PRACTICAL GUIDE TO LIME MORTARS

ANCADE (Asociación Nacional de Fabricantes de Cales y Derivados de España [Spanish National Association of Manufacturers of Lime and Lime Derivatives]) would like to thank the following people for their contributions to this guide: Anselmo Acosta (Chemical Sciences Department. Universidad de Castilla La Mancha [Castilla la Mancha University]), Eduardo Herrero (Honorary Member of ANCADE), Joan Ramon Rosell (Escola Politècnica Superior d'Edificació de Barcelona [Higher Technical School of Building of Barcelona]. Universidad Politécnica de Cataluña [The Technical University of Catalonia]), and David Sanz (E.T.S. de Arquitectura [Higher Technical Architecture School]. Universidad Politécnica de Madrid [The Technical University of Madrid])

TABLE OF CONTENTS

INTRODUCTION

The Spanish National Association of Lime and Lime Derivatives Manufacturers (ANCADE), is comprised of companies which produce and market calcium or magnesium based limes and their derivatives, throughout Spain.

Since its establishment, ANCADE has been continuously developing the modernization of the Spanish Lime Sector, as well as promoting the use of lime in numerous applications: Industry, the Environment, Construction, and Agriculture. Within the use of lime in the construction industry are pure lime mortars (with only lime as a binder) or composite mortars (with lime and cement).

By means of this document ANCADE aims to provide construction professionals with a Guide which provides them with information as regards the production and, more importantly, the use of lime mortars (pure or composite), since unfamiliarity with the working methods of lime mortars is common.

Figure 1: Building restoration work using lime mortar.
Courtesy: Hidrocal Morteros

1. INTRODUCTION TO LIME MORTARS

1.1 Origin and development

Lime has been one of the binding agents which man has used since ancient times as it can be obtained from carbonated stones, mainly limestones and dolomites, which are very common in the earth's crust (representing about 20%).

When the masons of ancient Rome discussed mortar (mortarius) they referred to the container or ladle in which they mixed and transported the lime and sand. Over time the word came to refer to the content and not its container: A mixture composed initially of lime, sand and water, which they used to bind stones or bricks together, smooth out surfaces and protect walls.

INTERVENTIONS

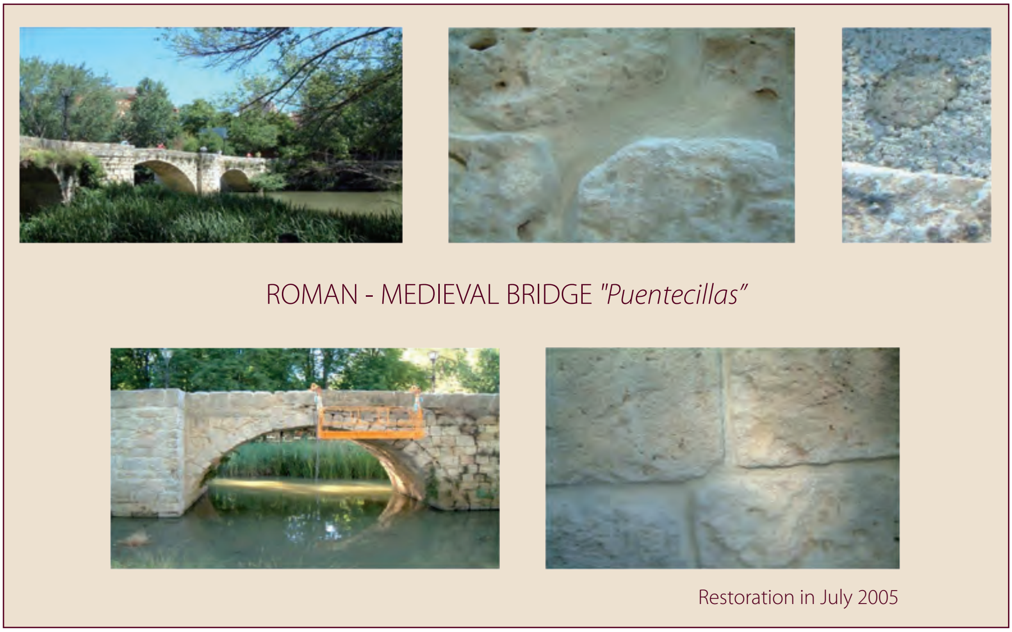


Figure 2: **Restoration of a Roman-Medieval bridge (Puentecillas). Courtesy: Hidrocal Morteros**

Today, lime is still used as a binder for pointing and rendering, in addition to, of course, cement. Mortars are produced for this purpose, made from lime, from cement, or composite mixtures, which are made by mixing both materials in certain proportions.

Hydrated lime mortars have been used in many applications such as coatings, mortars for paving, masonry, etc., in hydraulic mortars and mortars which are resistant to aggressive actions such as those caused by salt water through the incorporation of pozzolanic or hydraulic slag type active additives.

Currently, the need to refurbish and restore historic monumental works has led to a revival of lime based mortars, since this is the binder which is most compatible with historic mortars.

Figure 3: **Lime render. Sgraffito and Scraped. C/ Belén, Madrid.**
Courtesy: Hidrocal Morteros

The manufacture and use of lime mortars was a common practice until the first world war. Since then, the evolution of Portland cements with a faster rate of hardening and development of mechanical strength has led to cement based mortars replacing those which traditionally used lime. However, its greater shrinkage, cracking, and mechanical rigidity have led to hydrated lime being used again in the manufacture of mortars, used as the sole binder or in mixes with cement or gypsum for its use in internal (plasters) or external (renders) coatings, in brick walls, buildings, restoration of monuments, etc.

INSULAR TOWN HALL
TENERIFE

Figure 4: **Insular Town Hall (Tenerife).**
Courtesy: Hidrocal Morteros

COMPOSITE MORTAR
TOLEDO MUNICIPAL FUNERAL HOME

Figure 5: **Composite mortar (lime-cement). Toledo Municipal Funeral Home.**
Courtesy: Hidrocal Morteros

1.2 Current status: Technical Building Code (CTE)

The Technical Building Code ([Código Técnico de la Edificación, CTE], the regulatory framework which establishes the *basic requirements for quality, safety and habitability of buildings* and their installations which came into force on 29 March 2006) updates the suitability of the application of these mortars due to their previously stated properties. *Air lime mortars* are ideal for use in order to comply with its basic HS 1 documents: Protection Against Humidity, HS 3: Indoor Air Quality and HR: Noise Protection. This is because lime provides its mortars with a bioclimatic ability as they contain pores which allow walls to breathe, improving indoor air quality and at the same time protecting them from humidity. This produces an indoor temperature regulation in a house thanks to the "breathing" effect because moisture is allowed to diffuse but the passage of water at low pressures (rainwater) is prevented.

2. LIME MORTARS: DEFINITION AND CLASSIFICATIONS

A lime mortar is a mix of one or more binding agents (one of them is always lime), aggregates, water and sometimes additions and/or additives.

2.1 Mortars defined by their composition

This classification is made based on the binder which is present in the mortar.

a) Cement mortars

b) Hydraulic lime mortars

c) Air lime mortars: they are mortars produced with hydrated air lime and sand which are used for internal and external coatings

d) Composite mortars made from cement and hydraulic lime

e) Composite mortars made from cement and air lime: these limes can be mixed with different amounts of cement (common or white)

The characteristics of the cement and its amount greatly influence the properties of mortars, especially in their short term mechanical strength and setting times. The cement which is normally used, above all in restoration work, is white cement which facilitates the colouring of the mortars.

This kind of mortar can be used in all areas of a building. In order to use these mortars as coatings, their compatibility with the substrate materials should be taken into account (type, strengths, etc.).

Sometimes it is necessary to carry out a preparatory treatment on the substrate to obtain the correct adherence and stability.

2.2 Mortars defined by their application

This classification is based on their use in construction.

a) Mortars for masonry construction
b) Mortars for coatings
c) Mortars for paving
d) Adhesive mortars
e) Mortars for repair work
f) Waterproofing mortars

This classification is valid for all types of mortars, be they exclusively of cement, mixtures of cement and lime (known inappropriately as "bastards") or pure lime mortars.

In the case of mortar mixtures of cement with air limes, the principal applications of most interest would be mortars for coating and masonry work.

2.3 Mortars defined by their requirements

This classification comprises the production of mortars which are custom made for the customer, in order to obtain the required properties (performance) as well as the composition and proportion of their ingredients (recipe).

a) Mortars made with recipes or prescriptions: They are normally known based on their declared components. For example:

cement:lime:sand **lime:sand** **cement:sand**

b) Designed mortars: A mortar which is required to have a certain characteristic, which can be a particular strength, adherence or water resistance. For example: an M-5 masonry mortar should achieve a compression strength after 28 days of 5 N/mm^2 in accordance with the UNE EN 998-2 regulation.

2.4 Mortars defined by their production method

According to their production method, the UNE-EN 998-2 regulation defines three groups:

a) Masonry mortar produced on site: a mortar composed of the individual components measured and mixed on site.

b) Semi-finished factory produced masonry mortar:

b.1) Pre-dosed masonry mortar: a mortar whose components are completely factory dosed and are supplied to the place where they will be used and where they are mixed in accordance with the manufacturer's specifications and conditions.

b.2) A premixed lime and sand masonry mortar: a mortar whose components have been completely factory dosed and mixed and are supplied to its place of use where other factory specified or supplied components are added: (i.e.: cement).

c) Factory made masonry mortar (industrial mortar): mortar dosed and mixed in a factory. It can be "dry mortar", a prepared mix which only requires the addition of water or "wet mortar" which is supplied ready for use.

2.5 Mortars defined by their supply method

Industrial mortars depending on their manner of supply can be divided into:

a) Dry mortar in silos: the procedure is simple, clean and economical in its consumption. The manufacturer provides one or more silos and the exact type of mortar (transported in tank trucks) defined by the designer. It is only necessary to add the indicated water to create the mix at the construction site.

b) Dry mortar in bags: dry mortars can also be supplied in bags. Their use on site is very simple because there is no dosing or selection of components required on site. The supplier's instructions should be followed for manual or mechanical mixing with mixers.

c) Wet mortar: principally produced with lime putty, it is supplied ready for use in bags or containers.

