Introduction to modern mortars

Contents

Health and safety

All mortar mixtures, both wet and dry, are abrasive and alkaline. When working with wet mortar, waterproof or other suitable protective clothing should be worn. Guidance on the use of these materials can be found in MIA data sheet No. 20.

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Introduction

Mortar has played a major role in construction since ancient times with the oldest example having been found in Israel and thought to date back 10,000 years. Much of the ancient mortar still in existence remains durable today, a testament to the long lasting nature of the material.

In practice, a mortar joint acts as a sealant, a bearing pad, the glue that sticks the units together yet keeps them apart and, in this sense, performs as a gap-filling adhesive.

Today, mortar in the UK is produced to the specification BS EN 998-2: Specification for mortar for masonry - Part 2: Masonry mortar. It can made either by mixing on site in a concrete mixer or manufactured under factory-controlled conditions off site by specialist suppliers. In both instances, high quality cement, sand and sometimes lime are used in its production. The quality of today's mortars are due to the commercial development of Portland cement in the 1920s, which made the potential for masonry construction much greater.

New mortar materials provided far more reliable strength development and much increased rate of strength gain than previously achieved using various forms of lime. This enabled construction to be planned and executed far more rapidly. The limes previously used in mortar produced acceptable working properties but the rate of strength gain was low, especially in cold weather. This meant that even a high quality lime, with a good ultimate strength, could prove very problematic during winter usage. Indeed it is probable that the majority of masonry construction proceeded little, if at all, during winter months.

Availability of the new Portland cements changed this and enabled construction to carry on throughout the year, with the obvious exception of periods of very severe winter weather with heavy precipitation or freezing temperatures.

Masonry cement mortars

Masonry cement, produced at cement works, gives a mortar that is neither too strong nor too weak. It is a blended form of Portland cement, ground limestone or fine silica and an air-entraining admixture.

Whilst UK masonry cement has utilised mixtures of Portland cement and crushed or ground stone, in North America, the tradition has been to use mixtures of Portland cement and hydrated lime, together with air entrainment. This concept has been adopted at one UK cement works and has now been incorporated into the Code of Practice, BS 5628.

Current practice

Site-made mortars are less common today largely due to an increased emphasis on the need for accurate gauging and mixing. This has meant that factory-produced mortars are now taking an increasing share of the market to the extent that today it is rare to find site mixing taking place.

Factory-made mortar may be one of the following types:

- Wet ready-to-use
- Dry ready-to-use (delivered via silos or in bags)
- Lime sand for mortar

These different types of factory-made mortars are explained in greater detail in further Mortar Industry Association learning texts but are briefly described below:

Wet ready-to-use mortar

Wet ready-to-use mortar is a mixture of cement and sand (also referred to 'fine aggregate'), sometimes with the addition of lime and contains a cement set retarder. Water is added in the factory and the resultant mix remains workable for a specified period of time, generally up to 48 hours. The mortar is normally delivered to site in bulk, using agitators or specialist vehicles and discharged into designated containers ready for use.

Dry ready-to-use mortar

Dry ready-to-use mortar is cement and dried sand, sometimes with the addition of lime and/or admixtures. It is stored on site in bags or bulk silos. The silos incorporate their own integral mixer and are connected to water and power supplies. This allows the mixing of the desired amount of mortar at any one time.

Lime sand for mortar

Lime sand for mortar is pre-batched sand and lime, sometimes containing admixtures that require the addition of cement and water on site. The material is usually delivered to site in tippers, skips or jumbo bags.

Factory-produced mortars manufactured under controlled conditions have advantages in both quality and consistency when compared to site-mixed materials.

Historical background

The very wide use of mortars throughout history makes its development useful in providing background on building construction. This short historical review of various kinds of mortars aims to provide such background.

Gypsum mortar

The ancient Egyptians used gypsum mortars in the construction of the pyramids. More recently, this type of mortar was used to rebuild much of the city of Paris in the 19th century, hence gypsum sometimes being called Plaster of Paris, as a result of the natural gypsum deposits found under the French capital's district of Montmartre. Some gypsum-bonded masonry still exists in the older parts of Paris but many of these existing historic dwellings which have not been restored, suffer badly from damp and deterioration. Partly as a result of these adverse experiences and supported by the theoretical view that gypsum-based mortars do not form hydrates that are stable in the presence of water, they are not used today and are certainly not recommended for external work. However, gypsum mortars in very
dry climates, or where there is protection from the elements, could be used without problems. In these conditions, or in an internal environment without excessive damp, they can perform satisfactorily, as demonstrated by the widespread use internally of gypsum-based internal building blocks in continental Europe.

Lime mortars

Lime mortars harden and gain strength by the evaporation of water and the absorption of carbon dioxide from the atmosphere. This results in the gradual conversion of lime into calcium carbonate. This mechanism is theoretically correct but takes a very long time to produce any meaningful strength.

