Binder leaching from hydraulic lime mortars

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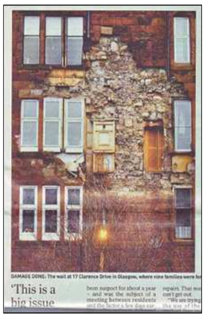
Binder leaching – the problem

Collapse of outer leaf of masonry



Source: Glasgow Herald

Stalactites in a vault

Background to lime mortar

- Burn limestone: $CaCO_3 \rightarrow CaO + CO_2$
- Slake the quicklime: $CaO + H_2O \rightarrow Ca(OH)_2$
- Mix with sand (either hot or cold, dry or as 'putty')
- Mortar sets by drying and reaction with air or water
- 'Air lime' (CL90) – also 'dry hydrate' is from pure limestone and hardens with CO_2: $Ca(OH)_2 + CO_2 \rightarrow CaCO_3$
- 'Hydraulic lime' (NHL2, NHL3.5, NHL5) is from limestone with clay impurities which form C_2S in the kiln. It hardens with CO_2 and by hydraulic reaction: $C_2S + H_2O \rightarrow$ C-S-H
- Some components are sufficiently soluble for leaching in water to be a possibility. (Climate change = more rain!!)

Accelerated leaching

- Hardened cement: 8M ammonium nitrate (Nguyen et al 2007)
- Hardened lime:

  $Ca(OH)_2 + 2NH_4NO_3 \rightarrow Ca(NO_3)_2 + NH_3\uparrow + NH_4OH + H_2O$

  $CaCO_3 + 2NH_4NO_3 \rightarrow Ca(NO_3)_2 + (NH_4)_2CO_3$

  Highly soluble
- 8M is too aggressive – 1M is sufficiently strong for lime

Objective of the work

To determine the rate of calcium leaching in a range of hardened hydraulic lime mortars, using ammonium nitrate as an accelerated leachant, and to assess the effect on physical and mechanical properties.

Procedure

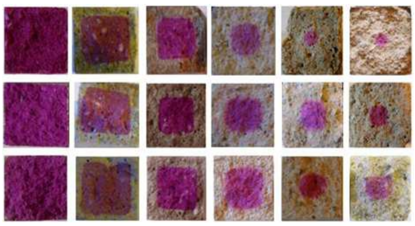
- NHL2, NHL3.5, NHL5 limes
- 1:3 Lime:sand mortars (proportions by volume, batched by mass)
- 160 x 40 x 40 mm prisms
- Cured in the moulds for 7 days at 100%RH
- 'Uncarbonated' or carbonated at 800-1000ppm CO_2
- Specimens immersed in 1M NH_4NO_3 for up to 169 days
- Tested for flexural strength, compressive strength, sorptivity, and by petrography on thin sections

