



ADDITIVE FOR DRAINAGE ASPHALT PAVEMENT MIXTURE

FIELD OF THE INVENTION

The present invention is related to materials for the production of asphalt pavement. In particular, the present invention is related to materials for the production of asphalt pavement with good drainage properties and method of using the same.

BACKGROUND OF THE INVENTION

Asphalt pavement mixes commonly used for paving roads contain three main components : mineral aggregates bitumen binders and fillers. The aggregates are generally graded stones passing 20mm sieve size. Fillers are fine particles of less than 75 μ m to fill up the spaces or voids between the stone aggregates. Bitumen is used to bind the stones and fillers together. In recent years, polymers or shredded tyre dust have been added to some dense mixtures. These components are mixed together to form a pavement typically with voids of around 3-7%. These types of mixtures are generally known as dense mixes.

The use of hydrated lime on dense mix pavement as mineral filler and anti-stripping agent is known in the art. Stripping refers to loss of structure from moisture. In the prior art document *Use of Hydrated Lime in Asphalt Paving Mixtures* published by the National Lime Association (1984), Kennedy discusses the mechanism of stripping and proposes



methods of treatment. These methods include achieving adequate compaction to reduce air voids and thus prevent penetration by moisture into the mixture; providing adequate drainage by rapidly removing surface water from the pavement through adequate pavement elevation
5 above the water table; or the use of treatment material to prevent moisture penetration. Hydrated lime is one of the most effective methods of treating aggregates. It has been suggested that lime improves moisture resistance by the bonding of calcium with the silicates in the aggregate, and by a possible interaction or modification of the acidic
10 portions of the asphalt. In some cases in which the aggregates have silt or clay surface coatings, the pozzolanic reaction between the calcium in the lime and the silica in the clay will occur, forming calcium silicate. In this prior art report, in which mixtures giving a target air void of 7% was used for testing, hydrated lime was shown to be an effective means of
15 improving the moisture resistance of asphalt mixtures when applied directly to the asphalt mixes.

Another type of asphalt pavement is known as drainage mix. The main difference between drainage mixes and dense mixes is that the amount of voids in the drainage pavement is higher, typically in the
20 range of about 15-25%. This is achieved by using angular stones, a polymer-modified bitumen binder (for example Cariphalte), or reducing or eliminating the fine aggregate component from the mix. Drainage pavements, due to the high porosity, allow water to drain directly through the pavement structure, thereby improving driving conditions during wet
25 weather. Furthermore, noise pollution to the surrounding environment of

the road is reduced due to the cushioning effect of the air pockets. This type of mix, therefore, is particularly useful in wet climates or in densely populated cities in which noise pollution from roads are environmental concerns. However, their high porosity also causes drainage pavements to be prone to moisture damage, resulting in poor durability.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a schematic diagram to show a conventional method for hydrated lime production.

Figures 2A-C shows the particle size distribution of types A-C hydrated lime particles respectively.

Figures 3A and B shows results of wheel tracking tests on pavement produced according to the present invention as compared to normal drainage mixes containing Cariphalte (Fig.3A) or normal Grade 60/70 binder (Fig. 3B).

SUMMARY OF THE INVENTION

The present invention provides, according to one aspect, an additive for drainage mixes comprises hydrated lime. In one specific embodiment, the additive is hydrated lime of 80-100% Ca(OH)_2 and has particle size distribution of 0.05-300 μm . In one preferred embodiment, the hydrated lime has a purity of around 80-100% Ca(OH)_2 , and a particle size distribution of around 8-12% in the range of 0.05-0.5 μm , 73-90% in the range of 0.5-75 μm and 0.5-7% in the range of 76-300 μm . In the most preferred embodiment, the hydrated lime has a purity of around 90-98%

Ca(OH)_2 , and a particle size distribution of around 8-12% in the range 0.05-0.5 μm , 85-90% in the range of 0.5-75 μm and 1-3% in the range of 76-300 μm .

According to another aspect, an improved drainage mix is provided containing aggregates, binders and hydrated lime. The binder may be polymer-modified or unmodified (i.e. normal). Examples of normal binders are normal Grade 60/70 or Grade 80/100 binder. An example of polymer modified binder is Cariphalte. The amount of voids in the drainage mix is at least about 15%, achieved through the use of angular mineral aggregates and/or reducing the amount of fine aggregates. The improved drainage mix has increased durability while maintaining the required drainage properties. In the specific embodiment, the improved mix comprises 0.5-5% hydrated lime per dry weight aggregate incorporated into the conventional components of aggregates and binders. In one preferred embodiment, 1-3% hydrated lime per dry weight aggregate is incorporated into aggregate and polymer modified binder. In the most preferred embodiment, the mix comprises around 2% hydrated lime of 90-98% Ca(OH)_2 per dry weight aggregate with 4-5% polymer-modified binders.

