



HYDRAULIC LIME

AN INTRODUCTION

Hydraulic lime was an important cementitious material before the arrival of Portland cement but it is little used now, except in conservation work. Production of good hydraulic lime is as much a craft as a technology, even more than ordinary lime but, with the decline in use of hydraulic lime, there are few skilled producers left and new producers often need to learn the required skills from scratch.

Hydraulic lime hardens partly by reaction with water and so differs from other types of lime which harden by chemical reaction with carbon dioxide in the air. Hydraulic lime has properties intermediate between ordinary lime and Portland cement but is produced in a similar way to ordinary lime. In addition to containing calcium hydroxide, the chemical which makes up ordinary lime, hydraulic lime also contains calcium silicates similar to the main cementitious components of Portland cement.

A cement with properties similar to hydraulic lime can also be obtained by mixing ordinary lime with a pozzolanic material. Hydraulic lime can be made stronger than ordinary lime and can be used in some applications for which ordinary lime is not suitable, particularly where water is present.

In developing countries hydraulic lime is rarely produced. There is probably considerable potential for increased production in situations where Portland cement is scarce or very expensive. However, in general, little mapping of reserves of raw materials or assessment of their quality has been carried out. This information is needed before successful production can take place.

Raw materials

The raw material for hydraulic lime is a limestone which contains calcium carbonate together with a proportion of clay. Such a limestone is known as argillaceous. Most limestones for hydraulic lime production contain between 15 and 35 per cent silica together with alumina - two important constituents of clays.

Most argillaceous limestones are somewhat grey or blue in colour. They can also be distinguished by having a dull surface which does not sparkle in sunlight when broken. As with all types of limestones, argillaceous limestones will fizz when a few drops of dilute hydrochloric or sulphuric acid are put on them. Marlstone - a soft limestone that is common in some areas, is often a suitable raw material for producing hydraulic lime.

Most limestones used for hydraulic lime production vary in properties such as clay content and type of clay minerals present in a single deposit. This results in the production of a lime



Figure 1: Slaking. Hydrated lime is produced by adding water to quicklime. Chenkumbe Hills Area, Malawi. Photo: Practical Action / David Mather.

with significant variation in properties such as strength and setting time, even with a high level of quality control during production. Allowance for such a variation should be made in using the lime.

Firing the raw materials

Heating of argillaceous limestones is done in order to:

- drive off carbon dioxide gas to produce quicklime, as in the production of ordinary lime,
- promote a chemical reaction between the quicklime and the minerals in the clay component to yield calcium silicate compounds.

The latter reaction begins if firing is done at temperatures between 50 and 100°C higher than when firing ordinary limestone. Kiln temperatures for production of hydraulic lime can be as high as 1200°C.

Most designs of kilns for the production of ordinary lime should also be suitable for producing hydraulic lime. However, burning times will be shorter for hydraulic lime because less carbon dioxide needs to be driven off. When using wood as fuel some softwoods may not have sufficient calorific content to reach the temperatures required. In this case, the choice would be to use another fuel such as coal, use wood from a different species of tree, or convert the available wood to charcoal.

Hydraulic limes of different properties can be produced by burning the kiln to different temperatures. Hence, it is not possible to give specific information on quantities of fuel required or on firing times. These values will also depend on the type of raw materials which are used and the performance of the kiln and, for a particular project, can be determined only by trials and from experience.

Hydrating Hydraulic Limes

Sufficient water should be used to hydrate the available quicklime but not cause calcium silicate components to start to set. Ideally the hydration process should just convert the quicklime lumps to a fine dry powder. Hydration can be done by hand on a firm level surface or in a mechanical hydrator. The hydration reaction is generally less violent and a lot slower than with ordinary quicklime and, in some cases, hot water needs to be used or even, with highly hydraulic lime, grinding of the quicklime before hydration.

With the quicklime containing between 10 and 15 per cent free or uncombined lime, most of the product can be converted to a powder on hydration. However, there may be some clinker-like lumps, known as grappiers, left particularly if the limestone has been fired close to the upper end of the temperature range for hydraulic lime and the raw material has a high clay content. These need to be removed on a screen and ground down separately. The product can then be used as a cement on its own (known as natural cement or Roman cement), in which case it will have properties approaching those of Portland cement, or it can be blended back with the hydraulic lime to give it slightly higher strength and a shorter setting time. This blending process allows the producer to meet strength standards even with a variable raw material. Hydraulic lime must be stored in a dry place and preferably in sealed bags if it is not going to be used straight away.

