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The Benefits of Hydrated Lime in Asphalt Mixtures

PAPA annual meeting – Nov. 6, 2009

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R&D Manager - Materials

Content

- Hydrated lime: What is it?
- Why put hydrated lime in HMA?
- How is it done?
- Conclusion

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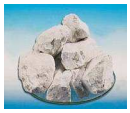
Hydrated Lime: What is it?



CaO
Quicklime

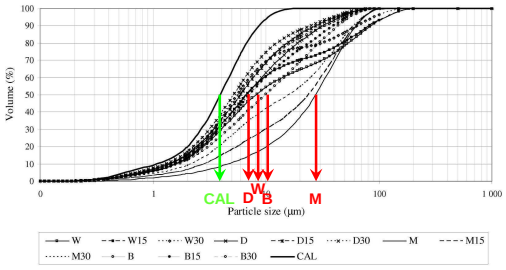
$CaCO_3$
Limestone

$Ca(OH)_2$
Hydrated Lime

Hydrated lime

- Standard product EN 459-1
- CE marked
- Density ~ 2 200 kg/m³
- Apparent density ~ 500 kg/m³
- Can be dosificated in the HMA (Schiffner, ZKG Int., 2003)

Hydrated lime is a fine filler



W: Limestone *D: Dolomite*
M: Melaphyre *B: Basalt*
CAL: Hydrated Lime

from Grabowski et al., Proc. Mairepav6, 2009

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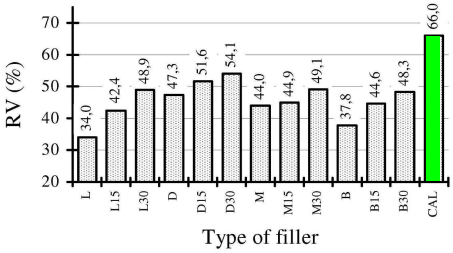
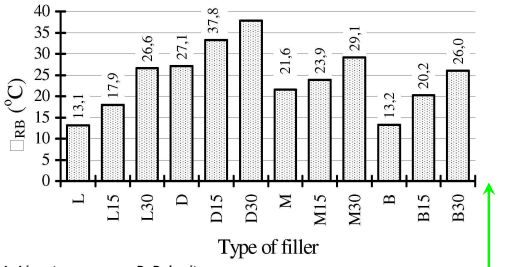
Hydrated lime has high Rigden voids



L: Limestone *D: Dolomite*
M: Melaphyre *B: Basalt*
CAL: Hydrated Lime

from Grabowski et al., Proc. Mairepav6, 2009

Hydrated lime has a high stiffening power



L: Limestone *D: Dolomite*
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from Grabowski et al., Proc. Mairepav6, 2009

CAL: too stiff to measure !!

Content

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- Why put hydrated lime in HMA?
- How is it done?
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Why put Hydrated Lime in HMA?

- Multifuncional additive for increased durability
  - improved moisture resistance
  - improved chemical aging resistance
  - improved mechanical properties

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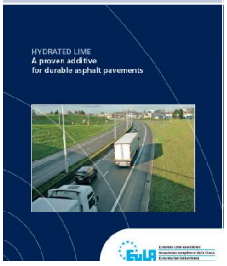


Hydrated Lime improves the Moisture Resistance of HMA

from LCPC, ME52, 1998

Hydrated Lime improves the Moisture Resistance of HMA

- Development in the late 1970s in the US
  - Moisture damage as a critical problem
  - Hydrated Lime as the best anti-strip additive (Hicks, Moisture Damage in Asphalt Concrete, NCHRP 175, 1991)
- Hydrated Lime now mandatory in some States

