IMPORTANCE OF LIME IN BUILDING CONSTRUCTION

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Why use lime

1. Lime Allows Buildings To Breathe

In the search by architects and conservators for building materials sympathetic to traditional construction, lime was found to be one of the most important. One of the reasons lime binders are promoted by the Society for the Protection of Ancient Buildings for repairs is because they are vapour permeable and allow buildings to breathe. This reduces the risk of trapped moisture and consequent damage to the building fabric.

2. Lime Provides A Comfortable Environment

Porous and open textured materials such as lime plasters, help to stabilize the internal humidity of a building by absorbing and releasing moisture. This makes for a more comfortable environment and reduces surface condensation and mould growth.

3. The Use Of Lime Has Ecological Benefits

- Lime has less embodied energy than cement.
- Free lime absorbs carbon dioxide in the setting process of carbonation.
- It is possible to produce lime on a small scale.
- The gentle binding properties of lime enable full re-use of other materials.
- A very low proportion of quicklime will stabilize clay soils.
- Small quantities of lime can protect otherwise vulnerable, very low energy materials such as earth construction and straw bales.

4. Lime Binds Gently With Early Adhesion

The fine particle size of lime, far smaller than cement, is linked to the root meaning of the word lime, which is ‘sticky material’. Due to the fine particle size, lime mixes penetrate minute voids in the background more deeply than other materials. They bind gently and the stickiness gives good adhesion to other surfaces.

5. Lime Mortar Can Protect Adjacent Materials

Lime mortars with a high free lime content are porous and permeable. These characteristics allow lime mortars to protect adjacent materials by handling moisture movements through the building fabric and protecting them from harmful salts. Adjacent materials frequently affected this way include timber and iron as well as stone and brick masonry.

6. Lime Renders Can Assist Drying Out By Evaporation

Dense and impermeable renders can trap moisture within the building fabric. Trapped moisture is often the agent for various decay mechanisms. Dense renders used in conjunction with softer materials or on weaker backgrounds can cause serious problems by creating local stresses. High calcium lime renders allow evaporation and reduce the risk of trapped moisture and decay. In simple terms, the greater the extent of pure lime and permeability the better this is for the building. This needs to be balanced with durability, however, and some reduction in permeability may be necessary to obtain adequate weathering qualities, hence the advantage of feebly hydraulic limes for external use.

7. Lime Mixes Have Good Workability

The ability of a mortar or plaster to remain smooth and mouldable, even against the suction it may experience from porous building materials, is termed workability. Good workability greatly assists good workmanship, helping to achieve full joints with good bonding to the other materials. This is what makes lime based mixes such a pleasure to use. The workability provided by the lime allows the inclusion of widely graded and sharp aggregates in the mix. These enhance both the performance and the aesthetic of the finished work.

8. Lime Binders Can Be Durable And Have Stood The Test Of Time

When used carefully, lime is exceptionally durable. Caesar’s Tower at Warwick Castle has stood the test of time for over 600 years, and many cathedrals have stood longer. An outstanding example is the Pantheon Temple in Rome which has a lime concrete dome spanning over 43 metres (142 feet). This has survived for nearly 2000 years.

9. Lime Finishes Are Beautiful

The double refraction of light through calcite crystals give a unique aesthetic combining a soft texture with a lustre that has a liveliness and delight of its own. The graceful softness apparent in lime based materials is a visual indication of their intrinsic permeability, workability and soft binding properties. They can rapidly develop a rich patina which has a glowing translucent quality.

10. Lime Contributes To A Healthy Environment

Lime is caustic and has been extensively used, often in the form of limewash, for its disinfectant qualities. Lime is also used for water purification. Lime mortars, plasters, renders and limewash have been used to create hygienic surfaces and improve comfort conditions within buildings for thousands of years.

