



LIME

AN INTRODUCTION

Lime is a remarkable and versatile material. It has a long tradition of use in construction, agriculture, water and waste treatment. More recently, lime has been used in numerous manufacturing and processing industries, most notably papermaking, sugar processing, steel production and the manufacture of calcium silicate bricks. This document is an introduction to lime, how it is produced, and what raw materials are required. It lays particular emphasis on lime utilization in the construction industry and the contribution it can make towards low-cost building materials.

How lime is produced

There are two main forms of lime; quick-lime and hydrated lime. Quicklime is produced by heating any material containing calcium carbonate to a temperature of around 1000°C for several hours. In this process, known as 'calcining' or simply 'burning', the carbon dioxide in the calcium carbonate is driven off leaving calcium oxide plus any impurities.

Quicklime is a chemically unstable and hazardous material and is therefore normally hydrated, becoming not only more stable but also easier and safer to handle. Hydrated lime is produced by adding water to quicklime in a process called 'hydration' or 'slaking', where the calcium oxide and water combine chemically to form calcium hydroxide.

Raw materials

Limestone is the most common raw material used to produce lime, although other calcareous materials such as marble, coral and shells are also used. With large-scale excavation of any raw material, care must be taken to minimize environmental damage, particularly in the case of coral and, to a lesser extent, sea shells.

Most industries specify lime which is of high purity and therefore the raw material must contain as few impurities as possible. A calcium carbonate content of 95 per cent would normally be considered the minimum for production of high calcium limes. In construction, chemical purity is less important and dolomitic and hydraulic limes are also used.

The excavation of rock for lime production is normally undertaken in a quarry with the use of explosives or mechanical rock breaking hammers, although for very small-scale lime production hand excavation methods may still be used. In most lime kilns, the raw materials must be broken down to a standard size, typically between 100 and 150mm. This is normally done by mechanical rock crushers, although again hand methods can be used for small quantities.

Almost any fuel can be used in lime burning. Traditionally, wood was most commonly used but increasing cost, environmental concerns and deforestation have restricted its use. Coal is probably the most common fuel used in recent years. Others fuels include oil, gas, some agricultural wastes and even, in a few cases, peat.



Figure 1: Loading limestone for the kiln.
Chenkumbe Hills Area, Malawi
©Practical Action

Burning

The techniques employed in burning lime can vary considerably. The simplest (and least efficient) method consists merely of a circular pile of logs with limestone heaped on top of it. This is then ignited and is likely to produce less than 500kg of lime per burn.

At the other end of the scale, sophisticated and energy-efficient rotary kilns operating continuously can produce over 500 tonnes of lime per day.

Probably the most common type of lime kiln is the vertical shaft, of which there are many variants. Basically they consist of a tall, chimney-like, cylindrical shaft. Limestone is loaded at the top and falls slowly under gravity as lime is withdrawn from the bottom.

The limestone is first pre-heated, burned and then cooled as it passes slowly through the kiln. Vertical shaft kilns will normally produce between 2 and 250 tonnes of lime per day depending upon kiln size.



Figure 2: A vertical shaft kiln for small-scale production of lime. Chegutu, Zimbabwe. ©Practical Action/Kelvin Mason

Other leaflets in this series describe a number of kiln types and give case studies of lime production at varying levels of output and mechanisation.

Hydration

Hydration, in small quantities, can be undertaken manually by sprinkling water onto a pile of quicklime which is then turned and mixed with a rake as more water is added. In large quantities, hydration is normally automated and done in large hydrators where measured quantities of water and quicklime are fed in and mechanically agitated.

During hydration, the quicklime lumps will disintegrate to a fine powder. For high quality limes some form of screening and/ or classification, during which the lime is sorted by particle size and density, will be required to grade the lime. Hydrated lime is normally supplied and sold bagged, as a dry powder.

If quicklime is hydrated with an excess of water and well agitated, it forms a milky suspension known as milk of lime. Allowing the solids to settle and drawing off the excess water forms a paste-like residue known as lime putty. Lime in this form is considered, by many, to be preferable for use in building as it ensures complete hydration, produces excellent mortars and, if kept in a saturated condition, will not deteriorate over time.

