

Hot-mix lime mortar guide



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Department of
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This Guide serves as an introduction to hot-mix lime mortars. It illustrates the way in which they differ from other types of lime mortars and the trials and research that have been undertaken to date. It also considers the merit and possible benefits of using them, and gives a brief overview of their preparation on site, as well as Health & Safety considerations.

The Guide also encapsulates the current position of the Building Limes Forum Ireland (BLFI) on hot-mix lime mortars, after successfully completing Phase I of the Hot Lime Mortars HLM Project, Technology Transfer & Applied Research, Scotland & Ireland, May 2015.

For over 1,000 years, hot-mix lime mortar was used extensively in the building of the masonry heritage of Ireland. To repair these structures following the accepted principle of conservation, 'like for like', we must seriously consider how we can create more closely-matched mortars than those we have been using to date. We have indigenous, commercially available quicklime, so a practical solution would be to use this in combination with imported natural hydraulic limes and/or pozzolans, as required.

The BLFI consider that the use of hot-mix lime mortars would not only ensure better compatibility and comparability with the original mortar, but would also be a practical, economic and environmentally-sound means of achieving their revival.

This document is based on the best knowledge available at the time of publication. With continuing research and trials, new discoveries will be made which will enhance our current understanding.

- Always seek professional advice for mixes, methodologies and risk assessments.
- Employ experienced crafts people to carry out the work.
- Educate and train personnel in the use of hot-mix lime mortars.

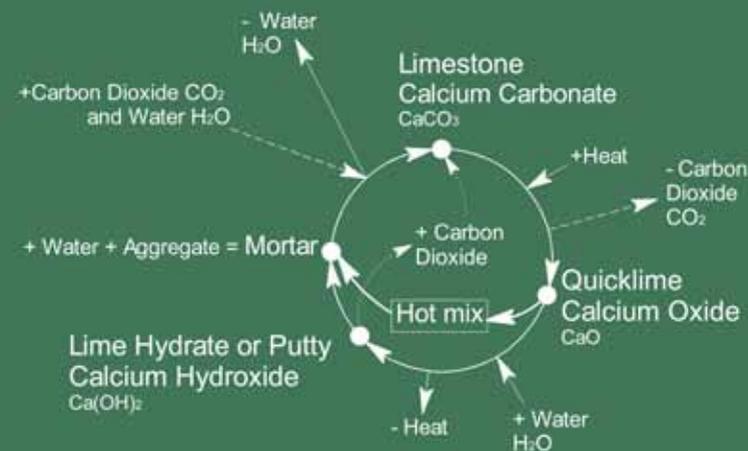
For further and more up-to-date information, please be directed to the BLFI webpage, www.buildinglimesforumireland.com, where there is also information on courses and workshops.



LIME CYCLE

Limestone, Cloch Aoil, when calcined (heated or burnt) is converted to quicklime (calcium oxide) and carbon dioxide. Quicklime reacts with water to form slaked lime (calcium hydroxide). The available quicklime in Ireland

(non-hydraulic) does not technically set, but hardens over time with the re-introduction of carbon dioxide from the atmosphere (carbonation). This process is called the Lime Cycle.



DEFINITIONS

Limestone & Sea shell (calcium carbonate CaCO₃)

Limestone is naturally occurring and in abundance in many areas of Ireland as both bedrock and glacial till. In the past, a variety of limestones were used to produce quicklimes, some with impurities such as clay, sand, mud or chert, which imparted a hydraulic set (see below). The quicklime that is available today is produced by calcining (heating) a near-pure limestone that does not produce a hydraulic set. Dolomitic limestones CaMg (CO₃)₂ are also present in Ireland, but are not currently used in our building limes.

Quicklime, non-hydraulic (Calcium Oxide CaO) CL90

When limestone or shell is calcined (heated) in a kiln at a temperature of around 900°C, carbon dioxide is driven off, leaving quicklime (calcium oxide). Non-hydraulic quicklime is highly reactive and available in lump, granular or powdered form.

Non-hydraulic lime (Calcium Hydroxide Ca(OH)₂) CL90

This is produced by either slaking non-hydraulic quicklime to a dry hydrate using just-sufficient water, or by running (wet slaking) it to a lime putty with excess water. During the slake, quicklime expands by up to twice its volume. CL90 does not technically set, but hardens with the re-introduction of CO₂ over time (carbonation).

Natural Hydraulic Lime (NHL)

This is produced by calcining limestone which naturally contains clay (argillaceous) or silica (siliceous) compounds. NHLs are available slaked to a dry hydrate, as NHL2, NHL3.5 and NHL5. The numbers following the letters represent the minimum strength in N/mm² of laboratory-cured samples, tested at 28 days. NHLs will set in wet/damp conditions, unlike non-hydraulic limes, but will also carbonate if they have access to carbon dioxide.