In a further aspect, both dry hydrated lime and wet lime slurry may be used as the additive. Alternatively, other divalent cation hydroxides are used instead of hydrated lime. The method of use is also given in detail in the following detailed description. Briefly, the method comprises the steps of mixing hydrated lime, mineral aggregates and binder into a mixture; pouring the mixture onto a base course; and compacting the

mixture such that a drainage asphalt pavement containing voids of at least 15% is formed.

DESCRIPTION OF THE INVENTION

The following detailed description describes the preferred embodiment for implementing the underlying principles of the present invention. One skilled in the art should understand, however, that the following
5 description is meant to be illustrative of the present invention, and should not be construed as limiting the principles discussed herein. In addition, certain terms are used throughout the following description and claims to refer to particular components or material. As one skilled in the art will appreciate, different companies may refer to a component by different
10 names. This document does not intend to distinguish between components that differ in name but not in function. In the following discussion, and in the claims the terms "containing", "including", "having" and "comprising" are used in an open-ended fashion, and thus should be interpreted to mean "including but not limited to".

15 As used herein, dense asphalt pavement refers to a pavement that has a target void level of 7% or less and does not allow significant water drainage therethrough. Drainage asphalt pavement refers to a pavement that has a target void level of 15-25%, for the purposes of allowing water to drain through.

20 Dense mix refers to an asphalt mixture that contains components that, when mixed in the standard batch or continuous mixing process and paved onto a road surface would produce a dense asphalt pavement. Drainage mix refers to an asphalt mixture that contains components that,

when mixed in the standard batch or continuous mixing process and paved onto a road surface would produce a drainage asphalt pavement.

Void refers to air pockets or air voids present in a formed pavement and is typically estimated by measuring the bulk density of the mix and then
5 subtracting off the volume occupied by the aggregates and binders. Filler refers to fine material added to the mixes to fill the air pockets between the stone aggregates.

Durability of a material may be determined by measuring the Marshall stability, tensile strength, resilient modulus, and resistance to moisture
10 damage. Relative resistance of mix types against moisture damage may be assessed by comparing their structural properties before and after the simulated weathering treatment, including Texas boiling test and wheel tracking test. The Texas boiling test is a visual assessment of the relative stripping resistance of binder aggregate.

15 A mix with hydrated lime additive is considered to have improved durability if one or more of the test results show improvement over the same mix without hydrated lime additive.

Hydrated lime as an additive for drainage mixes according to the present invention may be produced using standard methods. In another
20 aspect, the Type C hydrated lime is the most preferred material as the additive. The various types of additives and the methods of producing the same, and their use in drainage mixes are described below.

Production of hydrated lime additive

Referring to Figure 1, the hydrated lime ($\text{Ca}(\text{OH})_2$) additive according to the present invention may be produced by standard lime processing techniques. Typically, this involves the production of quick lime (CaO) by
5 calcination of limestone (CaCO_3), followed by dry or wet slaking of quick lime to form hydrated lime $\text{Ca}(\text{OH})_2$. Further downstream processing is sometimes performed for size segregation and removal of impurities. these optional steps are shown in dotted lines. One method of
10 downstream processing is the use of air separators to separate the coarse material from the fine material. If this step is performed, the fine material obtained is referred to as types A, B or C hydrated lime, depending on the size distribution.

Figures 2A-C show a specific example of each of the particle size
15 distribution of the three types of hydrated lime particles. In the example of a Type A hydrated lime shown in Fig.2A, a relatively narrow range size distribution, with 100% of the hydrated lime particles between $0.5\text{-}75\mu\text{m}$. The Type B hydrated lime example shown in Fig. 2B shows an intermediate size distribution, with approximately 93% in the $0.5\text{-}75\mu\text{m}$
20 range and 6% in the $0.05\text{-}0.5\mu\text{m}$ range. The Type C hydrated lime example shown in Fig.2C shows the broadest size distribution, with approx. 88% in the $0.5\text{-}75\mu\text{m}$ range; 10% in the $0.05\text{-}0.5\mu\text{m}$ range and 1.5% in the $76\text{-}300\mu\text{m}$ range. Table 1 shows the general range of the 3 types of hydrated lime.

