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LOAD SUPPORTING COMPOSITION

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This invention relates to a readily spreadable composition of matter particularly useful as a wearing surface or cover course for load supporting surfaces such as building roads, parking lots, industrial floors, roof decks, airport runways and the like. More particularly, this invention relates to a composition having special utility as a wearing course or surface course to be applied by placing on top of a load-supporting base.

Roads and similar load-supporting surfaces are conventionally constructed in layers, the uppermost of which is referred to as a wearing course or surface course. It has long been well known to provide various courses of graded stones as base courses, and in recent years pozzolanic materials such as those produced by combining lime, fly ash and aggregate have met with very substantial success as base courses and even as sub-wearing courses. Other types of stabilized bases containing portland cement and bituminous admixtures and chemical additives have been developed and successfully used for a number of years. All such base courses are lacking in abrasion resistance for many uses to which surface courses are normally subjected, and it has been conventional to cover the base courses and sub-wearing courses with a surface course normally consisting of either concrete or a bituminous mixture such as asphalt mixed with mineral filler, for example.

It is an object of this invention to provide a readily placeable material which sets up rapidly to form a surface course that is exceedingly resistant to stripping, penetration and tearing. Asphaltic surfaces presently used are subject to the difficulties just referred to, particularly when warm and when subjected to large stresses such as those exerted by rapidly accelerating and decelerating vehicles.

Another object of this invention is to provide a readily spreadable material which can be placed without requiring heat, to form a wearing course which has superior characteristics and which is lower in cost than those conventionally used.

Present day wearing courses employing bitumen binders are available covering a wide range of compositions and thicknesses. In some instances the surface course is made up of several layers with variations within the layers to develop adequate stability under traffic, resistance to penetration of water and overall durability. Many of these compositions are expensive in that they are required in thicknesses of several inches or more. Construction engineers have attempted for many years to develop low cost wearing courses in which the compositions may either employ inexpensive aggregates such as the sands dredged from rivers or ocean bottoms, or as an alternative to reduce the thickness of the high-cost wearing course without deleteriously affecting its ability to stand up under the stresses of modern traffic loading.

In working with inexpensive aggregates it has heretofore not been considered possible to build up a thick layer and even for thin layers it has been found necessary to add substantial quantities of the bitumen, otherwise the sandy materials tend to crumble, fall part and separate from the base. Unfortunately the addition of the bitumen has the effect of making the composition soft, particularly when exposed to direct rays of the sun. Sharp

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objects have a tendency to sink into the wearing course and highway traffic causes raveling, rutting and frequently stripping of the wearing course from the base course. This makes it impractical therefore to build up any substantial thickness of the wearing course which would provide improved wear resistance and sealing when using the lower grade aggregates.

In the case where the higher grade aggregates are used, it has been found that the thicker surface courses can be developed but due to the increased cost of the aggregate it would be advantageous in this instance to develop improved stability in these compositions so that the minimum thickness could be reduced.

Accordingly, another object of this invention is to provide a composition having utility as a surface course which permits the enjoyment of the objectives and overcomes the disadvantages just referred to.

A further object of this invention is to provide a composition as referred to above, which is easy to place either as a full wearing course or as a partial or retread or even as a patch, but which sets promptly providing a stable wearing course that has improved resistance to stripping penetration or tearing.

Another object of this invention is to provide a composition which sets up in a few hours, developing improved toughness as well as flexural, compressive and bearing strengths after a few weeks, but still having flexibility as well as excellent bonding characteristics with the base course.

It has now been discovered that the foregoing and other objects are attained by providing a mixture consisting essentially of hydrated lime, fly ash, a bitumen and an aggregate. The proportions of ingredients in accordance with this invention are critical. Such proportions, by weight, are as follows.

Ingredients:	Percentage by weight
Hydrated lime	0.5-3
Fly ash	1-10
Bitumen	3-8
Aggregate	Remainder

Preferred compositions which give radically superior results are in the following range.