Dolomitic and hydraulic limes

In some locations, raw material with high calcium carbonate contents will not be available. This may not be a constraint for lime used in the construction industry since lime containing impurities can be tolerated and may even have advantages.

One of the elements most often found in combination with calcium is magnesium and here the raw material is known as dolomite or dolomitic limestone, depending upon the percentage of magnesium in the rock.

When burning dolomitic limestones the temperature should be slightly lower and calcining period longer than for high calcium limestones.

Particular attention must be given to hydration as magnesium oxide will hydrate much more slowly than calcium oxide. If hydration is not fully complete this can lead to problems of unsoundness (expansion) in the mortar or plaster. With dolomitic limes, pit slaking over an extended period to form lime putty is probably the best method of hydration on a small scale.

Limestone containing clays (argillaceous limestone) will produce hydraulic limes which are generally considered advantageous for use in the construction industry. Hydraulic limes will gain greater strength, and at a faster rate, than high calcium limes. They will also set under water and produce a generally more durable product.

A limestone with less than 12 per cent clay will produce a slightly hydraulic lime, while limestone with a clay content of between 18 and 25 per cent will produce eminently hydraulic lime (see the leaflet in this series entitled *Hydraulic Lime: An introduction*).

Historical use of lime in building

History does not record where burning limestone to produce quicklime was first practised. We do know that the Cretan civilization in the Mediterranean made use of lime as a masonry mortar more than three thousand years ago. In China, the use of lime for mortar and plaster is of similar antiquity. The Great Wall of China, for instance, was built with lime mortars.

That lime is an appropriate and durable binding material is well proven. The Pont du Gard at Nimes in southern France, a Roman aqueduct built in 18AD with hydraulic lime-based mortar, is still water-proof; the excellence of the mortar is attributed to the selection of the materials used as well as to the time spent tamping the mix into place during construction. Until the twentieth century, lime was the principal cementing agent used in house construction, being widely used in concretes, mortars, plasters and renders. It was also used extensively as a decorative finish on many buildings in the form of whitewash.

During the nineteenth century, use of Portland cement which is considerably stronger than lime has developed. Although Portland cement is notably more complex and expensive to produce, it was heavily promoted and by the beginning of the twentieth century it was being extensively used. Within a few decades, Portland cement was being utilized for mortars and render, despite its technical disadvantages in comparison to lime, and it now dominates the cement market.

Why use and promote lime?

The use of lime as the cementing agent, particularly in mortar and plasters, has a number of advantages over Portland cement. Mortars and plasters made with a low percentage of Portland cement tend to have low workability (a building term meaning the correct combination of flow, water retention and cohesiveness), are porous and lack durability. Where the proportion of cement is increased to overcome this, other problems such as harshness, brittleness and shrinkage tend to occur.

Lime is much better than cement in plasterwork. The setting is slow, but the result will look better and the softer surface will be less likely to crack. Lime mortars have a high degree of workability which is highly desirable in mortars and plasters. Lime products also set more slowly which allows mixing in large quantities without fear of going off before use. In harsh climatic conditions, lime mortars and plasters may not be very durable but this can easily be overcome by the use of hydraulic limes or the addition of a small percentage of Portland cement into the mix. Siliceous materials, known as pozzolanas (eg volcanic ash and rice husk ash), can also be mixed with lime to improve its strength and durability.

Architects are increasingly becoming aware of the problems of Portland cement mortars and many now specify blended lime-Portland cement mortars. Recently, lime has played a leading role, worldwide, in the conservation of old buildings, most of which were built in the 'pre-Portland cement' era. It is well recognized that successful preservation of ancient monuments, such as churches, castles and other historic sites, necessitates the application

of the same binding systems as were used originally. Attempts in the past at patching up these buildings with ordinary Portland cement-based mixes have invariably led to even greater problems of decay occurring at a later stage.