Mortar

Mortar is composed of a binder (lime, clay, cement etc.) and sand/aggregate mixed together with water. It is used to bed masonry units such as stones or bricks together in masonry construction. Mortar can also refer to the stuff that forms renders and plasters.

Pozzolans and other additives

Non-hydraulic lime mortar will not set in wet/damp conditions unless a pozzolan is added to create a hydraulic set. Brick dust and volcanic ash have been used as pozzolans since Roman times. Wood, turf and coal ash, clay and other materials have been observed in historic mortars and appear to aid set and/or carbonation.

WHAT IS HOT-MIX LIME MORTAR?

It is not uncommon to find small white lumps (inclusions) in most older (historic) mortars, and studies have shown them to be formed from un-slaked and partially-slaked lime, combined with over-burnt and under-burnt fragments of lime. These are then incorporated within the binder used in the mortar production. Their presence, along with the condition of the mortar fabric surrounding the inclusions, would indicate that a high proportion of the mortars used in the past were mixed hot, and then used either hot or cold. Clarification of the actual form used may be obtained from further study of the mortar. A study of historic records, where details of mortar production and use have been extensively described, has also confirmed the use of hot-mix mortar.

Hot-mix lime mortars are prepared by mixing quicklime, sand/aggregate and water to form a workable mortar. Once water and quicklime combine, they generate heat, which is why this mortar is referred to as 'hot-mix'.

- At its simplest, a hot-mix lime mortar is just quicklime, sand/aggregate and water. A commonly used mix in the past was 1 part quicklime to 3 parts sand/aggregate. A key feature of quicklime is that it expands to approximately twice its volume on slaking, and mortar analysis often reveals just such a 2:3 mix ratio in our historic mortars.
- A similar type of mix gauged with an NHL (natural hydraulic lime) as a substitute for a pozzolan is a modern attempt to replicate the low hydraulic set found in many older mortars. A hydraulic set is essential in cold/damp/exposed conditions. In these mixes, a portion of the quicklime is replaced with an NHL.
- Crushed shell or limestone dust is sometimes added to the mix to act as seed-points for carbonation. These additions are substituted for part of the sand/aggregate.
- A pozzolan, natural or man-made, can be added to create a hydraulic set.
- Wood, turf, coal ash, clay and other materials have also been observed in historic mortars, and these appear to achieve a low hydraulic set or enhance carbonation. These materials will be included in further investigations into mix designs.



The basic materials for a hot mix lime mortar – quicklime and sand



A more complex mix - natural hydraulic lime, quicklime, limestone dust and sand

WHY USE HOT-MIX LIME MORTARS?

The architectural history of Ireland is one of masonry structures, built using hot-mixed lime mortars, which were either non-hydraulic or feebly hydraulic and had low compressive strengths. The defining characteristics of these mortars are: high vapour permeability and flexural capacity, qualities which continue to be of benefit to these structures today. Hot-mix lime mortars were being used as early as the 9th century, and this continued right up to the 20th century. It was the rise of patented hydraulic binders, including Portland cement in the 19th century, combined with new building technologies, which brought about the eventual demise of hot-mix lime mortars. In the late 20th century, recognition of the incompatibility of cement-based materials in the repair of historic structures led to the 'lime revival', beginning with lime putty mortars, then NHL mortars and now the ongoing research into hot-mix lime mortars that is under way today. Lime-based mortars have regained acceptance and are now recommended for repairs to older buildings. The role of NHLs in this process must be recognised. However, the present, near-exclusive use of NHLs in the repair of older buildings may prove detrimental, due to their higher compressive strengths and lower permeability, compared to the original lime mortars. It is obvious that hot-mix lime mortar technology must be developed for use in future repairs. Ongoing research, testing and trials are needed and are currently underway on hot-mix lime mortars. Tests are also being carried out on earth mortars, which are also sometimes used with quicklime.

For updates, it is recommended to visit the BLFI website:
www.buildinglimesforumireland.com

MIXING

Hot-mix lime mortars were used by all of the 'wet trades': stonemasonry, bricklaying and plastering. They combined various mixing techniques, periods of delay or immediate use, with methods of 'knocking up' and the adding of other materials. Craft skills and the application of these materials are a critical part of the process, as they have a strong influence on final performance, as does general good practice in the preparation, application, protection and after-care of lime mortars.

Mixing can be done by hand or by machine. Some of these processes are explained in the HLM Project Phase I report, which can be found at:

www.buildinglimesforumireland.com



Small quantities of mortar can be mixed by hand which was the traditional method. Note the steam rising



HLM Demonstration Workshop at Drimmagh Castle, Dublin



Larger quantities of mortar require the use of a machine.

TESTS

Mortar specimens were taken as part of the HLM Phase I Project, to test for: flexural strength, compressive strength, density (real and apparent), water absorption (total), porosity and depth of carbonation.

Petrographic thin sections were prepared to evaluate the condition of the mortars.

The ongoing Phase II Project will look at other methods of testing on both hot-mix and earth mortars.

