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BITUMINOUS PAVEMENT

Thomas L. Speer, Homewood, Ill., assignor to Standard Oil Company, Chicago, Ill., a corporation of Indiana
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This invention relates to bituminous pavements and more particularly pertains to bituminous pavements of increased strength, and durability and decreased tendency toward flexural cracking and surface rutting and a method for preparing bituminous compositions to be used for said pavement.

Conventional blacktop pavements have a tendency to not wear well under conditions imposed by dense truck, bus and other heavy commercial traffic. During the warm summer months, asphalt paving shoves about. Ruts form and the smooth surface is lost. At other seasons, the flexing of the roadway under large loads causes many cracks to form at the top and bottom slab surfaces. Repeated bending slowly propagates such cracks through the available slab thickness. At locations where several cracks intersect or are closely spaced, traffic slowly breaks the pavement wearing it into smaller and smaller parts. Eventually, some of the pieces break loose. When the loose pieces are thrown out by motor vehicle wheels, a chuck hole appears. Nearly all pavements fail through a combination of rutting, cracking, and accelerated wear near cracks.

The present invention slows these normal roadway breakdown processes. It accomplishes this with a three to twelve fold increase in the tensile strength of the material used to pave the roadway. This means the pavement is stronger in bending, requiring much higher loads or many, many more cycles of a given load to cause ruts and chuck holes.

It has been discovered that tensile and flex strength of bituminous pavements can be substantially increased by incorporating into a bituminous paving composition binder course and/or surface course containing aggregate and as an aggregate binder or asphaltic material, bituminous substance, mixed first by the conventional mixing cycle, of not less than 0.6 or more than 15% finely divided or powdered elemental sulfur and not less than 1.0 or more than 20.0% finely divided carbon both by weight based on the aggregate.

The two elements, sulfur and carbon, are "post mixed." This means the major dispersion of asphalt into films covering the surfaces of the roadway aggregate is completed without benefit of either additive. This is another way of saying the initial mixing procedures are normal. Further, the addition of sulfur and carbon as post additives is new, and unique, to road paving operations. An important point with this type of mixing may be the fact that the additives (elemental sulfur and carbon such as coke) are not permitted to contact directly the mixture aggregate or have any opportunity to adhere to its extensive surface area. Rather they incorporate themselves into the asphalt films enclosing the rock, sand, and dust particles. Through such a mechanism, my process is able to modify, change and strengthen these films. The result is a paving formulation having appreciably higher than normal tensile strength. Each of the two post mixing cycles should continue for about 1 to 3 minutes, depending on the efficiency of the particular asphalt mixer. Thorough dispersal of each additive is desirable and important to the final strength properties of the vulcanized paving material. Careful control of the two post mixing cycles is essential.

Small additional strength benefits are obtained when exact temperature control is required during pavement laying and rolling procedures. A minimum temperature

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of 290° F. is required. In practice, special heated truck beds may be required for construction projects where long haul deliveries of the asphalt paving material are practiced. Although this procedure is desirable, it is not an essential feature of this invention.

Essential components needed to prepare bituminous pavements according to this invention are (1) any standard road paving formulation which makes a satisfactory slab in terms of acceptable highway specification properties, (2) a post mix addition of not less than 0.6 or more than 15.0 weight percent finely divided or powdered elemental sulfur and (3) a final addition of not less than 1.0 or more than 20.0 weight percent finely divided or powdered elemental carbon. Properties of each of three principal components of vulcanized asphalt paving are hereinafter discussed.