11. Self Healing

The nature of ground conditions and the elements are such that all buildings are subject to varying degrees of movement over time. When buildings made with lime are subject to small movements they are more likely to develop many fine cracks than the individual large cracks which occur in stiffer cement-bound buildings. Water penetration can dissolve the ‘free’ lime and transport it. As the water evaporates this lime is deposited and begins to heal the cracks. This process is called autogenous, or self healing.

12. Free Lime Encourages the Growth of Calcite Crystals

Calcite crystals are a different shape to those formed by the more complex compounds in hydraulic limes and cements. The crystals form in voids in lime rich environments. The growth of calcite crystals adds strength over time and generally provides a more open and permeable material than the denser eminently hydraulic and OPC mixes with little or no free lime.

13. Local Limes Enhance Regional Identity And Diversity

The diversity of limestone types provides variety and local distinctiveness. Different limes will vary in colour, texture and setting properties. Local limes have a regional identity, they give a sense of place and provide a continuous link with the local aesthetic. Local colour is the obvious example in respect of limewashes.

14. Disfiguring By Cement Can Be Avoided By The Use Of Lime

On site the temptation to use quick and easy solutions for short term gain can lead to long term problems. The attraction of using excess cement to be ‘safe’ is understandable if not desirable. The fact that it is plentiful, inexpensive and readily available adds to the problem. There is a high probability that over-strong and dense mixes that are not fit for purpose will be used in excess. The physical damage and unsightly aesthetic that results from this can be avoided by the use of lime.

15. Indefinite Shelf Life

Non-hydraulic limes have an indefinite shelf life when stored without access to air, usually as a putty under water or in sealed containers. In fact the quality of the putty improves the longer it is stored.

This is an extract from *An Introduction to Building Limes* by Stafford Holmes, presented to the Foresight Lime research Conference at Manchester University on 19 November 2002 and revised March 2004.

Benefits of cement-lime mortar

Lime has been an important component of mortars for over 2000 years. The characteristics of hydrated lime provide unique benefits in masonry applications that distinguish cement-lime mortars from other masonry mortar materials. Major benefits include:

Flexural bond strength

Cement and Type S Hydrated Lime mortars have been shown to have high levels of flexural bond strength. High tensile bond strength is enhanced by the following properties of cement-lime mortars:

1. **Tensile Bond Strength** - This is the strength of the mortar that holds the masonry units together. High tensile bond strength is developed by the following mortar characteristics:
    - Lime provides high water retention that allows for maximum early curing of the cementitious materials.
    - High initial flow which permits easy complete coverage of masonry units.
    - The low air content of cement-lime mortar increases bond strength.
2. **Extent of Bond** - The extent of bond is the percent of brick to which the mortar adheres. The low air content and the fineness and stickiness of hydrated lime particles increase the extent of bond of mortar to brick. These factors allow cement-lime mortars to penetrate deeply into the brick and seal the brick/mortar interface.
3. **Durability of Bond** - (See Durability section below)

There are a number of studies that demonstrate the superior bond strength of cement-lime mortars. For copies of these studies, pleasecontact Graymont.

Water leakage

Studies have shown that cement-lime mortars can be used to minimize the potential for water penetration into masonry walls.

1. **Extent of Bond** - Low air content, a fine particle size, high plasticity and water retention contribute to excellent extent of bond for cement lime mortars. This eliminates easy migration paths for water penetration.

2. **Autogenous Healing** - When hairline cracks develop in the mortar, hydrated lime reacts with carbon dioxide in the atmosphere. This reaction produces limestone which helps to seal the crack and fill voids in the mortar. This explains the increased moisture resistance noted after six months of curing in two studies.

Durability

Masonry construction is a durable, low maintenance system. The use of lime in mortars contributes to the durability of this system. The durability of lime mortar is evidenced as follows:

1. **Elasticity** - Research has shown that high lime content mortars were slow hardening and remained elastic or flexible. Lime, therefore, enhanced the ability of the assemblage to accommodate stresses caused by building movement and cyclical changes without excessive cracking.