There are different compounds that are known loosely as lime and these are described in more detail in the MIA learning text number 2, Cementitious materials. In brief, they are:

Quicklime

Lime is generally produced by burning mineral raw materials, usually those based on calcium, although magnesium based limes also exist. Most commonly in the UK and Ireland, chalk or limestone are used but in theory any calcareous material could be employed. For example, in some countries shells, corals and other sources of calcium are used satisfactorily.

When the raw material - basically calcium carbonate whatever its actual form - is heated to about 850°C, carbon dioxide is driven off in the form of gas, resulting in calcium oxide or quicklime.

Hydrated lime

Quicklime is not used directly in mortar but is first treated with water to produce calcium hydroxide, known as 'slaked' or 'hydrated' lime. In this form it can be incorporated in a mortar mix. However, pure calcium hydroxide mortars, although in theory being capable of hardening and developing strength, in reality only react extremely slowly. It would take perhaps 100 years for a mortar joint to carbonate or harden to a depth of six to 10 mm (where carbonation is the conversion of calcium hydroxide to calcium carbonate). Ancient craftsmen realised this and knew that a very pure lime was actually inferior to one that had some impurities.

Hydraulic lime

To manufacture cement, limestone is burnt in a kiln with clay to make a compound that reacts with water to produce a hardened hydrate. It is the presence of clay impurities that effectively produces a weak cement and it is this mechanism that is behind the strength development and hardening of many lime mortars, both historical and modern. This is often misunderstood but without the inclusion of at least some clay during the burning of lime, lime mortars will not harden at a meaningful rate.

This lack of understanding leads to an erroneous interpretation of the properties of lime mortars. Some modern builders and specifiers ascribe a whole plethora of beneficial properties to 'lime' mortars, based primarily on their observations of the long life of historic structures, without realising exactly on what type of lime mortars they are basing their views. Many, probably the vast majority of the successful and long-lasting structures that they believe to contain lime mortars, are based on hydraulic lime. In reality this is a weak and crude cement when compared to the purer hydrated limes that are produced today. Use of hydrated lime will not produce a mortar with a great deal of strength or durability, as the carbonation process proceeds so slowly and produces relatively low strength development.

Due to the evident long lasting nature of hydraulic lime based mortars, some specifiers have again been stipulating their use, unaware of the way in which they were produced originally and in the belief that similar materials are readily available. In fact, hydraulic limes are not readily available in the UK today as only one small works in Dorset produces commercial quantities. Some hydraulic limes are imported from Italy and France but whilst these may be genuine, a number are formulated using mixtures of Portland cement, lime and air entraining admixture and are thus not hydraulic limes at all, but rather masonry cements.

In reality, almost every situation where historic limes are exampled, these are hydraulic and not hydrated lime.

Other historic mortars

Many examples of Roman mortar survive, many within the UK. For example Hadrian's Wall still has massive unrestored areas of original materials. The Tower of London, some 900 years old, provides further evidence of the durability of masonry materials and historic lime mortar.

Ash lime mortar

The potential pozzolanic properties of ash or other material containing reactive silica have been known since pre-Roman times. There are many historical references to the use of ground brick dust as a source of silica to mix with lime and thus generate a false set.

There are also misconceptions surrounding the use of brick dust and there have been examples of the inappropriate specification of this material. Early bricks were fired at low temperatures and the resultant product was quite highly reactive in the presence of free lime. In contrast, modern bricks are fired at much higher temperatures and are not nearly as reactive, indeed sometimes not at all, compared to historic examples.

This is an area where a great deal of confusion exists, with the specification of materials that are thought to mirror favourable historic characteristics being a potential source of failure. This means that any specification for a lime mortar to be used in conjunction with ground brick dust should be questioned.

In contrast, the relatively recent use of ash in ash lime mortars has been both more widespread and more successful, although that is not to say that these mixes should really be specified today without adequate research. From the time of the industrial revolution, with the widespread availability of furnace ashes, ash lime or black ash mortars have become more widely used. These materials are often criticised today, primarily because of their impurities, which in theory may lead to durability problems. It has been said that their use in cavity work built around the beginning and middle of the 20th century caused corrosion of wall ties, but it is unclear whether or not many of these ties would have corroded in any event regardless of the mortar used. Indeed, many structures exist where old ash lime mortars are still durable. Ash lime mortars were still used well into the middle of the twentieth century in those parts of the country where ash was widely available.

Glossary of Terms

The definitions in this learning text are based on those given in BS EN 459-1; BS 6100-9

Air limes
Limes mainly consisting of calcium oxide or hydroxide, which slowly harden in air by reacting with atmospheric carbon dioxide. Generally they do not harden under water as they have no hydraulic properties. They may be either quicklimes or hydrated limes.