Figure 6: **Silo.**
Courtesy: Tudela Veguín

3. COMPONENTS: CHARACTERISTICS AND REGULATIONS

3.1 Lime

Limes for construction, as per the European Standard UNE-EN 459-1 establishes the following types in accordance with their chemical composition:

Air limes:	**Calcium limes:**	Calcinated pure limestones >95% richness of calcium
	Dolomitic limes:	Calcinated dolomitic stones which contain magnesium
Hydraulic limes	Limestone contains clays rich in silica, aluminium and iron, which harden with water. French tradition. Contains more impurities and less whiteness	

It is very important to not confuse *air lime*, with *hydraulic lime*, since the latter contains silicates which have a different behaviour, above all as a construction material. *Hydraulic lime* has a behaviour similar to cement.

In the production of mortars, hydrated lime which has previously been completely slaked is always used, be it by industrial or artisan methods.

Should it be employed, the use of lime which has not been slaked or totally hydrated is harmful, given that it could hydrate after the application of the mortar causing cracking, due to the increase in volume, and other types of surface defects.

Calcium air limes are the most used in the production of mortars.

Only the following slaked calcium air limes will be used:

CL 90-S | **CL 80-S** | **CL 70-S**

In accordance with the European Standard 459-1 "Building Lime - Part 1: Definitions, specifications, and conformity criteria."

3.1.1 Air limes

These are the limes produced by the calcination of pure limestones or dolomites and are comprised of calcic oxide or hydroxide and/or magnesium. They have no hydraulic properties and are not able to harden underwater.

They can be quicklimes (composed basically of calcium and magnesium oxides) or hydrated limes (resulting from the controlled slaking of quicklimes, composed of hydroxides mainly of calcium and magnesium).

Quicklimes and hydrated limes are in turn divided into calcium (in which the principal component is calcium oxide and magnesium oxide does not exceed 5%) and dolomitic (in which the magnesium oxide is greater than 5%).

Similarly, calcic air limes are classified according to whether their calcium oxide content plus magnesium oxide is equal or greater than 90%, 80% and 70% respectively in CL 90, CL 80 and CL 70 (see table 1).

Table 1: Chemical requirements for Lime [a]

	Type of Lime	CaO + MgO	MgO [b]	CO_2 [c]	SO_3	Free lime [d]
1	CL 90	≥ 90	≤ 5	≤ 4	≤ 2	≥ 80
2	CL 80	≥ 80	≤ 5	≤ 7	≤ 2	≥ 65
3	CL 70	≥ 70	≤ 5	≤12	≤ 2	≥ 55
4	DL 90-30	≥ 90	≥30	≤ 4	≤ 2	-
5	DL 90-5	≥ 90	≥ 5	≤ 4	≤ 2	-
6	DL 85	≥ 85	≥30	≤ 7	≤ 2	-
7	DL 80	≥ 80	≥ 5	≤ 7	≤ 2	-

Note: The values are applicable to all types of lime. For quicklime, these values relate to the finished product; for all other types of lime (hydrated limes, lime putty and hydraulic limes), the values refer to the product without free or combined water.

[a] The values in the table are expressed in a percentage of the total.

[b] An MgO content up to 7% is admissible on the condition that the stability is confirmed according to the test described in section 5.5 of the UNE-EN 459-2 Standard.

[c] A higher content of CO_2 is acceptable if it is verified that all the other chemical requirements of this table are accomplished and the frequency of the tests is according to the standard

[d] These are minimum requirements, the user can request higher values of free lime

There will be an upcoming revision of the EN 459-1:2001, EN 459-2:2001 and EN 459-3:2001 European Standards.

In accordance with the European Standard 459-1 "Building Lime - Part 1: Definitions, specifications, and conformity criteria."

Production of calcic air limes (CL)

Calcium air limes (known hereinafter as limes, quicklimes, or hydrated limes) are produced by the calcination of limestones, with a calcium carbonate ($CaCO_3$) content of greater than 95% and a temperature of some 900 ºC as per the following reaction:

$$CaCO_3 + 770 \text{ kcal/kg} \rightarrow CaO + CO_2$$

Figure 7: Parallel Flow Regenerative Vertical Kiln. Courtesy: Tudela Veguín

Figure 8: Horizontal kiln with Pre-heater. Courtesy: Tudela Veguín

Hydration or slaking of the quicklime

The calcium oxide produced in the calcination of limestone immediately reacts with the water, transforming into calcium hydroxide ($Ca(OH)_2$). This phenomenon is known as hydration or slaking of quicklime: CaO.

The product obtained, calcium hydroxide ($Ca(OH)_2$), is known as hydrated or slaked lime.

The slaking process produces a large amount of heat according to the following reaction:

$$CaO + H_2O \rightarrow Ca(OH)_2 + 123{,}5 \text{ ca l/kg}$$

The slaking of the quicklime can be done in two ways:

Slaking with a small quantity of water: it is called dry hydration and is done with the exact amount of water. The product obtained is a dry powder.

Slaking with abundant water: it is accomplished by the immersion or flooding of the lime with water. The resulting product is a lime putty which is deposited in basins to mature.

The calcium hydroxide occupies a volume which is approximately 20-30% greater than the original calcium oxide, and as such, an expansive effect is produced, in such a way that a lump of quicklime transforms into powdered hydrated lime or into a more or less consistent putty in accordance with the amount of water used for slaking.

Modern industrial production processes of hydrated lime achieve the total slaking of quicklime, avoiding the damaging effects resulting from the referred to phenomenon of the expansive breaking-up effect due to the presence of non-hydrated quicklime (hardpan).

The production of lime mortars requires a completely hydrated lime which complies with the volume stability requirement in accordance with the UNE-EN 459-2 standard.

Hydrated lime in putty form, known historically as "cal grasa" (greasy lime), is used as a binder principally in the use of aesthetic finishing products such as plasters, stuccos and paints.

It is also used as an important additive to plasters.

Figure 9: Hydrator.
Courtesy: Caleras de San Cucao

Hardening of hydrated lime. Carbonation

The slaked lime progressively hardens as it reacts with the carbon dioxide of the air in the presence of moisture, forming calcium carbonate, according to the following reaction:

$$Ca(OH)_2 + CO_2 \xrightarrow{\text{(air humidity)}} CaCO_3 + H_2O$$

In order for this carbonation to occur, the contact of air with a particular level of humidity is essential (55% to 65% relative humidity); however, this reaction will not take place with water.

When hydrated lime is used, it begins to carbonate with the carbon dioxide, CO_2, of the air in the presence of humidity, from the surface inwards, maintaining a humid core which is what imparts its properties of transpiration and plasticity, thanks to which it possesses better mechanical behaviour than cement, as it does not shrink, becoming over time a stone-like crust of calcium carbonate, similar to the original stone, with less impurities: Furthermore shrinkage is optimized which results in a reduction of the tendency to crack.

Carbonation does not occur if a freshly applied coating is covered with paper or with a sheet of plastic.

3.1.2 Hydraulic limes

These are a mix of calcium oxide with silicates and calcic aluminates. While the oxide portion behaves in a manner similar to air lime, the silicate and aluminates portion reacts when it is mixed with water, producing hydrated silicates and calcium aluminates, in other words, a hydraulic reaction occurs similar to that which occurs in cement but of lesser magnitude allowing a faster hardening than in the case of air limes. Likewise, the calcium oxide becomes calcium hydroxide and a carbonation reaction occurs with the air similar to what occurs with air lime. Because of this, there are natural and artificial hydraulic limes (mixing air lime with a hydraulic binder).

Table 2: Chemical requirements for Hydraulic Lime [a]

	Type of Lime	SO_3	Free lime as $Ca(OH)_2$ in accordance with section 4.9, of the EN 459-2 standard.
1	HL 2	≤ 3 [b]	≥ 10
2	HL 3.5	≤ 3 [b]	≥ 8
3	HL 5	≤ 3 [b]	≥ 4
4	NHL 1	≤ 2	≥ 50
5	NHL 2	≤ 2	≥ 40
6	NHL 3.5	≤ 2	≥ 25
7	NHL 5	≤ 2	≥ 15

Note: The values for SO_3 refer to the product without free water and combined water.
[a] The values in the table are expressed in a percentage of the total.
[b] An SO_3 content greater than 3% and less than 7% is admissible, on the condition that the stability is confirmed after 28 days of being placed in water, according to the test described in the UNE-EN 196-2:2006 standard.
There will be an upcoming revision of the EN 459-1:2001, EN 459-2:2001 and EN 459-3:2001 European Standards.

Table 3: Chemical requirements for Formulated lime [a]

	Type of Lime	SO_3	Free lime as $Ca(OH)_2$ in accordance with section 4.9, of the EN 459-2 standard.
1	FL A	≤ 2	≥ 40 - < 80 %
2	FL B	≤ 2	≥ 25 - < 50 %
3	FL C	≤ 2	≥ 15 - < 40 %

Note: The values for SO_3 refer to the product without free water and combined water.
[a] The values in the table are expressed in a percentage of the mix.
There will be an upcoming revision of the EN 459-1:2001, EN 459-2:2001 and EN 459-3:2001 European Standards.

In accordance with the European Standard 459-1 "Building Lime - Part 1: Definitions, specifications, and conformity criteria."

They are divided into (As per draft Standard 459-1):

- Natural Hydraulic Limes (NHL), which are produced by the calcination of a stone with a mix of clays which are lean and rich in silica

- Artificial Hydraulic limes (HL), which are composed of calcium hydroxide, calcium silicates and calcium aluminates produced by the appropriate mix of ingredients

- Formulated Limes (FL), which are limes with hydraulic properties composed of air lime (CL) and/or natural hydraulic lime (NHL) with additional hydraulic and/or pozzolanic material

In turn, hydraulic limes are classified depending on their compressive strength as NHL 2, NHL 3.5, and NHL 5 and artificial limes (HL) are classified in the same manner (see table 2).