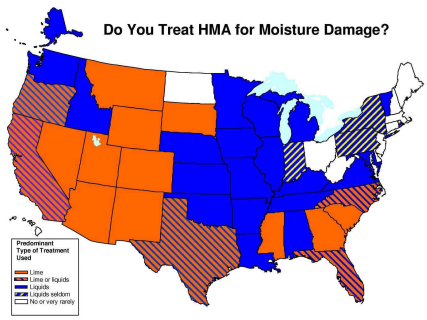
Hydrated Lime in the USA

Agency	Year Use Began
Arizona	1982[1]
California	1990
Colorado	1990
FHWA (WDFD)	1983
Georgia	1981
Mississippi	1991
Nevada	1987
Oregon	1984
South Carolina	1983
Texas	1983
Utah	1989

[1]Either lime or cement is permitted

from Hicks, NLA, 2003

Hydrated Lime in the USA



from Sebaaly, NLA, 2006 – data from Aschenbrener, 2002

US Agencies use Hy
it improves the Moisture Resistance of HMA

Agency	Resist Stripping	Improve Aging Resistance	Stiffen Binder	Improve Fracture Toughness	Alter Properties of Fines
Arizona	1	3	2	3	2
California	1	2	3	3	3
Colorado	1	3	3	3	1 (when appropriate)
FHWA	1	2	3	2	3
Georgia	1	3	3	3	3
Mississippi	1	1	2	—	3
Nevada	1	3	3	2	1
Oregon	1	2	3	3	3
South Carolina	1	2	2	2	2
Texas	1	3	2	3	2
Utah	1	2	2	2	2

Level of importance:
1 = very important
2 = moderately important
3 = less important

from Hicks, NLA, 2003

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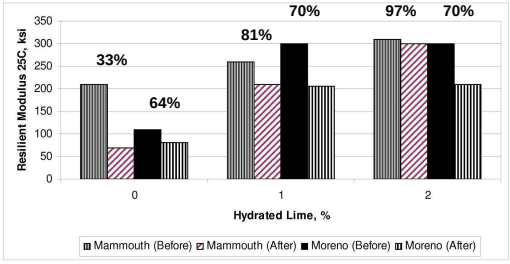
1-2% Hydrated Lime improves the moisture resistance of HMA



from Sebaaly, NLA, 2006 – data from Epps, Nevada DOT, 1992

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Impressive effect on repeated freeze-thaw cycles (granite)

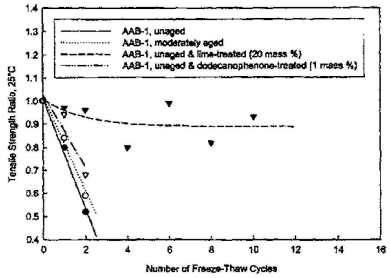

Fig. 2. Impact of freeze–thaw cycles on tensile strength ratio of several mixtures of AAB-1 (modified) coated on granite

from Huang, JMCE, 2005

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Impressive effect on repeated freeze-thaw cycles (limestone)

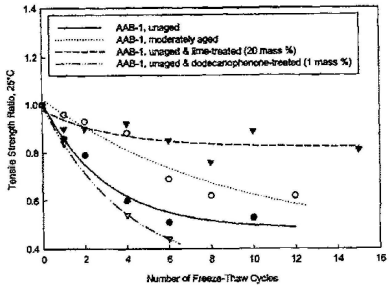

Fig. 1. Impact of freeze–thaw cycles on tensile strength ratio of several mixtures of AAB-1 (modified) coated on limestone

from Huang, JMCE, 2005

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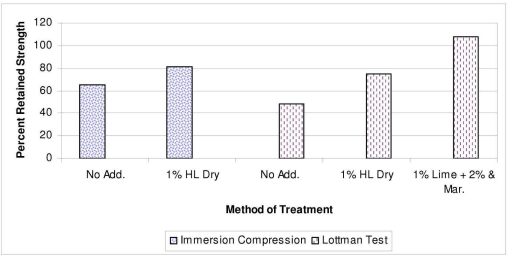
The effect is observed with every testing procedure (I/C vs AASHTO T283)



* 2% & Mar.: 2% moisture above SSD with marination.

from Sebaaly, NLA, 2006 – data from Betenson, Utah DOT, 1998

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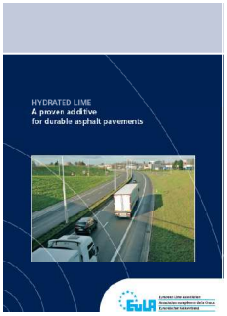
Why put Hydrated Lime in HMA?