Building limes
Limes mainly consisting of calcium oxide or calcium hydroxide without any additions of hydraulic or pozzolanic materials.

Calcium limes (CL)
Limes mainly consisting of calcium oxide or calcium hydroxide without any additions of hydraulic or pozzolanic materials.

Building limes
Limes used in building construction and civil engineering.

Calcium limes (CL)
Limes mainly consisting of calcium oxide or calcium hydroxide without any additions of hydraulic or pozzolanic materials.

Carbonation
Chemical reaction that occurs between the calcium hydroxide or the mortar matrix and atmospheric carbon dioxide.

False set
Premature stiffening of a binder in a mortar immediately after mixing that can be corrected.

Gypsum
Naturally occurring or chemically produced calcium sulfate dihydrate ($CaSO_4 \cdot 2H_20$) from which binders are produced by various degrees of dehydration.

Lime
Material comprising any physical and chemical forms under which calcium and/or magnesium oxide (CaO and MgO) and/or hydroxide ($(Ca(OH)^2$ and $Mg(OH)^2$ can appear.

Hydrated limes
Air limes, calcium limes or dolomitic limes, resulting from the controlled slaking of quicklimes. They are produced in the form of a dry powder or putty or as a slurry (milk of lime).

Hydraulic limes (HL)
Limes mainly consisting of calcium hydroxide, calcium silicates and calcium aluminates produced by mixing of suitable materials. They have the property of setting and hardening under water. Atmospheric carbon dioxide contributes to the hardening process.

Quicklimes
Air limes mainly consisting of calcium oxide and magnesium oxide produced by calcination of limestone and/or dolomite rock. They have an exothermic reaction when in contact with water. They are available in varying sizes ranging from lumps to ground powder materials. They include calcium limes and dolomitic limes.

Bibliography

BS 5628-1:2005 Code of practice for the use of masonry - Part 1: Structural use of unreinforced masonry.

BS 5628-2:2005 Code of practice for the use of masonry - Part 2: Structural use of reinforced and prestressed masonry.

BS 5628-3:2005 Code of practice for the use of masonry - Part 3: Materials and components, design and workmanship.

BS 6100-9:2007 Building and civil engineering-Vocabulary - Part 9: Work with concrete and plaster.

BS EN 459-1:2001 Building lime - Part 1: Definitions, specifications and conformity criteria.

Self-assessment questions

1 What is normally blended to make masonry cement?

A

2 What are the three types of factory-produced mortar?

A

3 Why is site-made mortar less common today?

A

4 How long generally is wet ready-to-use mortar expected to remain workable?

A

5 How is dry ready-to-use mortar stored on site?

A

6 How is lime sand for mortar normally delivered to site?

A

7 What are the basic raw materials from which hydraulic lime is manufactured?

A

8 What is quicklime?

A

9 How do quicklime and hydraulic lime differ?

A

10 What is ash lime mortar?

A

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Answers to self-assessment questions

1 Portland cement, ground limestone or fine silica and an air-entraining admixture.
2 Wet ready-to-use, dry ready-to-use and lime sand.
3 Increased emphasis on the need for accurate mortar gauging and mixing.
4 Up to 48 hours.
5 In silos.
6 In tippers, skips or jumbo bags.
7 Hydraulic lime is manufactured from chalk or limestone and clay.
8 Quicklime is calcium oxide .
9 Hydraulic lime contains siliceous components, quicklime does not.
10 Ash lime mortar is a mixture of lime and furnace ash.

MIA Learning Texts include:

1 Introduction to modern mortars
2 Cementitious materials
3 Aggregates
4 Admixtures, additives and water
5 Brick and block production
6 Properties of masonry mortar
7 Production, deleivery and storage of mortar
8 Mortar testing
9 Specifications
10 Quality assurance
11 Construction
12 Properties of rendering mortar
13 Best practice - potential site problems

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The Mortar Industry Association is part of the Mineral Products association, the trade association for the aggregates, asphalt, cement, concrete, dimension stone, lime, mortar and silica sand industries

Mineral Products Association Ltd
Gillingham House
38 - 44 Gillingham Street
London SW1V 1HU
Tel +44 (0)20 7963 8000
Fax +44 (0)20 7963 8001
brian.james@mineralproducts.org
www.mortar.org.uk

There is a real danger of contact dermatitis or serious burns if skin comes into contact with wet mortar. Wear suitable protective clothing and eye protection. Where skin contact occurs either directly or through saturated clothing was immediately with soap and water. For eye contact immediately wash out eyes thoroughly with clean water. If swallowed wash out mouth and drink plenty of water.

The relevant codes of practice, standards and statutory regulations must always be observed.