2. **Autogenous Healing** - When hairline cracks develop in the mortar, hydrated lime reacts with carbon dioxide in the atmosphere. This reaction produces limestone which helps to seal the crack.

3. **Proven Performance** - Prior to the early 1930's, all masonry buildings were constructed with lime or a mixture of cement and lime. Portland cement was not manufactured in the United States until 1871. Prior to this, lime was used as the primary ingredient of all mortars. The durability of these structures serves as testimony to the lasting durability of lime mortars.

Compressive strength

ASTM C270 allows for mortars to be specified by the proportion or property guidelines. Cement-lime (CL) mortars mixed under the proportion specification generally have enough compressive strength to meet the next highest C270 property specification. For example, a Type N cement-lime mortar, as defined by the proportion specification, will have enough strength to meet the Type S mortar property specifications. Specifying CL blends by proportion provides a margin of safety concerning compressive strength. If high compressive strengths are undesirable, lime content can be increased and the property specifications used. In either event, cement-lime mortar compressive strength levels are adjustable and predictable.

Hydrated lime improves the strength of the mortar by several mechanisms:

1. **Carbonation** - Hydrated lime reacts with carbon dioxide in the atmosphere to form limestone.
2. **Cementitious Reactions** - Pozzolonic reactions can occur between hydrated lime and silica compounds in the mortar mix.
3. **pH** - Hydrated lime helps to maintain high pH levels in the mortar mix. This makes siliceous materials more soluble and reactive.

Uniformity

Cement-lime mortars provide uniform performance characteristics in the field. ASTM C270 provides recommended proportions for Type O, N, S and M cement-lime mortars. This specification also requires that hydrated lime products meet ASTM C207 criteria, portland cement meets ASTM C150, and both ASTM C207 and ASTM C150 specify chemical composition as well as physical product qualities. The chemistry of each cement-lime blend is defined and contains a high percentage of cementitious materials (> 95%). Since the chemistry is well defined, performance characteristics such as compressive strength and flexural bond strength are predictable at given proportion levels. Air content of cement-lime mortars are restricted to 12% for Type M and S mortars and 14% for Type N and O mortars. Tighter limits on air content also helps to minimize variation between blends. Preblended cement-lime mortars are also available in most markets in 65-75 lb. bags, bulk bags or silo systems.

Building Construction

Masonry Mortars, Stuccos, and Plasters

Lime has been used as a primary ingredient in masonry mortars for centuries, and this important use continues to the present day in both historic and contemporary applications. Mortars made with lime and cement exhibit superior workability balanced with appropriate compressive strength as well as low water permeability and superior bond strength. Lime is a major constituent in exterior and interior stuccos and plasters, enhancing the strength, durability, and workability of these finishes. All of these lime applications are supported by ASTM specifications and standards. Papers and articles on a variety of building lime applications are available at www.buildinglime.org. Type S (Special) hydrated lime is a fine, white, high purity product specially hydrated for convenient, trouble-free use in mortar applications. It is a uniquely American product, with much more stringent requirements for masonry performance than those imposed by any other country. Type SA (Special Air-Entrained) hydrated lime is similar, except that it includes an air entraining agent which produces minute voids in the mixed mortar.

Either type will provide a superior quality mortar. Both are subject to the ASTM C207 Standard Specification for Hydrated Lime for Masonry Purposes.

Modern Masonry Applications

Studies have compared the performance of cement-lime mortars to that of masonry cement mortars (which use limestone and other additives in lieu of hydrated lime) and mortar cements. Cement-lime mortars have shown higher bond and shear strength and lower water leakage. For a more information on the use of hydrated lime for masonry purposes, click here. For a fact sheet on the use of lime-based mortars to create watertight walls, click here.

Historic Masonry Applications

Most masonry produced before the turn of the 20th century used lime-sand mortar. The elasticity of high lime content mortars allows for expansion and contraction of such historic masonry walls without damaging the masonry units. These units can have low compressive strengths and can be damaged by modern masonry products with higher strengths.