Ingredients:	Percentage by weight
Hydrated lime	0.5-2
Fly ash	1-6
Bitumen	3-8
Aggregate	Remainder

wherein the ratio of fly ash to hydrated lime lies in the range between 1½-1 to 3-1.

It has been found in accordance with this invention that a higher percentage of asphalt content may be provided as a result of the presence of the lime and fly ash. It is recognized that the use of lime in asphaltic mixtures is old and that one of the advantages of this addition is to improve the cohesion between the aggregates and the bitumen. This improvement appears to be the result of the effect of hydrated lime on the characteristics of the surface of the aggregate.

Fly ash has also been known to be useful as a mineral filler in asphaltic mixtures has never demonstrated advantageous properties over other mineral fillers such as pulverized limestones, clays and the like. It has now been discovered that the very large surface area available in fly ash together with the glassy character of the surface appears to react by heterogeneous catalysis in the solid state with the bitumen and hydrated lime to produce abnormally high bond linkages between the bitumen and the aggregate components of the system. The lime and siliceous glass (fly ash) coact to influence the electronic

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polarization of surface ions on the aggregate which now affords radically stronger bonding characteristics between the bitumen and the aggregate and the fly ash as well. It is this abnormally high bond strength that may be in part responsible for the unexpected stability that is developed in the composition. It is also postulated that the limiting ranges of proportions of fly ash to lime which are required in the performance of these compositions are based on the interaction of the lime with the fly ash and with the asphaltic material.

The mechanisms of the reaction are not fully understood and it is not intended that the above description be considered an accurate explanation of the surprising results obtained. It is a fact, however, that when the proportions fall within the limits given the abnormal characteristics of the product are obtained and a very marked improvement in properties is obtained as compared to those which may be expected from the additive effects due to the lime and the fly ash.

Compositions in accordance with this invention are not only easy to place, but they quickly form a highly stable wearing course. It has been found that, whereas a substantially thick wearing course has been required for asphaltic concrete, for example two inches, a course as thin as about one-half inch utilizing the composition according to this invention is ample.

Although the primary advantages of this invention appear in a wearing course, these compositions may also be utilized as a sub-wearing course and in some cases even for a base course.

As used herein, the term "hydrated lime" indicates a dry powder obtained by treating quicklime with water enough to satisfy its chemical affinity for water under the conditions of its hydration. Hydrated lime consists essentially of calcium hydrate or a mixture of calcium hydrate and/or magnesium oxide and/or magnesium hydroxide. Lime, of course, is a calcined material the major portion of which is calcium oxide (or calcium oxide in natural association with a lesser amount of magnesium oxide) capable of slaking with water. The term "slaked lime" is used interchangeably with "hydrated lime." Both hydrated lime and slaked lime may be associated with excess water, except as stated hereinafter. Hydrated lime within the meaning of this invention excludes those limes which are conventionally referred to as hydraulic limes which have the ability to set under water. In fact, the hydrated limes in accordance with this invention do not have the ability to set under water. Expressed chemically, hydraulic limes contain silica and alumina in sufficient quantities to impart the hydraulic properties referred to above. An hydraulic hydrated lime is the hydrated lime cementitious product obtained by calcining a limestone containing silica and alumina to a temperature short of incipient fusion so as to form sufficient free lime (CaO) to permit hydration and at the same time leaving unhydrated sufficient calcium oxide and silicon dioxide (calcium silicates) to give the dry powder its property of setting under water. Of course, the lime need not be pure lime and the term includes lime-bearing substances, but if such a substance is used we consider its $\text{Ca}(\text{OH})_2$ equivalent as the lime ingredient according to the invention.

Another material to be distinguished from hydrated lime is finely ground or pulverized, uncalcined limestone. This is a chemically inert material which is sometimes used as an inert filler, but it does not react with bitumen and fly ash and is outside the scope of this invention.

The use of a mixture of pulverized quicklime and water which readily forms the hydrated lime as defined previously is understood to be within the scope of this invention.