At the moment natural hydraulic limes are not produced in Spain, and therefore this Guide only considers *calcic air limes which are hydrated or slaked*.

Figure 10: Kiln.
Courtesy: Calcinor

3.2 Cements

Any of the common cements defined in the UNE-EN 197-1 European Standard can be used, or white cements according to the UNE 80.305 Standard and which are in accordance with the Cement Reception Instruction (RC-08).

Figure 11: Cement mortar.
Courtesy: Ministry of Education, Social Policies and Sports

3.3 Active additives

Active additives are inorganic materials which when finely divided can be used in the production of mortars in order to improve certain properties. These additions when mixed with lime develop hydraulic properties. They are explained in detail below.

3.3.1 Materials with pozzolanic properties

Pozzolanic materials are natural or artificial substances of siliceous or silico-aluminium composition or a combination of both. Said materials do not harden on their own when they are mixed with water, but finely ground and in the presence of water they react with calcium hydroxide to form silicates and aluminates able to develop strength in the short as well as long term depending on the nature of the material.

The following are the most frequently used:

Fly ash

It is the solid residue collected by electrostatic precipitation or by mechanical capture which is generated in tandem with combustion gases in the furnaces of power plants powered by pulverized coal.

Its use principally improves (in the case of lime mortars): strength, water-resistance and durability.

Its impact on the colour of the mortar should be taken into account as it normally contains a certain percentage of unburnt carbon.

Silica fume

It is a by-product which results from the reduction of quartz with a high level of carbon purity in electric arc furnaces for the production of silica and ferro-silicon, composed essentially of amorphous silica.

This additive improves the strength (especially in the short term) and reduces the permeability of the mortar.

Metakaolin

This is an amorphous material of a specific surface area and with an elevated content of acidic oxides (AL_2O_3 + SiO_2 greater than 90%) which reacts rapidly with calcium hydroxide, emanating from either the lime or released by the cement during its hydration. It is obtained by the dehydration of kaolin at temperatures of between 600-700ºC.

Among the most important characteristics provided by metakaolin, when added to mortar mixes, is a considerable increase in strength and a faster development of this strength, in the case of lime mortars. In addition permeability and capillary porosity are reduced, while at the same time resistance against chemical attack is increased.

Chamotte (ground ceramic)

A residue of the ceramics industry, it is a ceramic material which has been baked, ground and reduced to grains of various thicknesses which improves the characteristics of lime mortars, resulting in a material which produces a bonding mortar with very good hydraulic properties and great strength and durability. In addition its use is environmentally-friendly since it avoids its disposal in landfill.

Figure 12: **Chamotte.**

3.3.2 Materials with latent hydraulic properties

These are materials with hydraulic capacity which is activated in the presence of lime.

Slag from the steel industry

Slag is a by-product of the fusion of iron ore carried out in a blast furnace. When it is subject to a rapid cooling process, it acquires major hydraulic activity.

The mortar which contains granulated ground blast furnace slag develops an increase in strength which continues for longer than 28 days.

Figure 13: Interior of blast furnace complex in Avila, Asturias.
Courtesy: Ministry of Education, Social Policies and Sports

3.4 Sands

The specifications with which aggregates for the production of mortars must comply are contained in the UNE-EN 13139 harmonized standard. The following recommendations should also be taken into account:

Type:
The sands can be: calcic, dolomitic or siliceous.

Granulometry:
Sands should generally be used which have a maximum size which is appropriate to the thickness and finish of each coat. In any case, it is not recommended to exceed a maximum size of 4 mm. The applied mortar coat can be thinner in relation to the fineness of the sand; however, it should be noted that an excess of fines increases the need for water, and as a consequence, the shrinkage of the mortar during drying increases, adherence is reduced and there is a risk of microcracking.

Cleaning:

The cleaning of the sand is essential, sands should be used which do not contain clay materials, organic matter, compounds which reduce the durability of the mortars, for example: oxidisable iron sulphides (pyrites, marcasites); mica particles, shales with laminar or scaly structures in sufficient quantities that can affect the finish of the mortar, and its mechanical strength and hardness.

3.5 Additives

They are substances or materials added in small quantities (their proportion does not exceed 5% of the weight of the amount of binder) which provide to the properties of the mortar, in a wet as well as hardened state, certain well defined and permanent modifications, improving specific characteristics of the mortars.

The use of an additive should be preceded by the appropriate tests to determine the correct dosing and achieve the ideal performance without damaging the mortar's quality.

In order for the action of these additives to be truly efficient and to avoid undesired effects, it is essential to ensure the correct quantitative and qualitative mix of all the components.

The additives suitable for mortars should comply with the provisions contained in the UNE-EN 934-3 Standard.

These substances can produce a single modification in the characteristics of the mortar (principal function); or they can provide additional modifications (secondary function).

The most common additives are classified into the following types according to the properties which they provide to the mortar:

- Aerating agents: Air content modifiers
- Plasticizers: Rheology modifiers while in fresh condition
- Retardants: Modifiers of setting and/or hardening times (Setting retardants)
- Water repellents: Those which minimize the absorption of water
- Water retainers: Those which increase the capacity to retain water
- Resins: Provide chemical adherence

3.5.1 Aerating agents: Air content modifiers

Their effect consists in the introduction, within the mortar mix, of small air bubbles.

This additive improves the workability of the mortar, protects it from the effects of frost and helps to avoid the segregation and exudation of mortar while fresh.

The content of said additive should be carefully controlled as too much of it can result in a major loss of the final strength of the mortar.

3.5.2 Plasticizer: Rheology modifiers while in fresh condition

This additive increases the workability of the mortar while fresh, by reducing the water/binder ratio in favour of mechanical strength and durability and by increasing the plasticity of the mortar which allows the mix to remain workable for a longer time period.

Conversely, an incorrect plasticiser content can lead to an excessive setting time.

3.5.3 Retardants: Modifiers of setting and/or hardening times (setting retardants)

The main function of these additives is to retard the setting time of the binder, in such a way that the time required for the mortars to go from a plastic state to a solid state is extended but without significantly impacting on the development of the mechanical strength of the final stages. In this way, they prolong the workability of the mortar.

The proportions of the retardants employed should be measured carefully in order to avoid causing counterproductive effects in the final mix.

3.5.4 Water repellents: Water absorption reducers

The main effect of these additives is to minimize the absorption of water through the capillaries of the hardened mortar, making its ability to absorb water at low pressures (rainwater) substantially lower than that of a mortar produced without this additive.

3.5.5 Water retainers

These additives greatly increase water retention capacity and in this way prevent the mortar from losing water too rapidly, reducing the absorption of water and its tendency to evaporate, modulating the viscosity of the mortar mix and attenuating exudation tendencies in the cases of incorrect granulometry or lack of fines.

3.5.6 Resins

These additives principally add chemical adherence to the mortar. They improve the properties during the application of the mortar, while it sets and throughout its useful life.

The following are the most notable effects, among others: increase in adherence and elasticity and improvement of water resistance.

The use of an additive should be preceded by the appropriate tests to determine the correct dosing and achieve the ideal performance without damaging the mortar's quality.

In order for the action of these additives to be truly efficient and to avoid undesired effects, it is essential to ensure the correct quantitative and qualitative mix of all the components.

They are not recommended in pure lime mortars.

3.6 Water

The water used for the mixing of mortars should be clean and not contain substances which can modify setting times. In addition, they should not contain suspended solids which could affect the setting and durability of the mortars (clay materials).

Drinking water should be used and in the case of non-drinking water it should comply with the following characteristics:

- Acidity: $5 < pH < 8$ (UNE 7234 Standard)
- Dissolved substances content < 15 g/l (UNE 7130 Standard)
- Sulphate content expressed in SO_4^{2-} < 1 g/l (UNE 7131 Standard)

- Chloride content, expressed in Cl - < 6 g/l (UNE 7178 Standard)
- Oil and grease content < 15 g/l (UNE 7235 Standard)
- Carbon hydrates content: 0 g/l (UNE 7132 Standard)

In general, waters whose use in past practical experience has been positive can be used. In other cases it is necessary to analyse it.

Figure 14: **Laboratory. Courtesy: Cales de Pachs**

4. ADVANTAGES OF LIME MORTARS

Pure lime mortars

The lime which is used in the production of pure lime mortars for use as external and internal coatings, provides:

Figure 15: Traditional smooth wash finish lime render.
Courtesy: Hidrocal Morteros

- *Good plasticity and workability. The lime, because of its fineness, covers the surface between the aggregates, avoiding friction and improving sliding.*
- *Lack of shrinkage due to volume stability under variable conditions of humidity.*
- *Great elasticity which favours adaptation to the deformations of the substrate without producing cracking.*
- *Volume stability under variable conditions of humidity.*
- *Appreciable permeability to water vapour which allows walls to "breathe." Avoids condensation.*
- *Does not cause efflorescence due to the absence of soluble salts.*
- *Good thermal and acoustic insulation.*
- *Allows the creating of thinner coats achieving results which are impossible for other materials.*
- *Easy to colour with a great range in colourings and luminosity of colour.*
- *Ensure sealing and coating.*
- *Lime mortars have good resistance to the penetration of rainwater when applied as vertical external finishes.*
- *A natural disinfectant and fungicidal product thanks to the alkalinity of the lime.*
- *A fireproof product which does not emit toxic gases.*

Lime and cement composite mortars

The lime which is used in composite cement mortars (common or white) provides:

- *Greater adherence*
- *Greater plasticity*
- *Increase in vapour permeability*
- *Reduction of efflorescence*
- *Reduced shrinkage and cracking*

The mechanical strength values of these mortars depend on the proportions of hydrated lime and cement (type and class) of the mix. Mechanical strength will be higher and setting times shorter the greater the amount of cement; but they will be less plastic and less permeable to water vapour, with a greater tendency to crack due to shrinkage.