Plastering Uses

Type S (Special) hydrated lime shows its versatility and beauty when used for interior and exterior plaster or render. ASTM C206 Standard Specification for Finishing Hydrated Lime requires that finishing lime be free of any chemical or physical characteristics that would cause flaws in the plaster.

Other Uses of Lime in Building Construction

Limewash

Limewash is a versatile, accommodating, and robust surface covering compatible with a variety of building surfaces. It is maintainable, beautiful, stable, and long lasting. A copy of a paper on limewash presented at the 2005 International Building Lime Symposium is available here.

Site Preparation

Lime can be used to dry wet sites. Lime can also react with clays in soil to provide a more stabile base for building construction. For more information on these uses, click here.

Autoclaved Aerated Concrete (AAC)

Lime is also employed in the manufacture of innovative lightweight cellular concrete products, such as autoclaved aerated concrete (also called “aircrete”), which can be formed into block as well as large masonry units or insulation slabs. The 2005 International Building Lime Symposium included a paper on AAC.

Other Concrete Products

Hydrated lime can be added to concrete mix used to make block and other concrete products in order to produce a denser, more water-resistant product. By adding greater plasticity to the mix, lime also produces concrete products with more precise edges and corners, improves reflectivity, and reduces loss through breakage.

Calcium Silicate Brick

Calcium silicate (sand-lime) brick is employed in standard masonry construction in the same manner as common clay brick. Sand is mixed with high calcium lime (quick or hydrated) in a wet state, and then molded into bricks and autoclaved. The lime reacts with silica to form complex hydro(di)calcium silicates that bind the brick and provide high dimensional stability. Lime is also used to make hollow sand-lime building block, tile, slabs, and pipes.

Insulation Materials

Some insulating materials, molded as units, contain lime and diatomaceous earth or lime and silica. In these products, lime serves as a binding agent, reacting chemically with the available silica present in the mix to form calcium silicates. The lime-silica reaction is also employed in making microporite insulation.

MIX PROPORTIONS:

The usual **mix** contains 1 part Hydrated **Lime** and 3 parts sand by volume. **Lime mortar** should only be used in restoration work where the matching of existing construction is necessary. The usual **mix** is 1 part **cement** and 3 parts sand by volume.

Mix proportions and compressive strengths of some of the commonly used mortars are given in Table 1.

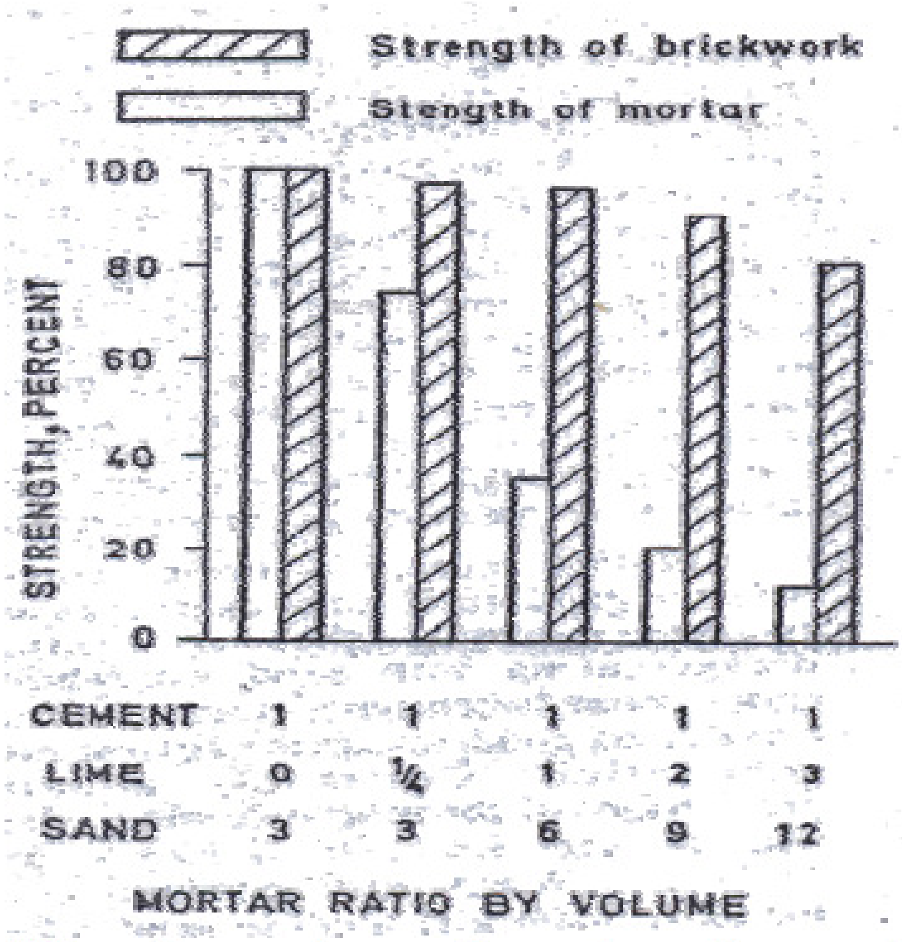
Table 1: Mix Proportion and Strength of Mortars for Masonry *(Clause 3.2.1)*