The term "fly ash" as used in the present specification is intended to indicate the finely divided ash residue produced by the combustion of pulverized coal, which ash is carried off with the gases exhausted from the furnace in

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which the coal is burned and which is collected from these gases usually by means of suitable collection apparatus such as electrical precipitators. The fly ash so obtained is in a finely divided state such that at least about 70% passes through a 200 mesh sieve. Other finely divided powdered highly siliceous glasses such as certain natural glassy pozzolans (volcanic ash, obsidian and pumicite for example), artificial pozzolans such as calcined siliceous glazzy shales and clays and the finely divided residue from plate glass grinding processes are equivalents of fly ash and are intended to be included within the meaning of the term "fly ash."

As used herein the term "bitumen" is intended to include the conventional types of asphalts, asphaltic cements and asphaltic oils and emulsions that are referred to in chapter II of the "Asphalt Handbook" of The Asphalt Institute (College Park, Maryland, Construction Series No. 81). Cutback asphalts (asphalts which have been fluxed with light volatile petroleum distillate) are classified in the trade as rapid curing, medium curing and slow curing, are classified further as high viscosity and low viscosity, and are made available either in the form of hot mixes or cold mixes.

The following specific examples of asphalt, which are not intended to limit the scope of the word "bitumen" but which are intended to be illustrative, are as follows:

Referring to ASTM Designation D946, bitumens are classified as (a) petroleum asphalt cement which is prepared by the distillation of asphaltic petroleum or (b) native asphalt cement which is prepared by fluxing native asphalt with a petroleum flux or by mixing a filler with a petroleum asphalt cement. According to this ASTM specification, the bitumen shall be homogeneous, free of water and shall not foam when heated to 347° F. The material is sampled and tested for penetration, flash point, ductility and loss on heating. Various grades have varying characteristics within these categories. For example, measuring penetration according to the standard ASTM method (Designation D5), the penetration at 77° F., 100 grams, after 5 seconds, varies from 40 to 300 hundredths of a centimeter. The flash point in degrees Fahrenheit (Cleveland open cup) varies between 350 and 450 for petroleum asphalt cement and is approximately 350 for filled or native asphalt cement. The ductility at 77° F., 5 centimeters per minute, expressed in centimeters, is approximately 100. The loss on heating at 325° F. for 5 hours is approximately 1%. The penetration of residue from loss on heating tested at 77° F., 100 grams, 5 seconds, is approximately 75% as compared to the penetration before heating. The solubility in carbon tetrachloride for petroleum asphalt cement is approximately 99% and in filled or native asphalt cements is approximately 69 to 86%. Bitumens in accordance with this invention ordinarily contain approximately 1% ash (petroleum asphalt cement) or from 12 to 28% filled or native asphalt cement.

According to this invention, the term "bitumen" includes emulsified asphalt which is described in ASTM Designation D977 and cut-back asphalt which is described in ASTM Designation D598. Cut-back asphalt includes liquid petroleum products produced by fluxing and asphaltic base with suitable distillates such as petroleum distillates for example. Cut-back asphalt of the rapid curing type are covered by ASTM Designation D597 and are produced by fluxing an asphaltic base with a suitable light volatile solvent such as the lower-boiling petroleum distillates.

The term "hot mix" refers generally to materials that are prepared in a plant at elevated temperature (approximately 285° F. $\pm$ 15° F.) and supplied to the job in this form. The cold mixes are asphaltic compositions which may be spread and compacted at normal atmospheric temperature.

The term "aggregate" as used herein is intended to indicate natural or artificial substantially chemical inert

organic material such as (for example) natural sand, sand prepared from stone, gravel, blast furnace slag which has not been water quenched and which is, therefore, inert in the combination according to this invention. The sizing or gradation of the aggregate is largely a matter of choice and may be varied depending upon the intended usage of the composition. For thicker courses, the mineral aggregate preferably has a graduation as follows: Percentage by weight—

Percentage by weight—	Screen size
85-100 -----	Passing 1".
65-90 -----	Passing ¾".
50-80 -----	Passing ½".
35-60 -----	Passing #4 mesh.
20-45 -----	Passing #10 mesh.
10-20 -----	Passing #40 mesh.
5-10 -----	Passing #80 mesh.
0-8 -----	Passing #200 mesh.