Figure 16: **Partial restoration with composite mortar. De Moreruela (Zamora). Courtesy: Hidrocal Morteros**

5. INDUSTRIAL LIME MORTARS

The production of industrial mortars is automated. These mortars are dosed, combined, and when required, mixed with water in a factory and supplied to the construction site. They can be dry mortars (which are mixed on site with the necessary water until obtaining a homogeneous mix for its use) or wet (which are mixed in the factory with the precise amount of water and are prepared until a homogeneous mix is achieved for their application) but in the case of lime, dry mortars are employed.

Dry mortars are mixes based on the weight of their components: binder or binder with dry aggregates. They can also have additives and/or additions. They are supplied in silos (in the case of works of a certain size and which require speed in the application) or in bags (for smaller works such as, for example, stuccos) and are mixed on site with the necessary water.

Figure 17: **Industrial lime mortars.**
Courtesy: Tudela Veguín

Dry mortar in silos

Dry mortar in silos: the procedure is simple, clean and economical in its consumption. The manufacturer provides one or more silos and the exact type of mortar (transported in tank trucks) defined by the designer.

It is only necessary to add the indicated water to create the mix at the construction site. In this way labour times are eliminated as regards:

- Gathering of ingredients
- Dosing
- Mixing, etc.

In addition, other possible problems are avoided such as:

- Incorrect dosing (by shovel, confusing volumes and weights, etc.)
- Mixing of incorrect components
- Wastage of material
- Saving of surface area at the work site

Dry mortar silos available on the market are of gravity and pressure types. The former are the most typical and they dispense the mortar at the foot of the machine. The latter use hoses through which the mortar is pumped to any part of the site, without the need for cranes.

A continuous device ensures the perfect mixing of the mix automatically. The operator can thus easily obtain the exact amount, keeping the rest of the dry mortar perfectly protected in the silo.

The process is as simple as pressing a button to supply the mortar and keeping it pressed until reaching the necessary volume. All of which eliminates labour costs for producing the mortar as well as indirect costs.

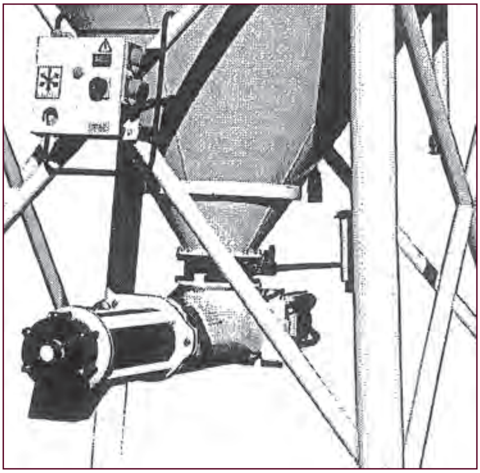


Figure 18: **Gravity silo mixer. Courtesy: Tudela Veguín**

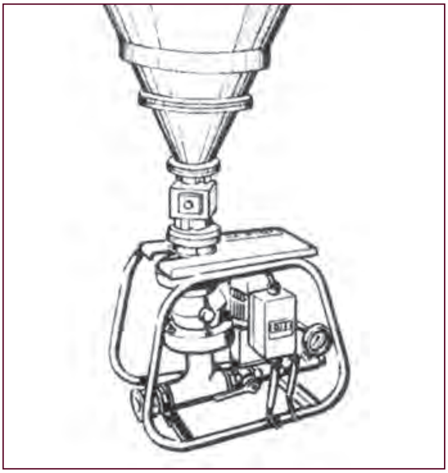


Figure 19: **Pressure silo transporter. Courtesy: Tudela Veguín**

Dry mortar in bags

Its constructional use is very straightforward as it avoids any dosing of components on-site. It simply requires manual or mechanical mixing following the supplier's instructions.

Industrial mortars are obliged to comply with the CE marking in accordance with the provisions of Directive 89/106/EEC and the conditions stipulated in it (transposed to Spanish legislation in "RD 1630/1992 of 29 December, by which Rules for the Free Circulation of Construction Products are Issued, in Application of Directive 89/106/CEE"), among said construction products are, air limes and hydraulic limes, cements and aggregates, along with industrial mortars.

The result of this is that no air or hydraulic lime can be sold or used in construction works which does not carry the referred to CE marking.

6. LIME MORTARS PRODUCED ON SITE

These mortars are comprised of the binder(s) and the aggregate which are dosed, combined and mixed with water on-site.

A general rule of thumb for the dosing Binder/Aggregate = 1 part / 3 parts (in volume)

Table 4 indicates as an index the dosing of mortar in relation to the variation of its principal characteristics.

Table 4: Type of Mortar

Type of Mortar	
LIME (Lime and Sand)	**COMBINED (Lime, Cement and Sand)**
-	1:1:6
-	1:2:9
1:4	-
1:3	-
1:2	-

Note: Going up the table mechanical strength increases.
Going to the left water retention, adherence and plasticity increase.
Going to the right frost resistance increases.

The correct dosing of the mortar should take into account the conditions of the surface on which it will be applied, the indications of table 5 being recommended.

Table 5: Conditions of the surface and the type of Mortar to be selected

Conditions of the surface	Type of mortar to be selected
Location of the walls	
· Walls particularly exposed to rain	· Finish with low capillary action
· Walls particularly exposed to impacts and deterioration	· Finish with high mechanical strength
· Walls in areas with high pollution levels	· Surfaces with low roughness
· Walls in areas that are at risk of being defaced	· Application on the finish coat of an anti-graffiti coating

6.1 Recommended dosages for pure lime mortars

A mortar without enough lime will not have the sufficient adherence and strength and will produce finishes which can crumble. Conversely, a mortar with a large quantity of powdered lime will need more water and will be more prone to cracking.

The characteristics of the sand influences the amount of lime to be used.

In addition, the amount of sand used and its granulometry are very important for the characteristics of mortars while fresh as well as hardened.

Table 6 includes by way of an example, the recommended dosing to carry out coatings of historic masonry structures.

Table 6: Recommended dosing (in mass), per cubic meter of dry sand

Coats	Thickness mm	Slaked lime kilos	Dry sand m³	
			Quantity m³	Maximum recommended size mm
1st coat	< 10	250 - 300	1	4
2nd coat	< 10	200 - 250	1	2
3rd coat		150 - 250	1	1

Table 7 contains the strengths of pure lime mortars depending on the type of aggregate.

Table 7: Strengths in pure mortars

Binder	Sands	Resistance MPa* (after 28 days)
Slaked lime 1 part	Ground limestone 1/3 mm 3 parts	1,1
Slaked lime 1 part	Ground limestone 1/3 mm 2 parts Marble dust < 0.3 mm 1 part	0,8

*1 MPa = 1 N/mm²

Note: Part equals volume.

6.2 Recommended dosages for combined lime and cement mortars

As a general rule the sand content should not be less than 2 ¼ times nor greater than 3 times the sum of the volumes of the cement and lime that are used.

a) Structures composed of concrete block, bricks and terracotta blocks.
Three coat finish. Dosing:

First coat
Class 42.5 CEM I or CEM II Portland Cement
500/600 kg per cubic meter of dry sand (Maximum size 3 mm).

Second coat:
Class 42.5 or 32.5 CEM I or CEM II Portland Cement
200/350 kg per cubic meter of dry sand (Maximum size 3 mm).
Slaked lime (CL 90-S, CL 80-S, CL 70-S)
100/150 kg per cubic meter of dry sand (Maximum size 3 mm).
Thickness of the coat
From 15 to 20 mm, depending on the tolerances of the substrate
A total coating of the surface of at least 10 cm should be ensured.

Third coat:
Class 42.5 or 32.5 CEM I or CEM II Portland Cement
100/250 kg per cubic meter of dry sand (Maximum size 3 mm).
Slaked lime (CL 90-S, CL 80-S, CL 70-S)
50/150 kg per cubic meter of dry sand (Maximum size 3 mm).
Thickness of the coat
From 5 to 7 mm.

b) Aerated concrete substrates
Coatings on aerated concrete blocks should be executed in three coats:

First coat
Class 42.5 CEM I or CEM II Portland Cement
400 kg per cubic meter of dry sand (Maximum size 3 mm).

Second coat:
Class 42.5 CEM I or CEM II Portland Cement
0/100 kg per cubic meter of dry sand (Maximum size 3 mm).
Slaked lime (CL 90-S, CL 80-S, CL 70-S)
200/250 kg per cubic meter of dry sand (Maximum size 3 mm).

Third coat:
Class 42.5 or 32.5 CEM I or CEM II Portland Cement
0/100 kg per cubic meter of dry sand (Maximum size 3 mm).
Slaked lime (CL 90-S, CL 80-S, CL 70-S)
100/200 kg per cubic meter of dry sand (Maximum size 3 mm).

Table 8 shows the characteristic strength of a 1:2 mortar with different types of aggregates.

Table 8: Strengths in combined mortars

Binder	Sands	Resistance MPa* (after 28 days)
Slaked lime ½ White cement ½	Ground limestone 1/3 mm 1 part 1/3 mm ground brick 1 part	16

*1 MPa = 1 N/mm²

Note: Part equals volume.

Table 9 displays the strengths and doses by weight and volume of combined mortars for masonry work.

Table 9: Illustrative strengths and doses by volume and weight in mixed mortars

Mortar Cement:lime:sand	Dosing Volume m^3	Dosing weight kg	Strength N/mm^2 (after 28 days)
1:2:10 Cement Slaked lime Sand	1 2 10	65 47 888	2
1:1:7 Cement Slaked lime Sand	1 1 7	91 33 876	4
1:1/2:4 Cement Slaked lime Sand	1 ½ 4	151 27 822	8
1:1/4:3 Cement Slaked lime Sand	1 ¼ 3	192 18 790	16

Tables 10 and 11 display an example of the conversion of volume to weight for the 1:2:10 dosing of table 9.