In production of Portland cement all of the clinker produced at the kiln stage is ground to a fine powder in expensive ball or tube mills. In contrast, hydraulic lime requires no mill or, possibly only a small mill for grinding down grappiers, or quicklime for hydration. Because of these and other less complex equipment requirements, hydraulic lime is much more suitable for small-scale production than Portland cement.

Using hydraulic lime

The main use of hydraulic lime is as a mortar. However, it can also be used as a render or plaster, in floors and ceilings, as a cement in making blocks and in unreinforced lime

concrete. It is generally not recommended for steel-reinforced concrete or for ferrocement unless, preliminary tests have been carried out and/ or expert advice sought. When preparing a mortar mix note should be taken of any sandy material already contained in the lime and only sufficient sand added to produce the desired properties of the mortar mix. Normally 1 part hydraulic lime is added to either 2.5,3 or 4 parts sand by volume depending on the characteristics required. Four hours is a typical time during which a hydraulic lime mortar is usable, but mildly hydraulic lime mortars might still be usable considerably later. It is possible to add a pozzolana if an increase in strength is desired provided that the pozzolana is mixed in well with the lime before adding sand and water. The plasticity of a hydraulic lime mortar is intermediate between that of ordinary lime and Portland cement.

Chemical composition, fineness, setting time, compressive strength and soundness are important properties of cementitious materials. A comparison of values of these properties for hydraulic lime, drawn from American (ASTM) and Indian standards, is presented below. The main controlling factor of the degree of hydraulicity or cementing power of a lime is the silica to lime ratio, i.e. SiO₂/CaO or, a more specific expression, the cementation index (CI). The latter takes into account other minerals which might be present in the lime. Based on the cementation index hydraulic limes have been classified as follows:

Type	CI
Mildly hydraulic	0.3 -0.5
Moderately hydraulic	0.5 -0.7
Eminently hydraulic	0.7- 1.1

$$2.8 \times \%SiO_2 + 1.1 \times \%Al_2O_3 + 0.7 \times \%Fe_2O_3$$

CI is defined as $\frac{\text{2.8 x \%SiO}_2 + 1.1 \times \%Al_2O_3 + 0.7x\%Fe_2O_3}{\%CaO + 1.4x\%Mg}$

The Indian standard recognises only two types of hydraulic lime: Class A, - eminently hydraulic for structural purposes, and Class B, -semi-hydraulic for masonry use. Hydraulic limes can be expected to attain compressive strengths of 0.5 to 1.0MPa (or N/mm²) after seven days and 3 to 7MPa after six months for a standard 1:3 lime to sand mix. More exact values will depend on the degree of hydraulicity and processing characteristics. In comparison Portland cement will attain compressive strength of 17MPa after 7 days and 28MPa after six months.

Property	Indian Standard		American Standard
	Class A (hydrated)	Class B (hydrated)	
Minimum calcium & magnesium oxides, %	60	70	65
Maximum calcium & magnesium oxide, %			75
Maximum magnesium oxide, %	5	5	
Minimum silica, alumina & ferric oxide, %	25	15	16
Maximum cementation value		0.6	
Minimum cementation value	0.6	0.3	
Fineness	No residue 2.36mm sieve, not more than 5% on 850 μm sieve and not more than 10% of fraction passing 850 μm sieve on 300 μm sieve	As for Class A	Residue of not more than 0.5% on a 600μ m sieve and not more than 10% on a 75 μm sieve
Setting time	Within 2 hours to initial set and within 48 hours to final set		Within 2 hours to initial set and within 24 hours to final set

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Minimum compressive strength	1.75 MPa after 14 days and 2.8 Mpa after 28 days	1.25 MPa after 14 days & 1.75 MPa after 28 days	Average 1.7 MPa after 7 days and 3.4 MPa after 28 days
Soundness	Maximum 10mm expansion in the Le Chatelier test	As for Class A	Mortar bars not to expand more than 1.0% in ASTM test

Note – not all the properties are specified in the standards are shown above. For more complete details consult the relevant standards.