For a thinner base course, or for a relatively coarse surface or wearing course, a preferred gradation is:

Percentage by weight—

	Screen size
75-100 -----	Passing ¾".
60-80 -----	Passing ½".
40-60 -----	Passing #4 mesh.
25-40 -----	Passing #10 mesh.
10-20 -----	Passing #40 mesh.
5-10 -----	Passing #80 mesh.
0-8 -----	Passing #200 mesh.

For fairly coarse surfaces or wearing courses, a preferred gradation is:

Percentage by weight—

	Screen size
90-100 -----	Passing $\frac{3}{4}$ ".
80-100 -----	Passing $\frac{1}{2}$ ".
60-85 -----	Passing #4 mesh.
40-60 -----	Passing #10 mesh.
15-30 -----	Passing #40 mesh.
5-15 -----	Passing #80 mesh.
0-8 -----	Passing #200 mesh.

For fine textured surfaces, employed in thin wearing courses, a preferred aggregate gradation is:
Percentage by weight—

Percentage by weight—	Screen size
100 -----	Passing $\frac{1}{2}$ ".
75-100 -----	Passing #4 mesh.
45-70 -----	Passing #10 mesh.
15-30 -----	Passing #40 mesh.
5-15 -----	Passing #80 mesh.
3-8 -----	Passing #200 mesh.

Accordingly, the particle size distribution in the aggregate may be widely varied within preferred upper limits of substantially all through ¾" and lower limits of no more than about 10% through 200 mesh. A particularly preferred sand for leveling, filling and for single course application and resurfacing is an aggregate substantially all of which passes through a standard ¾" screen and no more than about 10% by weight passes through a standard 200 mesh.

The presence of moisture on the surface of the aggregate particles is neither advantageous nor deleterious. However, it is an important advantage of this invention that it is unnecessary to remove moisture from the aggregate prior to use as has often been the case when using prior art compositions. The moist aggregate may contain about 1-6% by weight of water, and substantially all the aggregate may pass through a standard $\frac{3}{8}$ " sieve.

While the performance and quality of the composition of the invention are best evaluated by means of field performance, laboratory techniques may be employed to illustrate the advantage of the composition of this invention over the compositions previously used in the art. However, some of the standard tests that are frequently employed to evaluate bituminous compositions do not

necessarily demonstrate the superior performance of such products in the field. For example, the use of the conventional stabilometers, such as the Hveem and Marshall stabilometers, may merely indicate that such products are unstable or stable compositions. This has been recognized by workers in the field who have studied the utilization of organic anti-stripping agents. For this reason techniques have been evolved which represent modifications of the conventional tests as follows.

The materials are first hand-blended in stainless steel containers and then compacted three times with 4.4 foot pounds of energy into 3" diameter x ¾" high non-absorbent cylindrical molds. The samples were next tested for penetration at pre-selected intervals with a modified Vicat apparatus (ASTM C472) weighing 850 grams, one centimeter diameter. This weight corresponds to a light vehicle load. Measurements were made of the time required for total penetration of the weight. In all of the laboratory tests (Examples 1-5), a natural gravel aggregate was employed in which 100% passed a ¾" sieve and 4% passed a No. 200 sieve. In each case the percentage of aggregate was such that the aggregate made up the balance of the composition.

The following examples illustrate compositions in accordance with this invention:

EXAMPLES NOS. 1-3

These examples show the results, expressed in seconds, for complete penetration. In these examples the bitumen consisted of 4 to 6% by weight asphaltic oil and the tables show a comparison of specific compositions according to this invention with compositions containing hydrated lime alone, fly ash alone, and with a composition containing neither hydrated lime or fly ash. The tables show radically increased resistance to penetration in accordance with this invention, for all curing ages reported.