Table 10: Apparent density

Cement	1.1 kg/l = 1.100 kg/m^3
Slaked lime	0.4 kg/l = 400 kg/m^3
Sand	1.5 kg/l = 1.500 kg/m^3

Table 11: Conversion of volume to weight

Mix of the mortar 1:2:10	Weight of each component kg	Total weight	Dosage per ton
Cement	1x1.1 = 1.1	1.1+0.8+15 = 16.9 kg	65 kg cement
Slaked lime	2x0.4 = 0.8		47 kg slaked lime
Sand	10x1.5 = 15		888 kg sand

Table 12 includes, as an example, several dosages for renders.

Table 12: Dosage (by volume) of mortars for renders

Type of Mortar	Cement	Slaked lime	Sand
Slaked lime mortar in putty Recommended for restoration work		1	3
		1	4
Slaked lime mortar in powder Recommended for marble and terracotta paving		1	3
		1	4
Combined Mortar Recommended for new constructions	1	1	6
	1	2	9
Renders in old constructions should be carried out with lime putty Composite mortars can be mixed with slaked lime in powdered form			

7. LIME MORTAR COATINGS

A building's coatings have the function of protecting the structure and the interior of the dwelling, while at the same time allowing it to breathe. They are also aesthetic and decorative elements.

7.1 Preparation of the substrate

Stone and brick walls

Firstly, the strength of the mortar should never be greater than the strength of the substrate.

For any type of finish, the nature of the substrate and where it is to be applied, should be compatible with the mortar materials, in order to obtain a coating with quality and durability. In addition, the substrate should be sufficiently cured/hardened and its ability to absorb water should be limited.

The substrate should be clean, free from dust, traces of oil, de-shuttering products and should be rough, otherwise, it is necessary to create roughness in the surface by chiselling, or by installing a properly anchored metal or plastic lathe.

The substrate should be carefully wetted to avoid the movement of water from the mortar to said substrate, above all during hot weather; the substrate should be wet at the time of applying the finish.

The finishes should be executed on substrates which have been previously cleaned and moistened, they should have a thickness of 15 mm in the case of composite mixes (lime-cement) and if the thickness is to be greater, it should be executed in several coats, the first coat being mechanically the strongest.

In those cases where a prior coat has been applied in order to level out the substrate, this coat should have sufficient roughness to achieve good adherence with the next coat, which should be applied when the levelling coat has sufficiently hardened. This coat should be moistened previously before applying the next one.

24 hours after having applied the coating, the coated surface should be kept moist until the mortar has set.

7.2 Mixing of the mortar

Mechanical mixing is recommended (use of mixers) . The mixed mortar should have a creamy, sticky consistency and therefore be easy to apply; it is important to avoid a mix which is too fluid, because it lacks durability and is prone to cracking.

7.3 Application of the mortar

The application of the mortar should be done manually in 3 coats (or in two for soft substrates) and mechanically in two coats or one.

Figure 20: The process for applying Lime Mortar finishes.
Courtesy: Hidrocal Morteros

When the finish is carried out in two or more coats, once the first has been applied and before applying the second, it is necessary to wait until the first coat has sufficiently hardened.

First coat: Known as the bonding coat (thickness 15 to 20 mm)

The composite mortar (lime-cement) should be applied to the substrate, either manually or mechanically, ensuring uniform coverage across the entire surface without over application. The surface of this coat should remain rough to facilitate the adherence of the second coat.

Second coat: Known as plastering or levelling coat (Thickness from 1 to 15 mm)

This second coat of composite mortar (lime-cement) is applied on the first coat after wetting it; its surface should be rough, as in the previous instance. This second coat should be compact and homogeneous.

Third coat: Known as the finish coat; render externally or plaster internally (thickness of 5 to 7 mm in two coats)

This layer of mortar (lime-aggregate) has an essentially decorative role although it also contributes to the protection of the coating and the maintenance of its water resistance.

When the decorative effect is obtained by the use of large diameter aggregates projected onto fresh mortars, the thickness of this coat should be sufficient for it to ensure the correct anchoring of said aggregates.

The third layer of mortar (lime-aggregates) can be applied with a float or trowel. For the various traditional render finishes, in general, it is recommended to scrape or brush the finish coat during the hardening period. The scraping can be done with the edge of the float, with a wooden or steel ruler or with a sheet with nails. The brushing is done by means of a metal or fibre brush always on the final coat to highlight its decorative effect.

Figure 21: AVE Atocha Station. Composite mortars (lime-cement) in various façade finishes carried out by CLAR. Courtesy: Hidrocal Morteros

7.4 Special cases

7.4.1 Historic substrates

Historic substrates are normally masonry walls of brick and stone, or substrates with historic finishes. In these cases the preliminary operations which should be carried out in order to obtain the correct result are as follows:

- Rake the joints to 1 to 3 cm, (in several applications) clean them with a brush, wet them, and afterwards, fill them in with an air lime mortar. Adding water to the substrates is essential to prevent the wall from absorbing water from the mortar excessively.
- Chisel the old stone walls, as well as the old finishes, clean the surface removing all existing dust by means of a jet of compressed air or water.
- Replace the blocks of deteriorated or cracked materials.
- Fill in the cavities, cracks, and all the locally defective surfaces.
- Prevent rising damp from the ground by capillary action to stop alkaline sulphates or any other harmful product from causing the formation of efflorescence or, in certain cases, the formation of expansive compounds.

7.4.2 Stone masonry joints (restoration and new construction)

Two instances are defined:

- If the stone does not have a level face, a two coat finish should be applied, according to the formula suitable for the substrate.
- If the stone has faces which project sufficiently, a partial render will be executed known as "exposed face" to conceal the irregularities of the alignment, with a tolerance of ± 2 cm with regard to the non-coated level areas. The joint will terminate at the stone. The mortar will be projected and compacted, the excess mortar will be removed with the edge of the float.

  This operation removes the whitewash and conserves the texture and colour of the sand.

  The following will be rejected: joints with sealants, metal tooled or brushed joints, hollow joints.

7.4.3 Wood substrates

In the case of wood substrates, the adherence of the mortar to the wood is practically non-existent, and therefore a metal mesh should be installed between the mixture and the substrate in order to improve said adherence.

Wood beams are covered with wire or string, applied in a zigzag pattern and affixed with nails. Before this operation it is of benefit to chisel the surface of the wood with a chisel or gouge. This first coating receives a prior scouring which is very watery, in order to create a rough surface and improve adherence.

The entire surface is then lined with a metal mesh or perforated sheet to ensure the adherence of the mortar. Having prepared the substrate, the coating will be carried out in the normal way.

However, some workers are in favour of applying a coat of asphalt paint between the substrate and the metal mesh, so that the water from the mortar does not affect the wood.

7.4.4 Rammed earth walls (mud walls)

Finishes based on hydraulic binders are not always compatible with materials containing clay. The binder which is allowed for these substrates is slaked lime.

With slaked lime mortars it is not strictly necessary to use a mesh; however, when applying a very thick finish it is necessary to use a mesh, even when it is possible to use a traditional technique which consists of creating roughness to achieve adherence for the coating and installing intermediate supports to distribute the weight of the render (for example: galvanized 110 mm nails for walls with high roughness and 80 for walls with medium roughness). In these cases it is necessary that the finish coat covers the nails completely in order to have a satisfactory final appearance.

In general, the traditional working method can be used along with the normal preparation of the substrate: cleaning of the substrate and humidifying of the mud wall with a lime whitewash (25 kilos of lime per 100 litres of water).

7.4.5 Aerated autoclave concrete

Aerated autoclave concrete is a weak substrate; only a covering of air lime can be suitable and provide good results, even when it is recommended to carry out rendering in three coats, respecting the rule of decreasing mechanical strength from the substrate to the finish coat.

The substrate should be moistened and have a lime whitewash applied.

7.4.6 Substrates with auxiliary metallic elements

The same recommendations as in the case of wood substrates should be followed. Asphalt paint applied between the iron and the coating will avoid oxide stains on the surface.

7.5 Recommendations and tips

The general recommendations and tips for pure and composite mortars are as follows:

- The coating will present the colour resulting from the combination of the colours of its components, this colour being able to be modified by the addition of inorganic pigments. In the latter case, the addition of the pigment should not exceed 5% of the weight of the slaked lime.
- To avoid touch ups and rework which are translated in the different tones, it is recommended to carry out each panel in a single application.
- The drying time between each coat can vary between one or several days, depending on the nature of the coating, the weather conditions and the execution of the work.
- To avoid rising damp up the façade, it is advised to make an incision with a disk in the exterior coating approximately 60 cm from the ground. These first 60 cm should be preferably applied with a float. If the base of the wall is exposed to water splashes, the following is recommended:
  - On hard substrates, employ only a hydraulic binder on its lower section.
  - For mud wall, stone, aerated concrete or brick substrates, apply a waterproofing agent onto the surface.

7.5.1 Pure lime mortars

In the application of this type of mortars it is necessary to take into account, above all in external coatings, their thickness and the weather conditions during the execution (a temperature of between 10 ºC and 30 ºC is recommended for the work, spring and autumn being the best seasons for carrying it out), as well as avoiding carrying out the work in periods which are too dry, too humid and during the winter. In addition, considering that slaked lime hardens slowly due to carbonation, a less than 10mm thickness is recommended.

During the execution of the coating with lime, and during the days following its application, it should be protected from rain, sun, and wind by means of canvas or plastic sheets to avoid the mortar drying too rapidly (in the case of sun and wind), which would also involve the evaporation of part of the water of the mix. In addition, a deficient carbonation would occur, and as a result, a deficient hardening. The render can break apart or be reduced to a powdered material. Because of this, the substrate should be carefully moistened to avoid the coating from drying out. This phenomenon can be reduced and even prevented by using active pozzolanic aggregate material (fly ash, silica fume, pozzolans) or ground bricks (brick powder), provided that they have pozzolanic properties.