The standard road paving formulation may be any one of a large list of materials. Basically, it must be a compound produced by careful, precise blending of selected size graded stone or gravel, sand, asphaltic binder cement and powdered inert mineral filler. Each ingredient must be present in a specified amount; however, the actual quantity may be allowed to vary within certain formulation tolerances. Batching and mixing procedures must be specified and under exact control at all times. Types of blacktop pavements include: American Association State Highway Officials specifications M20-42 and M22-42 for penetration grades; M81-42; M82-42 and M149-49 for cutbacks and M140-49 for emulsified asphalt materials. Hot mixes employing penetration type (viz. grades 30-40; 40-50; 50-60; 60-70; 70-85; 85-100; 100-120; 120-150; 150-200, etc.), hot or cold mixes using rapid curing (viz. grade RC-0; RC-1; RC-2; RC-3; RC-4; RC-5, etc.), medium curing (viz. grades MC-0; MC-1; MC-2; MC-3; MC-4; MC-5, etc.), slow curing (viz. grades SC-0; SC-1; SC-2; SC-3; SC-4; SC-5; SC-6, etc.), cutback and emulsified (viz. grades RS-1; RS-2; MS-1; MS-2; MS-3; MS-4; SS-1, etc.) asphalts. Acceptable batching and mixing procedures are necessary; they must meet minimum requirements of the applicable specifications of individual highway departments. This means the resulting road paving material must have uniform physical properties and all ingredients must be completely mixed during this first step in the new process.

An example of a standard road paving formulation is Illinois Division of Highways Specifications for "Bituminous Concrete Binder and Surface Courses, Fine Dense-Graded Aggregate Type, Class I, Subclass 1-11." Mixture B of paragraph 45.10 of this specification would be used for the lower or binder course. Formulation tolerances are: aggregate passing $\frac{3}{4}$ in. sieve, 95-100 weight percent; passing $\frac{3}{4}$ in. and retained $\frac{1}{2}$ in. sieve, 15-30 weight percent; passing $\frac{1}{2}$ in. and retained No. 10 sieve, 35-50 weight percent; passing No. 10 sieve, 20-40 weight percent; penetration grade asphalt, 4-7 weight percent of the total aggregate used. Material described in paragraph 45.11 of this same specification would be used for the surface course. Formulation tolerances are: aggregate passing the $\frac{1}{2}$ in. sieve 95-100 weight percent; passing $\frac{1}{2}$ in. and retained on No. 4 sieve, 25-50 weight percent; passing No. 4 and retained on No. 10 sieve, 10-30 weight percent; the combined No. 4 and No. 10 sieve fraction, 45-65 weight percent; passing No. 10 and retained on No. 40 sieve, 5-18 weight percent; passing No. 40 and retained on No. 80 sieve, 7-22 weight percent; passing No. 80 and retained on No. 200 sieve, 5-13 weight percent; the combined No. 40, No. 80 and No. 200 sieve fraction, 25-40 weight percent; passing No. 200 sieve 4-8 weight percent; penetration grade asphalt, 5-7 weight percent of the total aggregate. Many other examples of standard road paving formulations are found in specifica-

tion documents of various highway departments and road contactors. The standard formulation is prepared and mixed in the normal way with conventional asphalt mixing or blending equipment.

The effect of sulfur and carbon actually begins with the second step. Before the mixture is discharged from the batching operation (either batch plant or mobile road mixing machine), but not until the conventional mixing cycle is completed, sulfur powder is added. This chemical should be elemental in form. Particle size is relatively important but not critical. Preferably 100 percent should pass the No. 60 sieve; 80–100 weight percent should be retained on the No. 325 sieve. The temperature of the sulfur should be close to ambient air temperature for both hot and cold type standard paving formulations. When the proper quantity of sulfur has been mixed into the paving material, the consistency of the mass may undergo a significant change. In many instances the paving mixture is readily pourable and behaves as a viscous fluid after the sulfur is introduced; on occasion, a pronounced sticky state may result.

Normal paving consistency returns when the second additive, elemental carbon, is introduced. This material is warmed to the temperature of the material being vulcanized. Once again, particle size of the carbon is relatively important but not critical. Preferably 100 percent should pass the No. 40 sieve; 80–100 percent should be retained on the No. 325 sieve primarily to control loss during post mixing. The form of carbon is not important, all types including petroleum coke are satisfactory.