TABLE 1

Particle size (μm)	Hydrated Lime Type A	Hydrated Lime Type B	Hydrated Lime Type C
0.05-0.5	0%	3-9%	8-12%
0.5-75	100%	85-95%	73-90%
76-300	0%	0-0.5%	0.5-7%

For practising the present invention, wet slurry or dry hydrated lime powder of types A, B and C and hydrated lime that has not gone through size separation may be used. The preferred concentration is 0.5-5% dry weight of aggregate. The more preferred concentration is 1-3% per dry weight of aggregate. The most preferred concentration is around 2% per dry weight of aggregate.

Hydrated lime is known in the art to react with asphalt mixes to form a water resistant barrier. According to the present invention, hydrated lime can also be used for the improvement of durability of drainage mixes while maintaining the drainage required for drainage mixes. Results (not shown) show that adding hydrated lime to drainage mix does not adversely affect the structural properties of the resulting pavement.

USE OF HYDRATED LIME FOR IMPROVING THE STRUCTURAL PROPERTIES OF DRAINAGE MIXES

The addition of 0.5-5% of hydrated lime may be added to drainage mix according to the present invention to improve one or more structural

properties of the resulting drainage pavement. In another preferred embodiment, 2% hydrated lime is added to a drainage mix. In the most preferred embodiment, 2% Type C hydrated lime is used.

Table 2 shows a study of Marshall stability of pavement produced according to the present invention. In these examples, 2% dry weight Type A, B or C hydrated lime per dry weight aggregate was added to drainage mixes containing 4.5% either normal Grade 60/70 bitumen or Cariphalte (polymer-modified binder). The use of all 3 types of hydrated lime increases the Marshall stability of the resultant drainage pavement with Type C hydrated lime showing the highest increase.

Type C additive also improves resilience modulus of both the normal and polymer-modified binder by 15-17% (results not shown).

TABLE 2

Type of drainage mix	Type of hydrated lime additive (2%)	Change in Marshall stability compared to no additive control prior to weathering process
Polymer-modified binder	Type A	+0.76kN (7.8%)
Polymer-modified binder	Type B	+2.15kN (22.0%)
Polymer-modified binder	Type C	+2.74kN (28.0%)
Normal binder	Type A	+1.38kN (15.4%)
Normal binder	Type B	+1.35kN (15.0%)
Normal binder	Type C	+2.77kN (30.8%)

USE OF HYDRATED LIME FOR THE IMPROVEMENT OF DURABILITY OF DRAINAGE MIXES

1-3% hydrated lime is added to improve the durability of drainage mixes against moisture damage. In the preferred embodiment, 2% hydrated lime is used. In the most preferred embodiment, 2% Type C hydrated lime is added to drainage mixes.

Laboratory simulation tests were conducted to assess the effectiveness of the present invention. All specimens were treated with 120 cycles of weathering comprising 2-hour wetting and 2-hour drying per cycle, before being tested for Marshall stability and resilient modulus. Table 3 shows the effect to resilient modulus after addition of Types A, B or C hydrated lime to drainage mixes containing 4.5% normal Grade 60/70 binder or polymer modified binder.

TABLE 3

Type of drainage mix	Type of hydrated lime additive	Change in Resilient Modulus compared to no additive control after the weathering process
Polymer-modified binder	none	-13.0%
Polymer-modified binder	2% Type A	+11.1%
Polymer-modified binder	2% Type B	+68.1%
Polymer-modified binder	2% Type C	+76.9%
Normal binder	none	-1.1%
Normal binder	2% Type A	+88.3%
Normal binder	2% Type B	+25.5%
Normal binder	2% Type C	+37.9%

The polymer-modified binder mix without hydrated lime suffered a significant decrease in resilient modulus after the weathering treatment, while the normal mix was unaffected. The addition of the three types of hydrated lime, however, brought about a significant increase in resilient modulus for both normal and polymer-modified binder mixes. Type C was found to be most effective for the polymer-modified binders, while Type A was most effective for the normal binders. Fig.3A and 3B further show that resistant to rutting of the normal binder mix has improved to the same level as the polymer modified binder. Therefore, in accordance with one aspect of the present invention, drainage mixes containing normal binder is used to produce drainage pavement that have the same durability as polymer modified binder. Since the cost of lime addition is lower than that of polymer, the present invention reduces cost of drainage mix production by using, in one embodiment, a lime additive on a normal binder to give the same performance as a polymer-modified binder. If further performance enhancement is required, the lime additive may be added to conventional polymer-modified mixes according to another embodiment of the present invention to produce a superior drainage pavement.