Figure 22: Restoration work on a historic mill. The pointing of the stones involved a mix of lime putty with two types of siliceous washed sands in a ratio of 1:4. The ochre tone was obtained by the natural colour of the sand.
Courtesy: Calcinor

Lime mortars should be applied observing conditions referred to above. Slaked air lime has proven to be, as it has been demonstrated in many constructed examples, a very suitable binder for the production of mortars for the restoration of historic buildings due to its very low salt content, because it remains deformable and porous and because - above all - it ensures sealing and rendering which is free of cracking thanks to its low shrinkage rate.

Mortars produced with combinations of slaked lime and inert materials (resulting from the crushing-grinding - and powder, occasionally - of brick, of marble, of stones, etc.) acquire, over time, similar characteristics to those of the walls, and in general, of the masonry structures being restored.

These coatings are perfectly suitable for prefabricated substrates of plaster, ceramics, concrete, etc.

Figure 23: New construction with lime mortar in Santander.
Courtesy: Ibercal

Figure 24: Traditional lime render with lined finish and dressing (The courtyard was restored to its original condition with 100 year old finishes).
Courtesy: Hidrocal Morteros

Figure 25: Traditional lime render with scraped finish.
Courtesy: Hidrocal Morteros

Traditional finishes with pure lime mortars

- Madrid style render with smooth wash finish, the fine layer of the lime coat is worked with a float in order to obtain a smooth surface.
- Madrid style render with scraped finish, the final layer of the coating is scraped with a steel brush scraper to achieve a grained effect.
- Catalan style render with hammered finish, the final layer of the coating is hammered with a steel pointed mallet.

- Madrid style render with floated finish, the final layer of the mortar is floated , burnished and finished with a wood float.

- Bush hammered render (imitating ashlar) this finish is used to give the effect of projections, imitating stone blocks, they are generally located at the corners of façades or in the dressings of openings.

- A render imitating granite stone (stone-like) this type of finish is used for the bases of façades because of its hardness as well as the granite stone effect.

- A render which imitates the classic Roman unpolished travertine stone.

- Sgraffito render several coats in different colours are applied, part of one or more coats are removed through the stencil technique in order to produce relief or drawings.

Figure 26: Different finishes for lime and combined mortars. From top to bottom and from left to right: 1- Scraped. 2- Scraped with Plinth, 3- Glossy external render 4- Hawk's beak (Pico Gavilán) 5- Sgraffito 6- Fine floated 7- Brick effect 8- Hammered with Plinth 9- Ashlar block effect.
Courtesy: Hidrocal Morteros

Figure 27: Hammered and Ashlar finish.
Courtesy: Hidrocal Morteros

Figure 28: Floated and Washed China finish.
Courtesy: Hidrocal Morteros

Figure 29: Traditional lime mortar with floated finish with plinth Zurbano Street nº 53 – Madrid.
Courtesy: Hidrocal Morteros

7.5.2 Lime and cement composite mortars

In order to use these mortars as coatings, their compatibility with the substrate materials should be taken into account (type, strengths, etc.). Sometimes it is necessary to carry out a preparatory treatment on the substrate to obtain the correct adherence and stability.

The coatings should be executed on substrates which have been previously cleaned and moistened, they should have a thickness of 15 mm and if said thickness is to be greater, the coating should be executed in several coats, the inner coat being the mechanically strongest.

In those cases where a prior coat has been applied in order to level out the substrate, this coat should have sufficient roughness to achieve good adherence with the next coat, which should be applied when the levelling coat has sufficiently hardened and has been moistened.

The coated surface will be kept moist until the cement has set.

Finishes for composite mortars (lime-cement)

- Floated finish, similar to pure lime mortars, this type of mortar can be coloured and for this purpose can be finished as follows.
- Scraped finish.
- Travertine stone finish.

Figure 30: Examples of new construction and restoration using industrially manufactured composite mortars. **Courtesy:** Calcinor

8. Stuccos

A stucco is a continuous finish coating, for internal and external use, which is used to render, composed of lime putty or gypsum and marble dust.

Composed of lime putty, marble dust and inorganic pigments, it hardens by carbonation of the lime, achieving a glossy finish resembling marble.

Figure 31: Stuccos for external use. Glossy stucco for internal areas. Façade executed in Talavera De La Reina (Toledo).
Courtesy: Hidrocal Morteros

8.1 Classification of stuccos

The best criterion for classifying them is based on the work process itself, and consequently there are the following basic techniques (table 13).

Table 13: Classification of stuccos (Source: Practical guide for lime and stucco)

Plastered stucco	Plaster Lacking tones Hot pressed (bordering in hot-ironed stucco, hot-ironed stucco painted al fresco and hot-ironed stucco marble imitation) Al fresco paint (plastered with a subsequent colour treatment)
Worked stucco	Saw worked Steel brush worked Cut stone effect Face brick effect
Sgraffito stucco	It combines both of the previous techniques and consists in superimposing coats of different colour and texture, in such a way that the base coat (plastered or worked) becomes exposed when part of the surface coat is scraped away (plastered, worked, cut stone, and ironed). Within this group is also found the ancient technique and the sgraffito stucco coloured al fresco

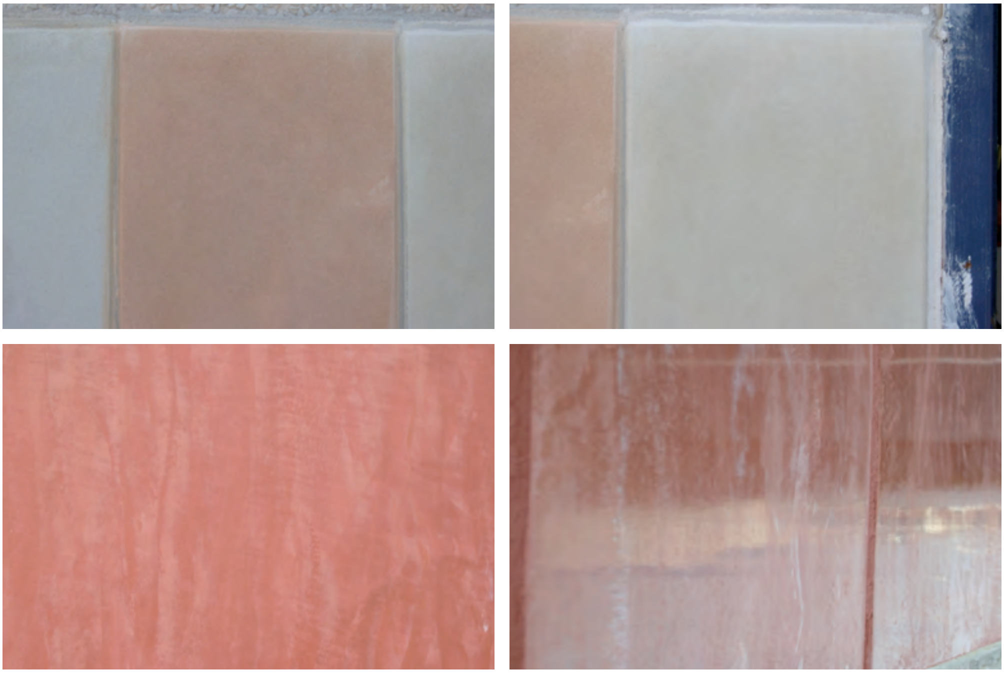


Figure 32: Stuccos. The working process for executing the stuccos, the base coat can be lime or composite (lime-cement) with fine aggregates is the perfect base coat for the execution of glossy or matte stuccos. Courtesy: Hidrocal Morteros

8.2 Execution

Stuccos are composed of at least two coats of lean paste and compacted paste. Before starting to apply the paste, a brush is applied to the wall to remove dust. Afterwards, a first coat is applied with lean plaster, with the help of a trowel. Subsequently the second coat is applied, and finally, the third coat or compacted coat is applied, the purpose of which is to smooth and compact the paste squeezing it by tracing circles with the trowel. The final thickness of the stucco can reach up to 2 cm.

The thickness of each of the coats is defined by the size of aggregate used. The first coats to be applied are those with the thickest aggregates and, subsequently, those with a finer grain.

The material should always be applied on a moist surface. The ideal time to apply a coat of stucco is when a hand passed across the mixture does not sink into or become soiled by the mix, even as it is still fresh. The drying out and carbonation of the middle coats should be avoided to achieve the adherence and consistency of the stucco.

Recommendations: the lime putty should remain in basins for at least 6 months, the sand should be white calcium carbonate (known as domestic white marble) and the pigments should be resistant to ultraviolet rays (to remain stable under sunlight), alkalis (so that the lime does not consume them and they remain unalterable) and acids (to resist weather and acid rain).

The highest quality of materials used as pigments should be ensured, in particular their micronisation and colour regularity.

There are three ranges of pigments:

Figure 33: Internal and external lime stuccos made with lime putty and white aggregates selected and pigmented.
Courtesy: Calcinor

- chromium oxide, of green colour,
- cobalt oxide, which results in a blue colour and
- those based on iron oxides, which go from yellow to black, and include ochre, sienna, leather, mangra and brown, among others.

Figure 34: External lime stuccos in León.
Courtesy: Ibercal

Pigments suitable for use with lime should be stable to alkalis, sunlight, the action of atmospheric agents and acidic attack (to avoid the formation of efflorescence).

The amount of pigment necessary for a stucco mix is between 3 and 5%. A higher quantity will result in a change of the proportion of binder/load (lime putty/aggregate).

8.3 Dosages

Table 14: Dosages for stucco mixes

Type of mix	Use	Hydrated lime	Maximum size of sand (mm)			
			2,5	1,2	0,8	0,4
Lean	First coat on ruled plaster	156 kg	125 kg	50 kg	25 kg	
Lean	First coat on floated plasters	156 kg		150 kg	25 kg	
Lean	First coats and compacted coats	156 kg			175 kg	
Rich	Finish for fine textured stuccos	156 kg			50 kg	25 kg

9. LIMEWASH WITH PUTTY OR LIME WHITEWASH

As it is an economic and hygienic process, limewash has been used throughout history to paint external and internal walls.