Lime also has considerable economic advantages over Portland cement. The latter is relatively expensive to produce and critically for developing countries, often requires expensive imported technologies and fuels. Lime has none of these disadvantages and is normally considerably cheaper to produce, needs much lower or even negligible capital inputs to get started, and requires far less imported technology and equipment. It can also be produced on a small scale to supply a local market. This greatly reduces transportation costs and provides a much greater degree of local accountability in the supply of building materials. Portland cement on the other hand tends to be produced in large centralized plants which inevitably leads to distribution difficulties and high transportation costs.

Lower production and transportation costs make for lower purchase costs to the consumer, enabling those who could not afford Portland cement to purchase and use a quality binding material on construction projects. The production and use of lime also has several social advantages. Its production is normally labour intensive, unlike the capital-intensive methods required for Portland cement, and provides opportunities for local employment. This can be particularly important in urban areas in developing countries where unemployment rates are frequently very high.

References and further reading

- *Alternatives to Portland Cement: An Introduction* Practical Action Technical Brief
- *Hydraulic Lime: An Introduction* Practical Action Technical Brief
- *Methods of Testing Lime in The Field* Practical Action Technical Brief
- *Calculating The Energy Efficiency of Your Lime Burning Process* Practical Action Technical Brief
- *How to Build a Small Vertical Shaft Lime Kiln* Practical Action Technical Brief
- *Lime Kiln Design: Small & Medium Scale Oil Fired Lime Kilns* Practical Action Technical Brief
- *A Small Lime Kiln for Batch and Continuous Firing* Practical Action Technical Brief
- *The Small-scale Vertical Shaft Lime Kiln: A Practical Guide to Design, Construction and operation*, Kelvin Mason, ITDG Publishing ISBN 1 85339 465 3, 1999
- *Building with Lime: A Practical Introduction 2nd Ed.* Stafford Holmes & Michael Wingate, ITDG Publishing, 2002 / 3
- *Small-scale Lime Burning: A Practical Introduction*, M. Wingate and others, IT Publications, London, 1985.
- *Small Scale Production of Lime for Building*, John Spiropoulos, GATE/GTZ, 1985, <http://ww2.gtz.de/Basin/publications/books/lime.pdf>
- *Limes for Building*, Advisory Leaflet No.6, Property Services Agency, Department of the Environment, HMSO, London, 5th Edn., 1976.
- *The Chemistry of Cement and Concrete*, P.M. Lea, Edward Arnold, London, 3rd Edn., 1970.
- *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).
- *Chemistry and Technology of Lime and Limestone*, R. Boynton, John Wiley and Sons Inc., 1980.
- *Lime and Limestone: Chemistry and Technology, Production and Uses*, J.A.H. Oates, Wiley - VCH, Weinheim, Germany, 1998.
- *Lime: The Basics*, Johnathan Taylor, 2000, <http://www.buildingconservation.com/articles/limebasic/limebasic.htm>
- *Vertical Shaft Lime Kiln Technology*, UN-Habitat, Nairobi, 1993, HS/303/93E, http://hq.unhabitat.org/publication/hs30393e/hs30393e_toc.pdf
- *The Use of Lime Mortars in Historic Structures*, Technical Conservation Note 2, April 2004, CADW, Cardiff, Wales, <http://www.cadw.wales.gov.uk/upload/resourcepool/Lime%20Mortar%20Notes%20ENg3000.pdf>

- *Building Limes Forum*, <http://www.buildinglimesforum.org.uk>
- *National Lime Association (USA & Canada)*, <http://www.lime.org/>

A Spanish version of this Technical Brief is available. *Cal: Introducción*

This technical brief was originally prepared for **basin**, Building Advisory Service and Information Network.

Website: <http://www.gtz.de/basin>



For further information contact:

Practical Action

The Schumacher Centre for Technology & Development,
Bourton Hall
Bourton on Dunsmore, Rugby CV23 9Z,
United Kingdom
Tel: 44 (0) 1926 634400
Fax: 44 (0) 1926 634401
E-mail: infoserv@practicalaction.org.uk
Website: <http://www.practicalaction.org>

This Technical Brief is possible thanks to the collaboration of DFID-UK and The Tony Bullard Trust.

technical brief