Evidence has been obtained relating certain molecular structure changes in blacktop pavements to the high strengths produced with additions to carbon and sulfur. X-ray diffraction and fluorescence analysis techniques were employed. With a standard paving mixture, X-ray diffraction analysis did not detect elemental sulfur in the acetone soluble fraction; however, a small amount of sulfur was found with fluorescence analysis. These data suggest the sulfur of this fraction is present as a compound, most probably a mercaptan. The vulcanized paving mixture was found to contain at least ten times as much sulfur by fluorescence analysis; the acetone soluble fraction contains sulfur by fluorescence analysis and elemental sulfur by diffraction analysis. Small visible crystals have been found in and isolated from the vulcanized material; none have been found in the standard paving material. X-ray diffraction pattern for these crystals contains the following lines:

<i>d</i> (Interplanar spacing), Å:	Relative intensity
3.081 -----	Weak
3.659 -----	Strong
3.785 -----	Medium
4.410 -----	Medium

This pattern does not correspond to elemental sulfur. The material has not yet been identified; however, these lines characterize it. These results have been compared with X-ray diffraction data available from the American Society for Testing Materials and the Engineering Research Department's extensive standards file. For reference the three characteristic interplanar spacings for elemental sulfur are given below:

<i>d</i> (Interplanar spacing), Å:	Relative intensity
3.818 -----	Strong
3.207 -----	Medium
3.032 -----	Medium

An illustrative example of bituminous paving composition of this invention, in preparation, use in paving and the results of the use of the resulting pavement under heavy load conditions are hereinafter described.

EXAMPLE

The following summarizes formulation and property data for two asphalt paving mixtures. One, the control

material, is a standard road paving mixture prepared with 85–100 penetration, C-Y Crude, negative spot test asphalt. The other, the vulcanized paving material, is approximately identical to the control; however, post additions of 7.5 weight percent sulfur and 7.5 weight percent coke were made, both paving materials are laid at a temperature of approximately 320° F. The amounts of materials employed are all expressed on the basis of weight percent.

Mixture Formula	Control	Inventive Example
A. Base Course:		
Crushed Limestone—		
Pass ¾ in. and retained ½ in. sieve.....	25	25
Pass ½ in. and retained No. 10 sieve.....	45	45
Lake Sand—Pass No. 10 sieve.....	30	30
Total Aggregate.....	100	100
85–100 penetration, negative spot, C-Y asphalt ¹	5.5	5.5
B. Surface Course:		
Crushed Limestone—		
Pass ½ in. and retained No. 4 sieve.....	30	30
Pass No. 4 and retained No. 10 sieve.....	26	26
Crushed Limestone and Lake Sand—		
Pass No. 10 and retained No. 40 sieve.....	18	18
Pass No. 40 and retained No. 80 sieve.....	11	11
Pass No. 80 and retained No. 200 sieve.....	8	8
Limestone Dust—Pass No. 200 sieve.....	7	7
Total Aggregate.....	100	100
85–100 penetration, negative spot, C-Y asphalt.....	6.0	5.5
Elemental Sulfur ²	0	7.5
Elemental Carbon ²	0	7.5

¹ Asphalt content is weight percent using aggregate weight=100.

² Asphalt, sulfur and carbon content is weight percent using aggregate weight=100.