SL No	Grade of Mortar	Mix Proportions (By Loose Volume)					Minimum Compressive Strength at 28 Days In MPa
		Cem-ent	Lime	Lime Pozzo-lana Mixture	Pozzo-lana	Sand	
1	H1	1	¼ C or B	0	0	3	10
2(a)	H2	1	¼ C or B	0	0	4	7.5
2(b)	H2	1	½ C or B	0	0	4½	6.0
3(a)	M1	1		0	0	5	5.0
3(b)	M1	1	1 C or B	0	0	6	3.0
3(c)	M1	0	0	1(LP-40)	0	1½	3.0
4(a)	M2	1	0	0	0	6	3.0
4(b)	M2	1	2B	0	0	9	2.0
4(c)	M2	0	1A	0	0	2	2.0
4(d)	M2	0	1B	0	1	1	2.0
4(e)	M2	0	1 C or B	0	2	0	2.0
4(f)	M2	0	0	1(LP-40)	0	1¾	2.0
5(a)	M3	1	0	0	0	7	1.5
5(b)	M3	1	3B	0	0	12	1.5
5(c)	M3	0	1A	0	0	3	1.5
5(d)	M3	0	1B	0	2	1	1.5
5(e)	M3	0	1 C or B	0	3	0	1.5
5(f)	M3	0	0	1(LP-40)	0	2	1.5
6(a)	L1	1	0	0	0	8	0.7
6(b)	L1	0	1B	0	1	2	0.7
6(c)	L1	0	1 C or B	0	2	1	0.7
6(d)	L1	0	0	1(LP-40)	0	1½	0.7
6(e)	L1	0	0	1(LP-20)	0	2½	0.7
7(a)	L2	0	1B	0	0	3	0.5
7(b)	L2	0	1C or B	0	1	2	0.5
7(c)	L2	0	0	1(LP-7)	0	1½	0.5

Table C1: Effect of Mortar Mix on Strength of Brickwork
[using clay brick of strength 32.7 MPa]

Mortar mix (Cement: Lime: Sand)	Mortar Compressive Strength (28 days) X	Brickwork compressive strength (28 days) Y	Ratio Y/X
(1)	(2)	(3)	(4)
	MPa	MPa	
1:¼:3	17.8	8.9	0.5
1:½:4½	10.8	9.3	0.86
1:1:6	4.7	8.5	1.82
1:2:9	1.7	4.6	2.69

NOTE: Lime used was in the form of well matured putty



Effects of mortar mix proportions on the crushing strengths of mortar and brickwork built with medium strength bricks

Strengths are shown relative to the strength of a 1:3 cement-sand mortar and the brickwork built with it

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