A simple set of field tests have been designed for the use of BLFI members who have successfully completed a field test workshop. Information on field test procedures can be found on the website, and it is encouraged that BLFI members undertake these tests. This will help the BLFI gain a better appreciation of materials and performance, and will be of benefit to all those working with hot-mix lime mortars. In some instances, laboratory tests will also need to be undertaken.

Quicklime is produced today through an industrialised process and is therefore much purer than the variable quicklimes of the past. We still have more to discover about the long-term performance and durability of modern hot-mix lime mortars.

Sands also vary from the calcareous to the silica rich, each imposing a different effect on the mortar. The wide range and strengths of NHLs which have been used for gauging hot-mix lime mortars add yet another variable. These factors have been taken into account during recent tests and further tests have been proposed.

Preparation mixing, application, after-care and protection procedures of hot-mix mortars are important and depend on craftsmanship. As also found with NHLs, incorrect methodology or poor practice can lead to leaching or spalling, due mainly to frost action. On occasion, expansion from late slaking can also occur with hot-mix, which can contribute to spalling. Further testing and observation are being undertaken and monitored, information of which will be available on the website.



Pointing test panel



Stonemasons building test walls at Portumna, Co Galway for HLM Project.



Samples being taken for testing purposes as part of the HLM Project

HEALTH AND SAFETY

Work involving all types of mortars requires the user to be familiar with the MSDS (Material Safety Data Sheets) and to prepare an appropriate Risk Assessment and Method Statement. All lime-based materials are classified as hazardous substances, but not dangerous and can be used on site, providing all health and safety procedures are put in place and followed. As part of the site procedures, control measures need to be put in place to manage the heat that is generated, as well as to minimise the risk of the mix spitting during slaking.

When working with all mortars, including those made with cements, NHLs, lime putties and quicklimes, they all require the same attention to Personal Protection Equipment (PPE): eye protection, dust masks, gloves and covering of exposed skin.

BLFI recommends that a supply of Diphotrine eyewash, or equivalent, be kept close to areas of delivery, storage, mixing and placement.

The use of granulated/kibbled quicklime (5 mm) is recommended, rather than the more finely-ground versions, so as to reduce the potential for quicklime dust being in the air pre-slaking.

CHARACTERISTICS OF HOT MIXED LIME MORTARS

The key features of a hot-mix mortar are the heat generated during slaking, and the doubling-in-size of the quicklime as it turns into a hydrate.

Using the mortar while still hot accelerates water loss, which speeds up the stiffening of the mortar. Due to the action of the heat generated, an excellent bond is created, which joins the binder to the aggregates within the mortar as well as to the stone. This is particularly advantageous when building with irregular, rounded and uneven-shaped stones. Above all, hot-mix lime mortars are highly workable mortars – a fact that is acknowledged by all those who use them. Stonemasons who were involved in the HLM Project Phase I Programme, and had experience working with hot-mix lime mortars, reported as follows:

- More solid full joints, without any slump
- Wall could be built higher than normal, without any danger of leaks or mortar slump
- Prevented bleeding from the face of the work, where the stones and sand were wet

- Allowed wet stones to be laid and stabilised
- Very wet sand could be used without adverse effects on the final consistency of the mix, due to the massive water absorption of and the heat produced by the quicklime.

Plasterers and bricklayers have different requirements regarding methods of mixing and application of lime mortars, though these are not yet defined or represented in this guide. Further research is planned.

For more up-to-date information, please be directed to the BLFI website www.buildinglimesforumireland.com

STANDARDS

Building limes are currently defined by Irish and European Standards; however, there is no standard definition of a 'hot-mix lime mortar'.

CaO (quicklime), which is currently available in Ireland, complies with EN 459 CL90 and is suitable for the design of mixes and in the production of mortars.

Note: Historic lime mortars were not standardised products but varied according to circumstance, availability of materials and the craftsmanship involved.

CONCLUSION

Hot-mix lime mortar, based on indigenous quicklime, is generally a more compatible and cost-effective material with a lower carbon footprint than any other lime binder.

In the construction and repair of traditional stone masonry, hot mixed lime mortars more closely replicate historic mortars. If gauged with an NHL or a pozzolanic additive, their performance can be adapted to suit a much wider range of conditions.

It is critical to maintain general good practice and craftsmanship throughout, such as protection and after-care of completed work.

Close monitoring of recent and proposed projects and further research is required, for which the BLFI through the HLM Project have recommendations for appropriate testing and recording.

When considering using hot mixed lime mortars, professional advice should be sought prior to specifying, and accurate site-recording should always be maintained.

FURTHER READING

The Building Limes Forum Ireland
www.buildinglimesforumireland.com

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Irish Standard (IS EN 459-1:2015)
Definitions, specifications and conformity criteria



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The Department of Arts Heritage, Gaeltacht and the Building Limes Forum Ireland accept no liability for any loss or damage resulting from reliance on the advice contained within this Guide.

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