The limewashes considered here are applied through a "lime whitewash" (1 part slaked lime per 5 parts water, in volume) or lime putty. This whitewash can be produced with hydroxide power and water or with lime putty or slaked lime.

Figure 35: Slaked lime and lime whitewash.
Courtesy: Calcinor

Lime paint is a more elaborated product than whitewash. It is produced with an added lime putty and can be pigmented. It represents one of best finishing systems from the aesthetic point of view, because of its chromatic effects, transparency and luminosity of the surface. Lime fully complies with all of the general criteria of bio-compatibility: biodegradable, components with natural origins, durability, easy to maintain and compact, hygienic, breathable and absorbs CO_2.

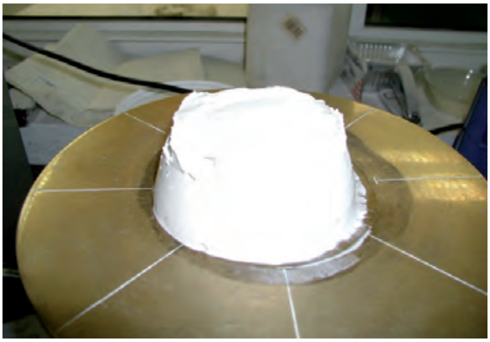


Figure 36: Lime putty.
Courtesy: Calcinor

Limewashes can achieve transparent "water coloured" colours, superimposing 2 or 3 coats of different tones on a uniform and clear backing. They dry quickly and should be applied on a wet or moistened coating. They can have a sealing effect on coatings with microcracks or cracks and can eliminate defects relating to their appearance (mixing, lack of whiteness, poor pigment dispersion).

To achieve a stable limewash an addition of polyvinyl acetate should be used.

When using fixatives to achieve more vibrant colour it is advised to carry out tests beforehand with the selected fixative.

9.1 Execution

9.1.1 Preparation of the substrate

Limewashes should be applied on backings which are solid, clean, free from dust and non-floury; in addition they should have a certain roughness. The limewash does not have adherence on coatings which contain waterproofing agents and on synthetic resin paints. When limewashes are carried out on a coating after two to four hours of its application, the finish coat is called "al fresco" (while fresh) the limewash becoming integrated into the coating. After this time, the coatings cannot be applied before the complete hardening of the substrate; in this case they are called "al seco" (while dry), it being necessary to moisten the substrate before each coat, especially during periods which are very sunny and dry, or with strong winds or on very absorbent backings.

9.1.2 Preparation of the limewash

In order to avoid joints, it is necessary to prepare all the quantities needed for a coat at the same time. An electric mixer makes the mixing easier and avoids the formation of clots during the mixing of the lime with the water. It ensures the homogeneous distribution of the pigments and prevents the sedimentation of the lime. The mix is easily stored from one day to the next if it does not contain additives, since hydrated lime does not harden upon contact with water.

Dosage of the mix:

Depending on the required transparency, the dosage will vary from 1 volume of lime per 2 volumes of water to 1 volume of lime per 5 volumes of water.

The weight of the pigment additions should never exceed 10% of the dry binder weight for oxides and 25% for earth based pigments.

Generally, the following mix is used:
25 kg of lime in 100 litres of water plus 2 litres of commercial polyvinyl acetate solution.

9.1.3 Application of the limewash

The limewash should not be applied when the temperature of the substrate is less than 5 ºC, nor on substrates which have been treated with curing or waterproofing products.

A flexible brush (never use nylon) should be used or a dense paintbrush; the application should be from top to bottom.

After moistening, the first diluted white coat is applied to unify the substrate and after 24 hours the second coat, white or pigmented.

Figure 37: Application of the lime putty.
Courtesy: Calcinor

Figure 38: Result of the application of the lime putty.
Courtesy: Calcinor

9.1.4 Observations

- Limewashes made from hydrated air lime can be easily applied on coatings which are plaster based.
- The colours will lighten as they dry. Shaded areas will fade away over time.
- It is necessary to lightly moisten the first coat before applying the second. On new surfaces the application of a diluted first coat is recommended.

Figure 39: Blue and lime, Formentera, Balearic Islands.
Courtesy: Ministry of Education, Social Policies and Sports

- It is recommended to add a small amount of liquid soap (it serves as a moistening agent) to the second coat when it is coloured, in the order of 5 ml per 10 litres of lime wash, so that the whole becomes more homogeneous and to aid dispersion of pigments.

- In the case of well prepared lime paint it can be applied with a roller, taking into account that it can splash more than a plastic paint. The drops are easily cleaned with water, more easily if they have not dried.

9.2 Additional uses and properties of limewashes

9.2.1 Treatment of wood

Limewash destroys and prevents the growth of bacteria, because of the high pH of the water contained in the wood. The subsequent finish of wood panels reinforces the disinfectant action of lime washes.

9.2.2 Disinfection using lime wash on the walls of cellars, basements, barns, etc.

Lime whitewash destroys bacteria and larva, providing a more pleasing aspect to the premises.

Figure 40: Disinfecting a basement using lime wash.
Courtesy: Calcinor

10. Gypsum and lime mixtures

Gypsum with the addition of lime is used to update coatings and for the production of mouldings, ceiling decorative elements, etc.

The incorporation of hydrated lime to gypsum improves its workability, adherence, mechanical strength and weather resistance. This incorporation gives it a basic pH (> 7), and thus avoids the risk of the possible corrosion of metals, in the presence of humidity, and the growth of bacteria is reduced, as well as the growth of mould patches caused by fungi and the appearance of stains. This plaster with additives is used above all in internal coatings, although it has also been used with success in external coatings, there being a tradition of these coatings applied onto façades.

It is not recommended to locate plaster nor hydrated air lime at the foot of walls in order to avoid splashes because they are water soluble.

A dosage used in the manufacture of plaster mortars for interior as well as external use is as follows:

Gypsum	39 %	Sand	29 %
Hydrated lime	7 %	Water	25 %

The components of the mix should comply with the following characteristics:

- The hydrated lime should be calcic, types UNE-EN 459-1 CL 90-S, CL 80-S and CL 70-S can be employed, all other types being excluded, according to the UNE EN 459-1 standard.
- The gypsum (without additions); should comply with the characteristics included in the current UNE-EN 13279-1:2006 and UNE 102.011 Standards.
- The sand should be clean and of the suitable maximum sizes for the thickness of each coat and its finish; it can be coloured with inorganic pigments (for example: ground ceramic brick, stone dust, chamotte, metallic oxides, etc.).
- Add water until reaching the correct consistency.

In many cases, additives that regulate setting and retain water are used to modify the characteristics of the mix.

ANNEXES

ANNEX 1. Lime mortar tests

a) Statutory tests

The UNE EN 998-1 and UNE EN 998-2 standards, in their ZA Annexes, describe the mandatory tests for mortars for render and plasterwork (apparent dry density, compressive strength, adherence, water absorption by capillary action, durability...) and for masonry mortars (usage time, ion chloride content, air content, compressive strength, adherence, water absorption...) respectively. Those which are effected on site are not described in these standards but there are a series of illustrative tests.

b) Illustrative tests

As illustrative tests, there are a series of technological tests complementing the above.

It is recommended, for each specific case, to determine the optimal dosage of slaked lime by means of the glass sheet test (to be carried out in the laboratory) or rasilla (long and thin brick) test (to be carried out on site), which is described below, to verify that the mix is neither too rich nor too poor in lime.

Figure 41: Laboratory.
Courtesy: Tudela Veguín

Should additives be used to modify any of the characteristics of the mortars it is recommended to carry out the pertinent tests to establish the optimal dosage of the additive in order to obtain the desired results.

b.1) Glass sheet test:

A sufficient amount of mortar is prepared for testing and a biscuit of this mortar of about 6 to 8 mm in thickness is made on top of a glass sheet. After 24 hours, the quality of the mix can be assessed, based on the following observations:

a) If the biscuit falls apart:
The mix does not have enough lime (lack of adherence and strength)

b) If the biscuit cracks:
The mix is too rich in lime (risk of cracking)

b.1) Rasilla test:

A quantity of mortar is prepared and applied on a rasilla. If after 24 hours of having applied the mix the following is observed:

a) it falls apart: the mix does not have enough lime (lack of adherence and strength)
b) the surface develops cracks: the mix has a high level of lime (risk of cracking)
c) the mix does not crack and is sufficiently strong (the trowel does not penetrate into the mortar): the mortar has the correct dosage

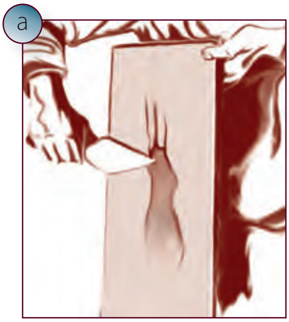


Figure 42: Mix lacking lime

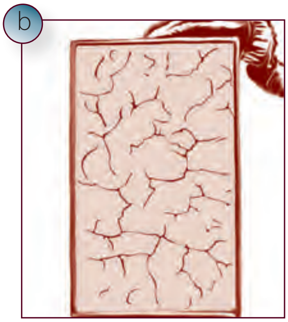


Figure 43: Mix with excessive lime

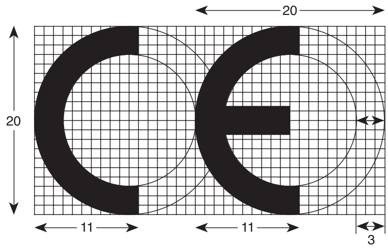
Figure 44: Mortar with correct dosage

Annex 2. Standards and CE Marking

The CE Marking is obligatory for all construction products contained in Directive 89/106/CEE in accordance with the conditions it establishes (transposed to Spanish legislation by means of "RD 1630/1992, of 29 December, by which Instructions are Issued for the Free Circulation of Construction Products, in Application of Directive 89/106/CEE") among them are air and hydraulic limes, aggregates and industrial mortars.