- Multifuncional additive for increased durability
  - improved moisture resistance
  - improved chemical aging resistance
  - improved mechanical properties



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Bitumen chemical aging leads to pavement cracking

from LCPC, ME52, 1998

Hydrated Lime reduces the chemical aging of the bitumen

EFFECT OF LIME TREATMENT ON OXIDATIVE AGE HARDENING

Asphalt	Aging Index	
	Untreated	Lime Treated
Boscan	214	27
California Coastal	134	52
W. Texas-Maya Blend	338	52
N. Slope-Maya Blend	90	33

Notes: 1. Aged by TFFAT procedure at 113°C, 72 hours. Lime left in asphalt.
2. Rheological data obtained at 60°C, 15.85 rad/sec for unaged asphalts and 60°C, 0.125 rad/sec for aged asphalts.

Ref: Petersen, Plancher and Harnsberger, AAPT, v. 56, 1987, 632-653.

from Little + Petersen, JMCE, 2005

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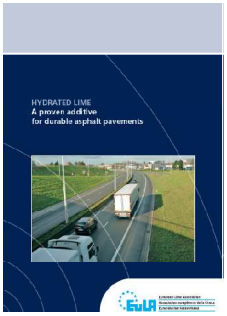
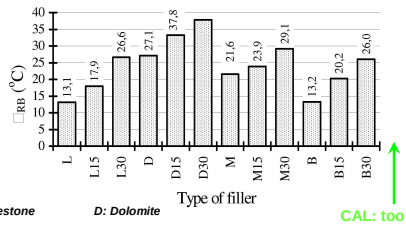


Hydrated Lime improves the mechanical properties of HMA

from LCPC, ME52, 1998

Hydrated Lime improves the mechanical properties of HMA

- Stiffening effect already mentioned as a filler

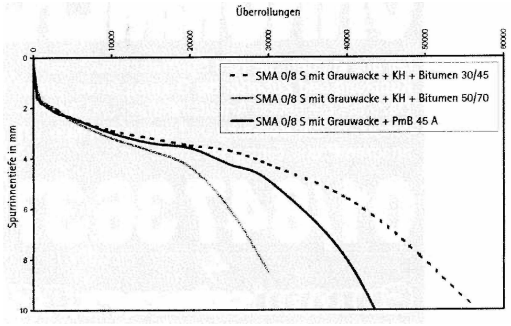


L: Limestone *D: Dolomite*
M: Melaphyre *B: Basalt*
CAL: Hydrated Lime

CAL: too stiff to measure !!

from Grabowski et al., Proc. Mairepav6, 2009

Hydrated Lime can improve the rutting resistance of HMA



from Cramer et al., Asphalt, 2001

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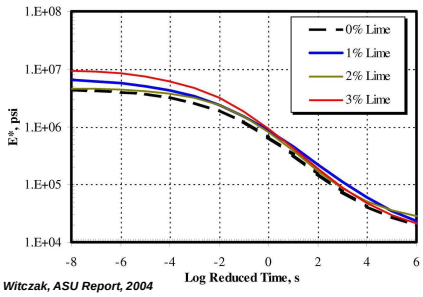
Hydrated Lime can improve the modulus of HMA

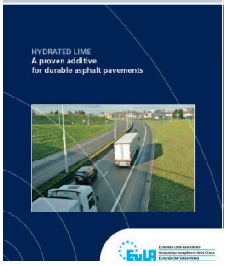
- 25% stiffer on average for 1-3% HL (17 mixes)



from Witczak, ASU Report, 2004

Why put Hydrated Lime in HMA?

- Multifuncional additive for increased durability
  - improved moisture resistance
  - improved chemical aging resistance
  - improved mechanical properties
- ... But how does it work??