Example No. 1

[Bitumen: 4% by wt. RC-2 asphaltic oil]

Hydrated lime, percent by wt.-----	0	0	1.5	1.5
Fly ash, percent by wt.-----	0	3.0	0	3.0
Curing Time in Hours	Penetration Time in Seconds			
1-----	15	23	65	100
2-----	20	40	92	225
4-----	50	43	180	585
6-----	100	55	310	540
24-----	590	450	1,980	Infinite

Example No. 2

[Bitumen: 5% by wt. RC-2 asphaltic oil]

Hydrated lime, percent by wt.-----	0	0	1.5
Fly ash, percent by wt.-----	0	3.0	0
Curing Time in Hours	Penetration Time in Seconds		
1.-----	9	10	70
2.-----	13	30	65
4.-----	21	35	150
6.-----	31	150	-----
24.-----	-----	450	285

Example No. 3

[Bitumen: 6% by wt. RC-2 asphaltic oil]

Hydrated lime, percent by wt.----- Fly ash, percent by wt.-----	0 0	0 3.0	1.5 0	1.5 3.0
Curing Time in Hours	Penetration Time in Seconds			
1.-----	12	17	22	33
2.-----	22	24	33	77
4.-----	33	37	93	105
6.-----	44	67	110	115
24.-----	540	550	1,260	-----

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EXAMPLE NO. 4

This example shows a comparison of penetration times which were measured for compositions in accordance with this invention having varying percentages of hydrated lime and fly ash. An optimum percentage of about 1½ by weight hydrated lime and about 3% by weight fly ash appears. In each of these examples the total content of hydrated lime plus fly ash has been maintained constant and the ratio has been varied.

Example No. 4

[Bitumen: 5% by wt. RC-2 Asphaltic Oil]

Hydrated lime, percent by wt.....	1.0	1.5	2.0
Fly ash, percent by wt.....	3.5	3.0	2.5
Curing Time in Hours	Penetration Time in Seconds		
1.....	25	200	70
2.....	40	250	90
4.....	88	654	195
6.....	115	900	260
24.....	875	1,845	995

EXAMPLE NO. 5

Several compositions were prepared which had varying percentages of bitumen (one of which contained no bitumen). All these compositions contained 1.5% by weight hydrated lime and 3.0% by weight fly ash. A penetration time for each sample appears below.

Example No. 5

Hydrated lime, percent by wt.....	0	1.5	1.5	1.5
Fly ash, percent by wt.....	0	3.0	3.0	3.0
Bitumen, percent by wt.....	0	4	5	6
Curing Time in Hours	Penetration Time in Seconds			
1.....	0	100	65	33
2.....	0	225	85	77
4.....	0	585	200	105
6.....	0	540	300	115
24.....	0	Infinite	1,980	-----

EXAMPLE NO. 6

The following examples are illustrative of further compositions in accordance with this invention, all ingredients being in parts by weight. The variations shown frequently reflect differences of gradation in aggregates.

Hydrated Lime	Fly Ash	Bitumen	Aggregate
½	10	8	81½
1	1½	3	94½
1½	10	8	80½
2	3½	5	89½
2½	5	6½	86
3	4½	5½	87
1	8	6	85
1½	2½	4	92
2	5	6	87
½	2	6	91½
3	5	6	86
2	7½	7	88½
2	10	8	80
1	3½	5	90½
1.5	4	6	98½

EXAMPLE NO. 7

A cold mixed asphaltic wearing course consisting of screened natural gravel aggregate with a top size of ½" and containing about 4% through a 200 mesh sieve and 6% of a blend of RC-2 and MC-2 asphaltic oils blended in the proportion of 1 to 1 by weight, was mixed by means

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of motor graders and spread with an asphalt paver. The mixture was applied over an old asphaltic concrete base which showed considerable distress from continued use in a heavily congested area. It was noted that this mixture when open to traffic quickly became rutted and was found to strip as a result of picking up on the tires of automobiles. The identical mixture was made up with the exception that 1½% hydrated lime and 3½% fly ash was added based on the total weight of the composition. After using the same construction procedure on an identical type road base, the road was immediately open to traffic and was found to have developed sufficient stability to prevent marring due to rutting and traffic pick-up. It was further noted that the aggregate was completely coated with the asphaltic oil and subsequent experience over one winter showed much greater durability for the mixture of the invention by direct comparison with the remaining sections of the original mixture not containing lime and fly ash. The latter mixture was found to break up to a substantial degree in the period of the year when thawing occurred in the road base.