Indian Standard = IS: 712-1973 Building Limes

American Standard = ASTM C 141 – 67; Standard Specification for Hydraulic Hydrated Lime for Structural Purposes

A simple test to determine whether a lime is hydraulic is to take a lump of the quicklime and sprinkle water on it. If reaction starts within five minutes accompanied by hissing and spitting the lime is unlikely to have any significant hydraulic activity. If the reaction begins after about 15 minutes and is not violent then the lime could be mildly hydraulic. If the lime lump has collapsed to a powder after about an hour and the container has only become warm, not hot, then the lime could be moderately hydraulic. If the lump has only partially turned to a powder or has remained intact after an hour then the lime could be eminently hydraulic. It might then be necessary to use boiling water to get any reaction going or even to grind the lump. On hydration a high-calcium lime can show a threefold increase in volume while hydraulic limes show volume increases which are much smaller. After hydration some water can be added to the lime to give it the consistency of a potter's clay and the lime rolled into a ball and put in water. If the lime is high in calcium or mildly hydraulic the ball will probably break up. For a moderately hydraulic lime the ball should stay intact and after a month have the consistency of a bar of soft soap. However, an eminently hydraulic lime would have become like a soft stone which would be hard to scratch with a fingernail.

References and further reading

- [Alternatives to Portland Cement](#) Practical Action Technical Brief
- [Lime - An Introduction](#) Practical Action Technical Brief
- [Calculating The Energy Efficiency of Your Lime Burning Process](#) Practical Action Technical Brief
- [Methods for testing lime in the field](#) Practical Action Technical Brief
- [How to Build a Small Vertical Shaft Lime Kiln](#) Practical Action Technical Brief
- [A Small Lime Kiln for Batch and Continuous Firing](#) Practical Action Technical Brief
- [Pozzolanas - An Introduction](#) Practical Action Technical Brief
- [Small Scale Production of Lime for Building](#) John Spiropoulos, GTZ,1985
- [Gypsum Plaster: Its Manufacture and Use](#), A. Coburn, E. Dudley and R.Spence, Practical Action Publishing, 1989
- [Small-scale Lime-burning: A practical introduction](#) Michael Wingate, Practical Action Publishing,1985
- [The Small Scale Vertical Shaft Lime Kiln: A practical guide to design, construction and operation](#), Kelvin Mason, Practical Action Publishing, 1999
- [Building with Lime: A practical introduction. Revised Edition](#) Stafford Holmes & Michael Wingate, Practical Action Publishing, 2002/3
- [A Case Study in Lime Production: Improved design of a lime kiln in Sri Lanka](#), Practical Action Technical Brief
- [Lime Production: Traditional batch techniques in Chenkumbi](#), Practical Action Technical Brief
- [A Case Study in Lime Production No2 Improved Techniques at Chenkumbi, Malawi](#), Practical Action Technical Brief
- [Lime Production: A traditional kiln at Bou Noura, Algeria](#), Practical Action Technical Brief
- [Lime Production: Traditional batch techniques in Pattará, Costa Rica](#), Practical Action Technical Brief

- [Lime and Alternative Binders in East Africa](#), Elijah Agevi et al, Practical Action /ODA, 1995
- [Lime and Other Alternative Cements](#) Neville Hill et al, Practical Action Publishing, 1992
- *Limes for Building*, Advisory Leaflet No.6, Property Services Agency, Department of the Environment, HMSO, London, Sth Edn., 1976.
- *The Chemistry of Cement and Concrete*, Lea, P.M., Edward Arnold, London, 3rd Edn. 1970.
- *Supplementary Cementing Materials for Use in Blended Cements*, R.J. Detwiler, J.I. Bhatta, S. Bhattacharja, Research and Development Bulletin RD112T, Portland Cement Association, Skokie, Illinois, USA, 1996
- *Chemistry and Technology of Lime and Limestone*, R.S. Boynton, Interscience Publishers, John Wiley & Son, New York, 1980.
- *The Cement Industry 1796-1914: A History*, A.J. Francis, David & Charles, Newton Abbot, 1977.
- *An Introduction to Building Limes, Information Sheet 9*, M. Wingate, Society for the Protection of Ancient Buildings, London.
- *Lime and Lime Mortars*, A.D. Cowper, Building Research Special Report No.9, His Majesty's Stationary Office, London, 1927 (republished 1998 by Donhead Publishing, Shaftesbury, Dorset, England: full address – Donhead Publishing Ltd, Lower Combe, Donhead St. Mary, Shaftesbury, SP7 9LY, UK, Tel. +44 (0)1747 828422, Fax. +44 (0)1747 828522, E-mail: sales@donhead.com, Website: <http://www.donhead.com>).
- *Hydraulic Lime Mortar for Stone, Brick and Block Masonry*, G. Allen, Donhead Publishing, Shaftesbury, Dorset, England, 2003 (address as above)
- *The Technology and Use of Hydraulic Lime*, J. Ashurst, 1997,
- *A Brief Description of HL2's New Plant*, M. Farey, Lime News, Vol. 6, 1998, pp. 101 – 105

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