Leaching depth – uncarbonated mortars

NHL2

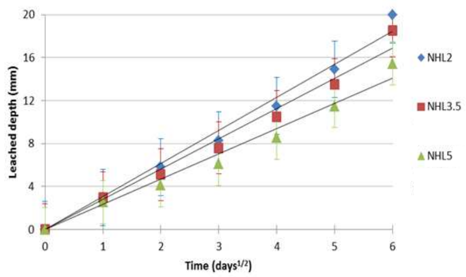
NHL3.5

NHL5

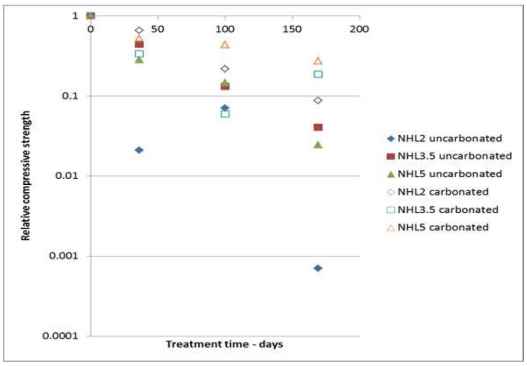


Time of leaching 1 4 9 16 25 36 days

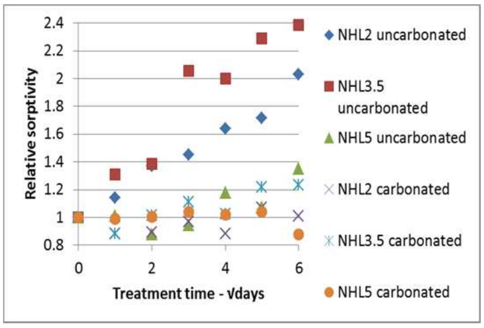
Leaching depth – uncarbonated mortars



Strength reduction – all mortars

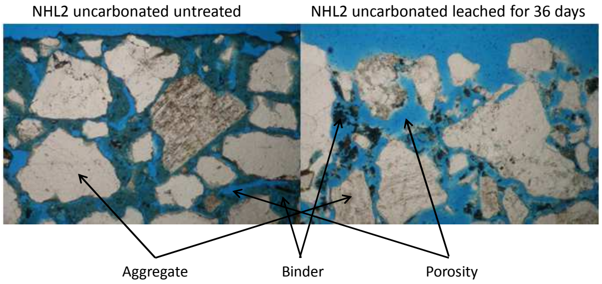


Sorptivity changes – all mortars



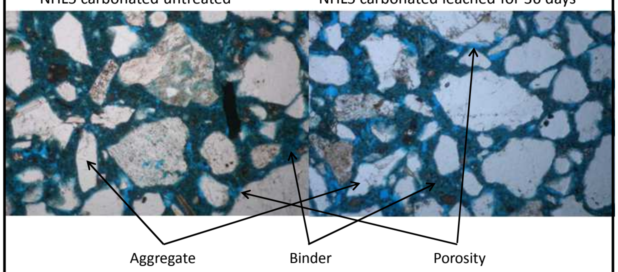
Thin sections – examples 1

NHL2 uncarbonated untreated NHL2 uncarbonated leached for 36 days

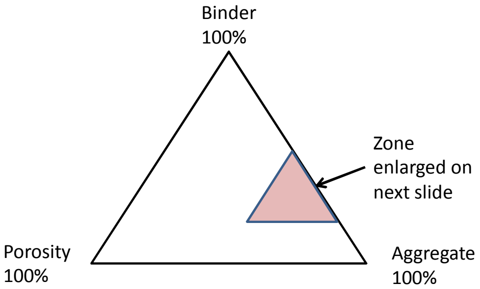


Thin sections – examples 2

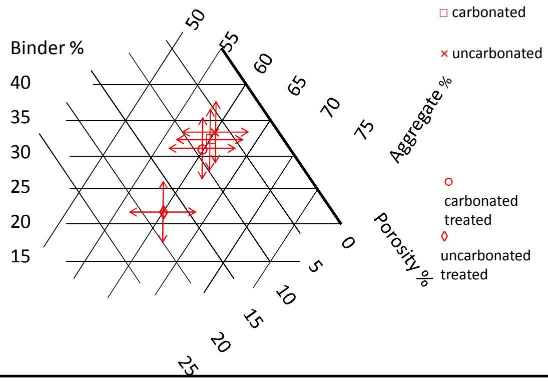
NHL5 carbonated untreated NHL5 carbonated leached for 36 days



Thin sections – point counting assessment



Thin sections – point counting assessment



Water exposure: predicted lifetimes (assuming acceleration factor = 20)

	uncarbonated			carbonated		
	NHL2	NHL3.5	NHL5	NHL2	NHL3.5	NHL5
Leached depth one year (mm)	3.5	2	2.5	2	2	1.5
Leached depth 100 years (mm)	33	22	24	20	20	15
Time to leach to 20mm (years)	40	80	70	100	100	190
Time to leach to 50mm (years)	230	500	440	630	630	1200

Conclusions

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- 1M NH_4NO_3 works as an accelerated leachant for NHL mortar
- Leaching of calcium from the binder reduces strength, increases porosity and sorptivity: this has implications for durability
- Leaching resistance increases in the order NHL2<NHL3.5<NHL5
- Carbonated mortar is more resistant to leaching than uncarbonated mortar.

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