Mechanisms of lime modification

- 3 Effects
  - Aggregate effect
  - Bitumen effect
    - Chemical effect
    - Physical effect

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Mechanisms of lime modification (1/3): Aggregate Effect

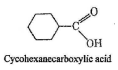
- Ca sites on aggregate surface (Ishai + Craus, AAPT, 1977)
  - Bitumen adhesion better with Ca than Si (cf. Hicks, NCHRP 175, 1991)
- Flocculation of clayey materials on “dirty” aggregate (cf. soil treatment)

Mechanisms of lime modification (2/3): Chemical Effect on Bitumen

- Reactions between the HL surface and some bitumen molecules
  - The “bad surfactants” (acids) are taken away from the aggregate surface: Moisture resistance
  - The oxidation prone molecules are chemically bond: Aging resistance

Table 4. Analysis of Components of Boscan Asphalt Adsorbed and Not Adsorbed on Hydrated Lime [Based in Data from Petersen et al. (1987a, b, c, d)]

		Concentration, mol/1,000 g	
Asphalt fraction	Percent of total asphalt	Carboxylic acids	2-Quinolone types
Adsorbed on high-calcium lime	5.6	0.83	0.15
Adsorbed on dolomitic lime	4.7	0.80	0.23
Not adsorbed on high-calcium lime	94.4	<0.005	<0.015
Not adsorbed on dolomitic lime	95.3	<0.005	<0.015



Cycohexanecarboxylic acid

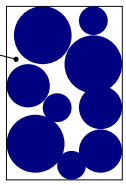
2-Quinolone

from Little + Petersen, JMCE, 2005

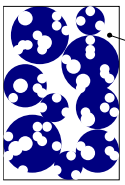
Mechanisms of lime modification (3/3): Physical effect on Bitumen

- High internal porosity gives high Rigden voids

35% air voids



mineral filler

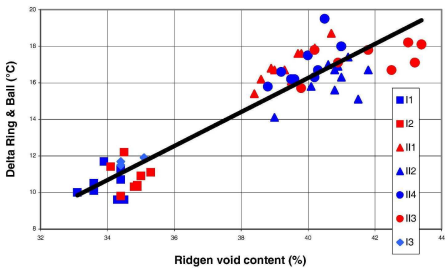


hydrated lime

65% air voids

Mechanisms of lime modification (3/3): Physical effect on Bitumen

- The high Rigden voids generate a strong stiffening effect



from Vansteenkiste + Vanelstraete, AAPT, 2008

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Several Methods of Addition

- 1-2% by weight based on aggregate
- Mix design must account for HL as fraction of mineral filler
- Match to needs:
  - Dry HL in drum
    - Add with mineral filler prior to AC
    - Possibility to use a mixed filler
  - Dry HL on damp aggregate
    - Moist aggregate surface & pugmill
  - HL lime slurry
    - Best method for clay contaminated aggregate

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Hydrated Lime in HMA: Dry Method

- Earliest method - Georgia, Montana, Wyoming
- Introduce HL into drum just before asphalt is added
  - 1-2% by aggregate weight commonly used
  - Vane feeder or screw for metering with mineral filler
- Benefits
  - Easiest method - not much equipment or handling
  - Some HL on aggregate, some dispersed in mix
  - Possibility to use mixed filler if only one silo
- Possible drawbacks
  - Lose HL into baghouse
  - HL content can't be adjusted separately in mixed filler

Double drum asphalt plant with 2 silos – one for hydrated lime & one for mineral filler

from E. Berger

Hydrated Lime in HMA: Dry HL on Damp Aggregate

- Currently most common method
  - Arizona, Colorado, Texas, South Carolina, Nevada (with marination), etc.
- Dry lime added to damp aggregate on cold feed
  - 1-2% HL metered with vane feeder, screw feed, etc.
  - Mixed in pug mill before entering drum
- Benefits
  - Relatively simple setup and metering
  - Aggregate coverage plus dispersion in mix
- Drawbacks
  - May have inadequate coverage for worst stripping (clay)