For limes the applicable harmonized standard is UNE-EN 459, for cement UNE-EN 197 (common cements), for aggregates UNE-EN 13139, for mortars for render and plasterwork UNE-EN 998-1 and for masonry mortars UNE-EN 998-2.

The CE Marking is a label given by an authorized body which indicates that the manufacturer's products comply with the applicable harmonized standards. It is the manufacturer's responsibility to maintain this compliance and update the renewals of its CE markings in accordance with the respective regulations.



The consequence of the above is that no air or hydraulic lime, cement, aggregate or mortar can be used in any construction work which does not carry the aforementioned CE marking .

The CE marking is a guarantee that the product complies with the respective specifications and is subjected to the appropriate monitoring of its production in order to ensure its quality, with the advantages that result for the purchaser or user, from having the manufacturer's guarantee that the product is fully compliant with the essential requirements, as set out in the referred to directive, as a construction product.

In accordance with the CE Marking Regulations, the documents which should accompany an air or hydraulic lime for its use in construction should be the following:

- Identification No. of notified body: i.e.: 1170
- Name or brand and address of the manufacturer: i.e.: Cales ANCADE, S.A. Goya, 23, 3º Dcha, Madrid (28001)
- Two last digits of stamp date: i.e.: Year 07
- Certificate of Compliance No: i.e.: 1170/CPD/CL002
- Reference to the European Standard: UNE-EN 459-1
- Description of the product: i.e.: CL 90-S slaked lime for construction
- Essential requirements:
  - $CaO + MgO > 90$ %; $MgO < 5$ %; $CO_2 < 4$ %; $SO_3 < 2$ %
  - Stability of volume < 20 mm
  - Retained 0.09 mm < 7 %; Retained 0.20 mm < 2 %
  - Penetration > 10 and < 50 mm

In the case of mortars for render and plasterwork, the documents to include are as follows:

- Name or brand and address of the manufacturer
- Two last digits of stamp date
- Reference to the European Standard: UNE-EN 998-1
- Description of the product: i.e.: General purpose (GP) mortar for render for external use
- Product information regarding the regulated characteristics
- "No Performance Determined" (NPD), for suitable characteristics, depending on the case

CE	EU conformity marking represented by the "CE" symbol given in Directive 98/68/EEC
AnyCo Ltd, PO Box 21, B-1050 00	*Name or identifying brand and registered address of the manufacturer* *Two last digits of the year in which the marking was stamped*
EN 998-1 **General purpose (GP) mortar for use in external render** **Reaction to fire:** Class A 1 **Adhesion:** 0.3 N/mm² – **FB**: B **Water absorption:** W 1 **Water vapour coefficient:** μ 25 **Thermal conductivity:** ($\lambda_{10,dry}$) 0.93 W/mK (tabulated value) **Durability (freezing-thawing cycles):**): assessment based on the valid instructions in the location where the mortar is to be used	*No. of the European Standard* *Description of the Product* *and* *information regarding the regulated characteristics*

Figure 45: Example of CE marking information .

And in the case of mortars for masonry, the documents to include are as follows:

- Certification Body Identification No.
- Name, or identification, and registered address of the manufacturer
- Two last digits of stamp date

- No. of conformity Certificate or of the factory production record
- Reference to the European Standard: UNE-EN 998-2
- Description of the product
- Product information regarding the regulated characteristics
- "No Performance Determined" (NPD), for suitable characteristics, depending on the case

The legislation related to the CE Marking is as follows:

- Directive 89/106/EEC Construction Products OJ/EC (11.02.89)
- Directive 93/68/EEC CE Marking
- Royal Decree 1630/1992 Transposition of Directive 89/106/CE (B.O.E., Boletin Oficial de Estado [Official Journal of the State] 9.2.93)
- Royal Decree 1328/1995 Directive Transposition of CE Marking (B.O.E. 19.8.95)

CE	*EU conformity marking represented by the "CE" symbol given in Directive 98/68/EEC*
AnyCo Ltd, PO Box 21, B-1050 **00**	*Name or identifying brand and registered address of the manufacturer* *Two last digits of the year in which the marking was stamped*
EN 998-2 Mortars prescribed for general (G) use to be used in external constructions subject to structural requirements **Proportion of components (by volume)** Cement: 15% Lime: 10% Aggregates: 75% **Chloride content:** 0.07% Cl **Reaction to fire:** Class A 1 **Water absorption:** 0.1 [kg/(m^2 – min$^{0.5}$)] **Water vapour coefficient:** μ 15/35 **Thermal conductivity:** ($\lambda_{10,dry}$) 0.83 W/mK (tabulated value) **Durability (freezing-thawing cycles):** assessment based on the current provisions in the location where the mortar is to be used	*No. of the European Standard* *Description of the Product* *and* *information regarding the regulated characteristics*

Figure 46: Example of CE marking information.

Annex 3. Precautions to be taken during the use of quicklime or slaked lime

Quicklimes or hydrated limes are not toxic materials; however, taking into account their alkalinity it is advised to use appropriate protection methods while manipulating them, because they can provoke irritation in nasal mucous membranes. Skin and eye contact should also be avoided.

In all cases the instructions of the Safety Data Sheets should be followed which are supplied by the lime manufacturer.

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Annex 5. ANCADE Members

As of 1st May 2009 the following companies are members of **ANCADE**:

MEMBERS

ANDALUZA DE CALES (ANCASA)
Ctra. Morón - Montellano, km. 3
41530 - Morón de la Frontera (Seville)
Tel: 954851112 - Fax: 954852959
calcinor@calcinor.com
http://www.calcinor.com

CALERA DE ALZO
Factory in Alzo Guipúzcoa
Factory in Mondragón
Egileor Auzoa, 101
20268 - Alzo (Guipuzcoa)
Tel: 943653243 - Fax: 943654895
calcinor@calcinor.com
http://www.calcinor.com

CALCINOR
Egileor Auzoa, 101
20268 - Altzo (Guipuzcoa)
Tel: 943653243 - Fax: 943654895
calcinor@calcinor.com
http://www.calcinor.com

CAL DE CASTILLA (CALCASA)
Ctra. Valencia, km. 31
28500 - Arganda del Rey (Madrid)
Tel: 918715481 - Fax: 918700867
calcinor@calcinor.com
http://www.calcinor.com

CALES DE LA PLANA (CAPLANSA)
La Pedrera, s/n
12592 - Chilches (Castellón)
Tel: 964590105 - Fax: 964583046
calcinor@calcinor.com
http://www.calcinor.com

CALES DE LLIERCA
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http://www.calesdellierca.com

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Tel: 938903011 - Fax: 938903689
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San Cucao de Llanera
33425 - Llanera (Asturias)
Tel: 985770858 - Fax: 985770133
caleras@sancucao.flcnet.es
http://www.caleras.com

CAL GOV
Ctra. Fuente de Santiago, km. 2.5
41560 - Estepa (Seville)
Tel: 955912600 - Fax: 955912899

CAL INDUSTRIAL (CALINSA)
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31007 - Pamplona (Navarre)
Tel: 948268511 - Fax: 948170202
http://www.lhoist.com

CALES PASCUAL
Ctra. Valencia – Ademuz km. 9.3
43980 - Paterna (Valencia)
Tel: 9613211273 - Fax: 961324358
http://www.calespascual.com

CALESTEP
Pozo de la Albujea s/n
41560 - Estepa (Seville)
Tel: 955912696 - Fax: 955912908
http://www.calestep.com

COMERCIAL E INDUSTRIAL ARIES (CIARIES)
Factory in Olesa de Bonesvalls (Barcelona)
Factory in La Puebla Albortón (Zaragoza)
Alí-Bei, 25 7º 1ª
08010 - Barcelona (Barcelona)
Tel: 938984140 - Fax: 938984227
info@ciaries.com
http://www.ciaries.com

DERIVADOS CÁLCICOS (DECSA)
Pont Major-Despoblado, 14
17007 - Gerona (Gerona)
Tel: 972207350 - Fax: 972213636

DOLOMITAS DEL NORTE
Barrioa de Santullan, s/n
39706 - Castro Urdiales (Cantabria)
Tel: 942879294 - Fax: 942879300
calcinor@calcinor.com
http://www.calcinor.com

SEGURA S.L.
Mina Matagallar
41566 - Pedrera (Seville)
Tel: 954819061
http://www.ugeycia.com/segura/segura.html

TUDELA VEGUÍN
Argüelles, 25
33003 - Oviedo (Asturias)
Tel: 985981100 - Fax: 985981105
http://www.tudela-veguin-sa.es

ASSOCIATED MEMBERS

HIDROCAL MORTEROS
C/ Electrónica nº 9 Pol. Ind. "URTINSA II"
28923 Alcorcón (Madrid)
Tel: 914 86 12 59
Fax: 916 41 12 69
http://www.hidrocalmorteros.com

IBERCAL MORTEROS
Ctra. Badajoz, km. 55.8
06200 - Almendralejo (Badajoz)
Tel: 924677002 - Fax: 924677005
info@ibercalmorteros.es
http://www.ibercalmorteros.es

SODIMATE IBERICA S.L.
Pol. Ind. Fontsanta, C/ Samonta 6A
08970 Sant Joan Despi
Tel: 934525135
Fax: 933231582
http://www.sodimateiberica.com

TALLERES CARLOS DOMENECH, S.L.
Pol.Ind. Pla de la Vallonga. Calle 6. Parcela 116
03006 Alicante
Tel: 965114508
Fax: 965280412
http://www.domenechmaquinaria.com

UNICMALL, S.L.
C/ Puigverd s/n Apto 46
07200 Felanitx
Mallorca (Balearic Islands)
Tel: 971 580 634
Fax: 971 582 609
http://www.unicmall.com

Edited by:

ANCADE

Asociación Nacional de Fabricantes de Cales y Derivados de España
[Spanish National Association of Manufacturers of Lime and Lime Derivatives]
C/ Goya, 23, 3º Derecha
28001 Madrid
Tel.: 914 261 291
Fax: 914 315 799
www.ancade.es
info@ancade.es

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