Mechanical Strength Average Values	Control	Inventive Example
Compressive Strength—lbs. per sq. in., Marshall.....	116	650
Tensile Strength—lbs. per sq. in., Cohesimeter.....	2	31

Traffic service ratings

Initial results from laboratory highway tests—expressive of probable field experience. Rating values are:

- A—Much better than average service
- B—Somewhat better than average service
- C—Average service expected with this type of paving and expert construction
- D—Somewhat poorer than average service
- E—Very poor service
- F—Abnormal deterioration

Such a laboratory highway testing apparatus for simulating traffic conditions comprises, for example, a circle of paving about 44 feet in circumference. Automobile and/or truck tires, mounted on rotatable wheels and inflated as in actual highway use, are driven around the indoor track of test pavement under actual highway traffic conditions of speed, load, weather, etc. In the test apparatus employed, a braking means (a generator) is connected to at least one of the wheels traveling on the test pavement and a power (electric motor) means is connected to at least another one of the wheels traveling on the test pavement. The braking means is adapted to apply decelerating torque to the wheels on which it is mounted and to generate power. The power generated is employed to apply an accelerating torque through the motor to the wheel or wheels to which the motor is connected. The testing apparatus employed is unaffected by

either the level of direction or individual wheel torques. All wheels are mounted by individual suspensions to a common rotating power source for the suspensions. By

hereinbefore defined traffic service ratings. These ratings are shown in a side-by-side comparison throughout said table for each time interval of observation.

TABLE.—TRAFFIC SERVICE RATINGS

	After 26 Hours ¹		After 55 Hours ²		After 110 Hours ³		After 260 Hours ⁴	
	Control	Invention Example	Control	Invention Example	Control	Invention Example	Control	Invention Example
Pavement Surface Texture.....	C-----	A-----	C-----	A-----	C-----	A-----	C-----	A-----
Total Overall Abrasive Wear.....	B-----	A-----	B-----	A-----	C-----	A-----	C-----	B-----
Resistance to Rock Loss Under Wheel Torque.....	B-----	A-----	B-----	A-----	C-----	A-----	C-----	A-----
Effective Slab Flexural Action.....	A-----	A-----	A-----	A-----	A-----	A-----	A-----	A-----
Pavement Crack Resistance.....	A-----	A-----	B-----	A-----	B-----	A-----	C-----	A-----
Pavement Shove Resistance.....	B-----	A-----	B-----	A-----	C-----	A-----	C-----	A-----
Pavement Rut Resistance.....	B-----	A-----	C-----	A-----	C-----	B-----	C-----	B-----

¹ Approximately 250,000 wheel passages of machine.
² Approximately 525,000 wheel passages of machine.
³ Approximately 1,050,000 wheel passages of machine.
⁴ Approximately 2,500,000 wheel passages of machine.

unique wheel suspension, there is achieved constant vertical load control which remains unaffected by non-uniform roughening and wear along the test pavement. This unique suspension also forces the individual wheels to follow road roughness features and thus uniformly load stronger and weaker areas of test pavement. This uniform loading, as it will be readily appreciated, duplicates vehicular travel conditions even though the paving suffers appreciable elastic and plastic road-strain deformations. The test apparatus is so constructed as to minimize the vertical shock vibrations. In the test apparatus, therefore, there are driving wheels which exert tractive forces on the surface of the test pavement. Other of the wheels are driven, that is, just follow as do the non-driving wheels of a motor vehicle. The driving wheels, of course, produce a tractive force rearward the direction of the movement of the wheels and shove the pavement rearwardly. The rolling action of the wheels exerts a force which tends to move the pavement forward. When braking action is applied to the wheels rotating on the test pavement, the decelerating torque produces an additional forward acting force which tends to make the paving surface move forward. The test paving is also subjected to lateral force as a result of the loading factor on individual wheels. The torque force applied to the wheel rolling on the test pavement is varied to approach jack-rabbit starting and panic braking. Sections of the circular pavement are subjected to temperature gradients (heating and cooling), other sections are intermittently frozen and thawed. Subgrades of the pavement are frozen and thawed. Ultra-violet radiation is applied to the pavement to induce aging, and in general, all types of weather conditions are simulated. Such laboratory traffic simulator for miniaturized highways can test at one time the various conditions of weather to which pavements are normally subjected. For example, a portion of the length of the miniaturized pavement can be subjected to accelerated aging, another portion to changes in temperature encountered where daytime maximum pavement temperatures reach say 160° F. and nighttime temperatures drop to 50-60° F., another portion can be subjected to freezing and thawing of either the pavement or sub-soil, another portion can be subjected to normal temperatures of day and night with normal rain cycles, etc.

