Using lime as a construction material

Lime is a 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. Lime plays an important role as a construction material. The main uses of lime are as follows:

In soil treatment and stabilization to provide a platform for heavy construction such as roads, earthen dams, airfields, and building foundations.

As an additive in asphalt, lime improves the cohesion of asphalt, reduces stripping, and retards the aging process.

As a binder in the productions of bricks, aircrete, fire resistant board and concrete.

Lime is also a key ingredient in mortar and plaster.

BUILDING LIME STANDARD

For the preparation of mortar for masonry, rendering and plastering and production of other construction products using lime is outlined on BS EN 459-1.

2. 1. BUILDING LIME TERMINOLOGY

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.

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

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.

Calcium limes: limes mainly consisting of calcium oxide or calcium hydroxide without any additions of hydraulic or pozzolanic materials

Dolomitic limes: limes mainly consisting of calcium oxide and magnesium oxide or calcium hydroxide and magnesium hydroxide without any additions of hydraulic or pozzolanic materials.

Natural hydraulic limes (NHL): limes produced by burning of more or less argillaceous or siliceous limestones with reduction to powder by slaking with or without grinding. They have the property of setting and hardening under water. Atmospheric carbon dioxide contributes to the hardening process

Hydraulic limes: 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

2. 2. CLASSIFICATION

Air limes shall be classified according to their (CaO + MgO) content and hydraulic limes according to their compressive strength given in Table 1.

SOIL TREATMENT & STABILISATION USING LIME

Lime can be used to treat soils in order to improve their workability and load-bearing characteristics in a number of situations. Quicklime is frequently used to dry wet soils at construction sites and elsewhere, reducing downtime and providing an improved working surface. An even more significant use of lime is in the modification and stabilization of soil beneath road and similar construction projects. Lime can substantially increase the stability, impermeability, and load-bearing capacity of the subgrade. Both quicklime and hydrated lime may be used for this purpose. Application of lime to subgrades can provide significantly improved engineering properties.

Lime is an excellent choice for short-term modification of soil properties. Lime can modify almost all fine-grained soils, but the most significant improvement occurs in clay soils of moderate to high plasticity. Modification occurs because calcium cations supplied by hydrated lime replace the cations normally present on the surface of the clay mineral, promoted by the high pH environment of the lime-water system. Thus, the clay surface mineralogy is altered, producing the following benefits:

Plasticity reduction;

Reduction in moisture-holding capacity (drying);

Swell reduction;

Improved stability; and

Ability to construct a solid working platform.

Soil stabilization occurs when lime is added to a reactive soil to generate long-term strength gain through a pozzolanic reaction. This reaction produces stable calcium silicate hydrates and calcium aluminate hydrates as the calcium from the lime reacts with the aluminates and silicates solubilized from the clay. The full-term pozzolanic reaction can continue for a very long period of time, even decades — as long as enough lime is present and the pH remains high (above 10).

LIME IN MORTARS

Lime in one form or another has been a binder in mortars for centuries, well before cement was invented. Lime today is still used as the primary binder in many mixes. usually in the form of lime putty or Hydraulic lime. Hydrated lime is used in modern cement based mortars mainly for its properties as a plasticiser.

Lime mortar has important characteristics. These are:

High workability

Water retentivity very high. This makes it particularly suitable for use with some applications.

The lime in the mortar improves adhesion (bonding strength) and reduces rain penetration. (Thereby reduces frost damage to unprotected masonry wall tops)

In mortars containing lime, carbon dioxide dissolves in water and reacts with lime to produce insoluble calcium carbonate crystals. These crystals form in spaces such as cracks and grow, thereby sealing the cracks. This self-sealing characteristic reduces water penetration and increases durability. Especially in areas where masonry work is prone to frost damage. The rate of carbonation is dependent upon several environmental conditions.

High plasticity, which allows the user to produce a flexible masonry structure, capable of contending with movement resulting from both, thermal and moisture content changes without cracking. Movement joints are not required since the lime mortar can absorb the expansion. This reduction in the risk of cracking reduces problems related with water penetration.

Lime mortar has a lower structural strength than Portland cement but it insures a lasting durability, as many old historical building and medieval castles prove.

TYPES OF LIME USED IN MORTARS

Air Lime

Air Lime gains strength slowly, by combining with atmospheric carbon dioxide to form calcium carbonate (as per the lime cycle). Air Lime, or high calcium lime does not have any hydraulic component. It can be quicklime for slaking or hydrated lime. Several grades of Air Lime are identified in EN459-1 the European standard for Building Lime.