EXAMPLE NO. 8

A cold mix asphalt was incorporated into a composition similar to that of Example No. 7 and placed as a road leveling course. It was discovered that the mix containing 1½% by weight of hydrated lime and 3½% by weight of fly ash immediately developed sufficient stability to resist the rutting effect when laid 5 to 6" thick. Again, traffic was immediately allowed on the road after rolling with an 8-10 ton roller and no marring, rutting or stripping occurred.

EXAMPLE NO. 9

Utilizing a composition containing approximately 1½% by weight of hydrated lime, 3½% by weight of fly ash, 6% of 85-100 penetration asphalt cement as a hot mix and the balance sand aggregate all of which passed a standard ¾" screen, a surfacing and resurfacing composition was prepared which was laid in a thickness of from ½" to 1". This was open to traffic immediately and was found to have developed sufficient stability to resist rutting, stripping, etc.

Using the standard stability test which is official in the State of New York, this composition showed stability in excess of that required by that State for Type 1-AC asphalt concrete which contains a high percentage of crushed stone.

In all of Examples 7-9 it was found that the composition developed a strong adhesive bond with the sub-surface course.

It has been observed that this composition in many cases has a beneficial effect on the base, for example, if the base contains a sandy soil and there is considerable rainfall during the early setting period, the non-permeable nature of the surface course waterproofs the sub-surface course to a considerable extent, providing a protective blanket. Moreover the rigidity or strength of the surface course mechanically braces the base.

If the base contains sand and the sand dries out too fast, producing a dusting problem, the dusting problem is also minimized in accordance with this invention, since the surface course cooperates by forming a sealing blanket for the base. The above advantages are particularly important when the base is composed of lime, fly ash and aggregate.

Although this invention has been described with reference to particular forms thereof, it will be appreciated that equivalents may be substituted for particular ingredients and components specifically referred to, that certain features may be utilized independently of the use of other features, and that other changes may be made, all without departing from the spirit and scope of the invention as defined in the appended claims.

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Having thus described the invention, the following is claimed:

1. A load supporting composition of matter consisting essentially of the following ingredients in about the proportions by weight specified:

Ingredients—	Percentage by weight
Hydrated lime	½-3
Fly ash	1-10
Bitumen	3-8
Aggregate	Balance

2. A load supporting composition of matter consisting essentially of the following ingredients in the proportions by weight specified:

Ingredients—	Percentage by weight
Hydrated lime	½-2
Fly ash	1-6
Bitumen	3-8
Aggregate	Balance

wherein the ratio of fly ash to hydrated lime is in the range of 1½:1 to 3:1.

3. A load supporting composition of matter consisting essentially of the following ingredients in the proportions by weight specified:

Ingredients—	Percentage by weight
Hydrated lime	½-3
Fly ash	1-10
Bitumen	3-8
Moist aggregate containing about 1-6% by weight of water, substantially all of said aggregate passing through a standard ¾" sieve	Balance

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4. A load supporting composition of matter consisting essentially of the following ingredients in about the proportions by weight specified:

Ingredients—	Percentage by weight
Hydrated lime	1.5
Fly ash	3
Bitumen	5
Aggregate (substantially all of which passes through a standard ¾" sieve)	Balance

5. A load supporting surface consisting essentially of a sub-base comprising lime, fly ash and aggregate, and a wearing course superimposed upon and combined with said base course, said wearing course consisting essentially of:

Ingredients—	Percentage by weight
Hydrated lime	½-3
Fly ash	1-10
Bitumen	3-8
Aggregate (substantially all of which passes through a standard ¾" sieve)	Balance

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