Test results (not shown) also revealed no significant deterioration in Marshall stability due to weathering process. In addition, the use of all three additives improves the durability of both types of drainage mixes, as indicated by the Wheel Tracking Test as shown in Fig. 3A and 3B. Type B was found most effective for the normal binder mix, while there were no differences in the performance of the three types in polymer-modified binders.

Table 4 shows results of Texas boiling test conducted using 2% Type A, B or C hydrated lime on the same two type of drainage mixes. Improved binder coating performance was observed with the use of all three types of hydrated lime. The effect of the boiling test, as visually assessed based on the percent binder coating remaining, was more significant on bigger size aggregates. Finer aggregates tend to retain binder better than coarser aggregates when lime is not used. Such dependence on aggregate size is less significant when lime is used. Among the three types, type C hydrated lime had the best performance.

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Table 4

Type of binder in mix	Type of hydrated lime additive	Aggregate Size (mm)				
		13.0	9.5	4.75	1.18	All Sizes
Polymer-modified	None	80%	85%	85%	85%	100%
Polymer-modified	2% type A	95%	95%	95%	98%	98%
Polymer-modified	2% type B	95%	90%	95%	95%	98%
Polymer-modified	2% type C	98%	95%	98%	98%	98%
Normal G60/70	None	70%	60%	85%	90%	95%
Normal G60/70	2% type A	90%	90%	100%	100%	98%
Normal G60/70	2% type B	100%	95%	95%	95%	98%
Normal G60/70	2% type C	100%	100%	100%	100%	100%

Figures 3A and B show results of wheel tracking tests on pavement produced according to the present invention as compared to normal drainage mixes with 4.5% normal Grade 60/70 binder (Fig. 3B) or polymer modified binder (Fig.3A). Both drainage mixes without hydrated lime additives produced signs of failure during the wheel tracking test. The

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addition of any of the types of hydrated lime improved the rutting resistance of both drainage mixes. For both types of mixes, the rut depths were reduced by about half with the use of hydrated lime additives, and no signs of failure was observed up to 6,000 wheel passes for mixes with
5 polymer-modified binders and up to 5,000 wheel passes for mixes with normal binders. All three types of additives were equally effective for the mixes with polymer-modified binders, and Type B and C hydrated lime performed better than Type A in normal binder mixes.

METHOD OF LIME ADDITION

The hydrated lime may be added to a drainage mix in various manner. Some non-limiting examples of methods of mixtures are described below.

Example 1

- 5 (a) Transport damp or wet aggregate onto a premix plant.
- (b) Add dry hydrated lime to wet or damp aggregates that have not gone through the drying process yet.
- (c) Dry this mixture together in a dryer.
- (d) Load the dried mixture into hot bins where their size gradation is
10 controlled.
- (e) Release a correct amount of aggregate of the prescribed gradation into a batch mixer.
- (f) Mix in the batch mixer.
- (g) Blend in the softened binder.
- 15 (h) pour the mixture onto the prescribed wearing course and compact the wearing course to the desired compaction.

Example 2

Add dry hydrated lime to wet or damp aggregates and then spray a small amount of water to the mixture, followed by steps (c) to (h) of Example 1.

20 Example 3

Spray a small amount of water onto the wet aggregate and then add dry hydrated lime, followed by steps (c) to (h) of Example 1.

Example 4

Spray hydrated lime slurry onto damp aggregates to the desired concentration, followed by steps (c) to (h) of Example 1.

Example 5

- 5 Add dry hydrated lime onto dry aggregates that have previously gone through the normal drying process i.e. after steps (a) to (f) of Example 1. Then add softened bitumen binder to the lime-aggregates mixture i.e. steps (g) to (h) of Example 1.

Example 6

- 10 Add dry hydrated lime directly into the softened bitumen binder, and follow steps (a) to (h) of Example 1.

Example 7

Mix quicklime powder with wet aggregates and spray some water to allow the quicklime to be fully hydrate. Then follow steps (a) to (h) of Example 1.

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- While the present invention has been described particularly with references to the aforementioned Types of hydrated lime and drainage mixes, it should be understood that the figures and results are for illustration only and should not be taken as limitation on the invention. In
- 20 addition it is clear that the method and materials of the present invention has utility in many applications where the production of durable drainage mixes is required. It is contemplated that many changes and modifications may be made by one of ordinary skill in the art without departing from the

spirit and the scope of the invention described. For example, although hydrated lime is used as the example for the present additive in the drainage mix, other alkaline material with divalent cations such as dolomite lime and magnesium hydroxide are considered equivalents.