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Hydrated lime added to aggregate and fed into pugmill for mixing

from E. Berger

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Hydrated Lime in HMA: Slurry

- Lime slurry added to aggregate before mixing
  - Typical application 1-2%
  - May be marinated before use (CA)
  - May be fed directly into drum (UT)
- Benefits
  - Best aggregate coverage - ultimate in stripping prevention if aggregate is contaminated with clay
  - Easy to control quantity
- Drawbacks
  - Double handling of aggregate - need additional space
  - Excess water slows plant production
  - Little dispersion into mix

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Portable hydrated lime slurry operation

from E. Berger

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Feeding the pugmill – CA slurry operation

from E. Berger

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Stacking lime treated aggregate

from E. Berger

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Benefits of Hydrated Lime in HMA (1/2)

- Hydrated Lime is a standard CE marked asphalt additive
- Hydrated Lime content can be easily measured in the HMA
- Hydrated Lime improves the Moisture Resistance of HMA
  - Reason of the big success in the USA
  - Works with all types of aggregates
- Hydrated Lime also improves other properties
  - Aging resistance
  - Mechanical Properties

Benefits of Hydrated Lime in HMA (2/2)

- Hydrated Lime is thought to work through a combination of 3 effects
  - aggregate surface modifier (adhesion)
  - bitumen chemical modifier (adhesion + aging)
  - bitumen physical modifier (mechanical properties)
- Hydrated Lime is easily added to the mix
  - as a mineral filler (best with separate silo)
  - on the damp aggregate
  - in slurry form on the damp aggregate
- The overall effect is an increased durability of HMA

Increased durability of HMA with Hydrated Lime (1/2)

- USA experience:
  - HL treated mixes last 2-10 yrs longer
  - 20-50% more durable

Agency	Lime Treated			Non-Lime Treated		
	10%	Average	90%	10%	Average	90%
a) Interstate						
Arizona	13	15	17	10	12	14
California	8	10	12	6	8	10
Colorado	8	10	12	6	8	10
Georgia	7	10	15		N/A	
Mississippi	7	10	15		N/A	
Nevada*	7	8	9	3	4	7
Oregon	10	15	20	8	12	15
South Carolina	10	12	15		N/A	
Texas	8	12	15	7	10	12
Utah	15	20	25	7	10	15
b) State and U.S. Highways						
Arizona	18	20	22	15	17	20
California	8	10	12	6	8	10
Colorado*	8	10	12		8	
FHWA	15	20	25		N/A	
Georgia	8	10	14		N/A	
Mississippi	12	15	17		N/A	
Nevada	10	12	14	6	8	10
Oregon	15	17	20	8	12	15
South Carolina	8	10	12		N/A	
Texas	10	12	15	8	10	12
Utah	15	20	25	7	10	15
c) Low Volume Roads						
Arizona	20	25	30	15	20	25
California		N/A			N/A	
Colorado*	10	12	15	8	10	12
FHWA	15	20	25		N/A	
Georgia	8	10	15	8	10	15
Mississippi	12	15	17		N/A	
Nevada	18	20	22	12	15	18
Oregon	15	20	25	7	10	15
South Carolina	10	15	20		N/A	
Texas	8	12	15	7	10	15
Utah	7	10	15	3	5	7

*Pavement preservation
N/A = not applicable

from Hicks, NLA, 2003

Increased durability of HMA with Hydrated Lime (2/2)

- European experience
  - Many examples all over Europe
  - French motorway agency (SANEF) makes HL mandatory for wearing courses
  - Porous Asphalt with HL in the Netherlands
  - Common solution in Germany (SMA, AC) validated by the FIA

Country	Race Course	Year built	**Hydrated Lime +**
Brasilien	Rio de Janeiro	1999	PMB
Portugal	Estoril	2001	
Italien	Fiorano	2002	
Bahrain	Manama	2003/04	
China	Shanghai	2004	
Spanien	Barcelona	2004	
Türkei	Istanbul	2005	B50/70+TE

Thank you for your attention