The test pavement is constructed as a highway should be, paying particular attention to subgrade soil, rock base, and the hot mix asphalt courses.

The asphalt pavement hereinbefore noted as "Control" and the pavement hereinbefore noted as "Inventive Example" were each tested on such a traffic simulating apparatus under identical conditions of temperature, temperature fluctuation, precipitation, wheel loading, cycles of torque variation, aging, etc. The results of these tests are set forth in the table hereinafter following, using the

The foregoing example contains data for one specific vulcanized asphalt paving formulation. This material appears to approach optimum strength conditions when evaluated with slow, nearly static, California cohesiometer bending test procedures. It has also exhibited good resistance to traffic type deterioration forces in laboratory highway test machine. The particular mixture summarized in the example represents the magnitude of changes which can be expected from roads built with the compositions of this invention. However, the function of the foregoing example as a part of this disclosure is purely illustrative and it is not a limitation of the applicability of the preparation of compositions of this invention.

One unexpected result was observed with vulcanized mixtures. The roadway surface was abnormally smooth and flat. Small depressions or surface discontinuities did not appear between individual pieces of aggregate. The tight uniform surface was observed to form under the action of the heavily loaded rollers used to compact asphalt roadways. Under the action of wheel traffic surface wear of the vulcanized material is materially reduced. The rubber tires did not contact exposed corners of rocks as accelerating and braking torque forces were applied. With the standard mixes, particles are worked loose and torn out of the pavements by these forces. This action leaves a deeply pockmarked surface. In winter, moisture collects and freezes in the pits; expansive forces then crack the cold, brittle asphalt and the hole is enlarged by the loss of loosened aggregate under the action of vehicular wheels. Eventually, a very rough dangerous condition develops in areas where adequate surface maintenance through surface seal treatments is not provided. Roadways prepared according to this invention minimize this problem. Considerable economy results because the expense of seal treating can be eliminated or alternatively appreciably reduced.

Vulcanized asphalt formulations may be used for all classes of expressways, highways, roads and streets. It is well suited for new construction and makes excellent resurfacing for worn pavements. It may also be used for airport paving, parking lots, service areas around commercial buildings and shopping plazas, tennis courts and all other installations where a strong, smooth and durable paving is required.

What is claimed is:

1. A bituminous paving composition consisting essentially of aggregate, a bituminous substance as aggregate binder, finely divided elemental sulfur in the range of from 0.6 to 15% and finely divided carbon in the range of from 1.0 to 20% by weight based on the aggregate weight wherein sulfur and carbon are added as post mix additives to the mixture of aggregate coated with said aggregate binder.

2. The composition of claim 1 wherein the sulfur particles are of a size permitting 100% to pass through a No.

60 sieve and the carbon particles are of a size permitting 100% to pass through a No. 40 sieve.

3. The composition of claim 1 wherein the sulfur particles are of a size permitting 100% to pass through a No. 60 sieve and 80 to 100% to be retained on a No. 325 sieve and the carbon particles are of a size permitting 100% to pass through a No. 40 sieve and 80 to 100% to be retained on a No. 325 sieve.

4. A bituminous paving composition consisting essentially of aggregate, a bituminous substance as aggregate binder in the range of 4 to 7% finely divided sulfur in the range of 0.6 to 15% and finely divided carbon in the range of 1.0 to 20% all by weight based on the aggregate

wherein the sulfur and carbon are added as post mix additives to the mixture of aggregate coated with said aggregate binder.

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ALEXANDER H. BRODMERKEL, *Primary Examiner*.
JOSEPH REBOLD, MORRIS LIEBMAN, *Examiners*.