5 Besides Cariphalte, other types of modified binders may be included in the drainage mix according to the present invention. These include, but are not limited to, Gilsonite-modified binders (Gilsonite from American Gilsonite Co.), and synthetic or natural rubber-modified binders, or a combination thereof. The types of binder that can be used according to the
10 present invention include, but are not limited to grade 40/50, 60/70, 80/100, 120/150 or a combination thereof. Various types of modified or normal binder may be mixed with the appropriate mineral aggregates and lime additive to produce improved drainage mixes and pavement according to the present invention.

CLAIMS

1. An additive when used in drainage mixes for improving the durability of asphalt pavements, said additive comprising hydrated lime, said hydrated lime having a purity of 50-99% $\text{Ca}(\text{OH})_2$ and having particle size range falling substantially in the range of 0.05-300 μm .
2. An additive according to claim 1 wherein said asphalt pavement drainage mix comprises stone aggregates and binder used for the production of asphalt pavement containing at least 15% voids.
3. An additive according to claim 2 wherein said binder is a normal binder or modified binder.
4. An additive according to claim 3 wherein said binder is a normal grade 40/50 binder, normal grade 60/70 binder, normal grade 80/100 binder, normal grade 120/150 binder, Gilsonite-modified binder, synthetic rubber-modified binder, natural rubber-modified binder, polymer modified binder or cariphalte.
5. An additive for drainage mix used when used in the production of asphalt pavement, said additive selected from a group consisting essentially of hydrated lime, magnesium hydroxide and dolomite.
6. An additive according to Claims 1 or 5 wherein said hydrated lime having a purity of 80-99% $\text{Ca}(\text{OH})_2$ and a particle size distribution of around 8-12% in the range of 0.05-0.5 μm , 73-90% 0.5-75 μm and 0.5-7% in the range of 76-300 μm .
7. An additive according to claim 6 wherein said asphalt pavement drainage mix comprising stone aggregates and binder used for the production of asphalt pavement containing at least 15% voids.
8. A mixture for the production of drainage asphalt pavements comprising mineral aggregates, binder and hydrated lime.
9. A mixture according to claim 8 wherein said binder is normal binder or modified binder.
10. A mixture according to claim 9 wherein said binder is a normal grade 40/50 binder, normal grade 60/70 binder, normal grade 80/100 binder, normal grade 120/150 binder, Gilsonite-modified binder, synthetic rubber-modified binder, natural rubber-modified binder, polymer modified binder or cariphalte.
11. A mixture according to any one of claims 8-10 wherein said mixture is capable of producing drainage asphalt pavement containing at least 15% voids.
12. A mixture according to any one of claims 8-11 wherein said binder is 4-5% vol/vol, said hydrated lime is 1-3%, with the rest of the volume containing stone aggregates.
13. A mixture according to any one of claims 8-12 wherein said hydrated lime concentration is 1.5 - 2.5%.

14. A mixture according to any one of claims 8-13 wherein said hydrated lime has a purity of 80-98%.

15. A mixture according to anyone of claims 8-14 wherein said hydrate lime has a particle size distribution of around 8-12% in the range of 0.05-0.5 μ m, 73-90% 0.5-75 μ m and 0.5-7% in the range of 76-300 μ m.

16. A mixture for the production of drainage asphalt pavement comprising mineral aggregates, polymer-modified binder and an additive selected from the group consisting essentially of hydrated lime, magnesium hydroxide and dolomite.

17. A mixture according to claim 16 wherein said mixture is capable of producing drainage asphalt pavement containing at least 15% voids.

18. A mixture according to any one of claims 16-17 wherein said binder is 4-5% vol/vol, said hydrated lime is 1-3%, with the rest of the volume containing mineral aggregates.

19. A mixture according to any one of claims 16-18 wherein said hydrated lime concentration is 1.5 - 2.5%.

20. A mixture according to any one of claims 16-19 wherein said hydrated lime has a purity of 80-98%.

21. A mixture according to any one of claims 16-20 wherein said hydrate lime has a particle size distribution of around 8-12% in the range of 0.05-0.5 μ m, 73-90% 0.5-75 μ m and 0.5-7% in the range of 76-300 μ m.

22. A method of producing a drainage asphalt pavement comprising:
mixing hydrated lime, mineral aggregates and binder into a mixture;
pouring said mixture onto a base course; and
compacting the mixture such that a drainage asphalt pavement containing voids of at least 15% is formed.