CONCLUSIONS

1. Liquid asphalts and mineral aggregates are the two main materials employed in the construction of low cost asphalt pavements. Therefore, the highway engineer should always have a clear understanding of these two pavement materials.
2. For best results a proper asphalt should always be used for the right type of climate and the soil in use. A variety of materials may be used including all types of locally available aggregates.
3. Definite consideration should be given to soil-asphalt stabilization whenever such materials are encountered which can be upgraded by asphalt treatment. Each time the strength characteristics of the natural material should be compared to the stabilized material.
4. Soil-aggregate bases treated with asphalt have shown excellent performance. To get maximum stability, too great a quantity of fines should be avoided, anyway, the primary criterion should always be the cost.
5. Granular soils as well as highly cohesive soils can be stabilized with asphalt. The procedure for sand-gravel mixtures is the same as for sand.
6. Plant-mix and mixed-in-place are both good methods for construction of economical asphalt pavement surfaces. They should be adopted whenever cheap pavement construction is required.

REFERENCES

1. Hatherly, L. W., and Leaver, P. C., Asphaltic Road Materials, Edward Arnold (Publisher's) Ltd., London, 1967, pp. 1-49.

2. Krebs, Robert D., and Walker, Richard D., Highway Materials, McGraw-Hill Book Company, 1971, pp. 331-374.

3. Road Research Laboratory, Bituminous Materials in Road Construction, H.M.S.O., London, 1969, pp. 9-49.

4. Ingles, O. G., and Metcalf, J. B., Soil Stabilization, Butterworths Pty. Limited, Australia, 1972, pp. 145-168.

5. Yoder, E. J., and Witczak, M. W., Principles of Pavement Design, John Wiley and Sons, Inc., 1975, pp. 504-551.

6. O'Flaherty, C. A., Highway Engineering Vol. 2, Edward Arnold (Publishers) Ltd., London, 1974, pp. 352-391.

7. Transportation Research Record No. 521, "Asphalt Concrete Pavement Design and Evaluation," 1975, pp. 47-59.

8. Wallace, Hugh A., and Martin, J. Rogers, Asphalt Pavement Engineering, McGraw-Hill Book Company, 1967, pp. 118-131 and 174-181.

9. UNESCO, Low Cost Roads, Butterworths and Co. (Publishers) Ltd., London, 1971, pp. 55-87.

10. Oglesbey, Clarkson H., Highway Engineering Third Edition, John Wiley and Sons, 1975, pp. 563-643.

LOW COST ASPHALT PAVEMENTS AND BASES EMPLOYING LIQUID ASPHALTS

by

Iftikhar Ahmed Khan

B.Sc., University of Peshawar,
Peshawar, Pakistan, 1974

AN ABSTRACT OF A MASTER'S REPORT

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Civil Engineering

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1976

ABSTRACT

The object of this report is to present some general principles for the design and construction of low cost asphalt pavements.

The various materials that are the components of such asphalt pavements are explained. The different liquid asphalts are discussed and procedures are given for their manufacture and application. Mineral aggregate is the most important part of a flexible pavement, therefore, the different specifications and tests are given for such materials used.

Soil-asphalt stabilization is described along with the laboratory investigations that are required. It also presents the asphalt treatment of cohesive, non-cohesive, and mixed soils, thus showing that no matter what type the soil is, it can always be made more stable and durable if asphalt stabilization is used. Plant-mix and road-mix are two methods explained in the end of this report, they should be adopted whenever construction of economical asphalt pavings is desired.