Hydrated lime

Hydrated lime is NOT hydraulic lime and will not set in contact with water; hydrated lime is added to cement mixes to give the benefits listed above under ‘ Benefits of using lime mortars’.

CL90 Q & CL90 S

Grades of air lime for building as described in EN459 the European standard for Building Lime. CL90 Q is the purest grade of building quicklime and CL90 S is the purest grade of hydrated lime for building. Several grades of air lime are identified in EN459 the European standard for Building Lime.

Lime with Hydraulic Properties

Lime with hydraulic or cementitious properties which will set when exposed to moisture. Several grades of Lime with Hydraulic Properties are identified in EN459-1 the European standard for Building Lime.

Natural Hydraulic Lime (NHL)

Hydraulic lime which does not contain any performance enhancing additives. Its properties are as a result of the mineralogy of the calcium carbonate stone which is quarried for burning.

Formulated Lime

Lime with Hydraulic Properties based on NHL or Air Lime, which is a designer blend of constituents from a designated list. Formulated Lime may contain cement or clinker, pozzolana, ground granulated blast furnace slag or other performance enhancing additives. It is blended to give the required performance characteristics. Any additions are identified by the manufacturer.

Hydraulic Lime

Hydraulic binder which can contain many performance enhancing additives, including cement and clinker. There is no requirement for the manufacturer to notify the customer of its composition.

PLASTER

Internal plastering is used to cover up differences in level and to provide a surface which is suitable for the final decorative finish. The use of lime with cement nowadays provides a quick, strong and easily applied process of coating durable plaster. Other benefits are described as follows:

The high water-retentivity of lime based plasters, coupled with their high workability, ensures a good bond to the background material.

The ability of lime to promote the healing of cracks helps to ensure its durability by reducing water penetration.

The high alkalinity of the plaster inhibits the growth of mould and the corrosion of iron and steel.

In general the benefits raised from the addition of lime in the plaster, far outweigh the small increase in raw material costs.

AERATED CONCRETE BLOCKS

Quicklime is mixed with cement, sand, water and aluminium powder to give a slurry which rises and sets to form honeycomb structured blocks which have excellent thermal and sound insulation properties.

The heat generated when quicklime reacts with water and the alkaline conditions combined with aluminium powder generates hydrogen bubbles which cause the blocks to rise. The heat generated subsequently causes the slurry to set. The blocks are then heated in an autoclave, which promotes reactions between calcium and silicates in the sand or PFA and gives extra strength. Dolomite lime and/or modified quicklime can be added to reduce excessive shrinkage or cracking, an issue which is increasingly useful for highly stressed materials, such as busy road junctions.

LIME CONCRETE

Lime concrete or “ limecrete” is made by mixing controlled amounts of sand, aggregate, binder and water.

Portland Cement is normally used as the binder, although nowadays hydraulic lime or hydrated lime can also be used. This type of concrete is used all over the world, including almost every type of transport surface from roads, runways, bus and rail tracks to the construction of buildings and even large dams.

LIMEWASH

Limewash is a traditional method of painting walls with a colour base that allows the masonry to breathe, providing both protection and aesthetic appeal.

Limewash is also widely used in agricultural buildings due to its germicidal qualities coupled with its extreme ease of application and low cost.

ASPHALT

Hydrated lime can be used as an additive to hot mix asphalt used for road surfacing. The addition of lime increases the resistance of the asphalt to water stripping, allowing it to maintain strength and provide good resistance to heavy stress i. e. for road surfaces prone to regular traffic or congestion. Lime also acts as a mineral filler which increases the viscosity of the binder, increasing the stiffness, tensile strength, compressive strength and resistance to water stripping.

Asphalt is currently used for the majority of road networks throughout the world. Infrastructure is often dependent on the quality of road surfaces, and without its superior materialistic properties, roads would be more hazardous and all types of vehicles would be prone to damages and accidents. (https://www. eula. eu/construction-civil-engineering)

Find out more in the technical section.

Asphalt

Hot Mix Asphalt

Hot Mix Asphalt (HMA) is a composite material comprised of two major ingredients; aggregate and binder. The aggregate is usually obtained from quarry operations (or through recycling) and the binder is a petroleum product, sometimes occurring naturally but usually the by-product of refining crude oil. The function of the binder is to basically coat the aggregate, creating a stable mixture of aggregate and asphalt that can resist numerous stresses induced by highway traffic and the environment.

Asphalt pavements are a crucial part of the UK's strategy for building a high performance transportation network for the future. Asphalt construction is fast and relatively simple; it is economical, safe, quiet and the most sustainable solution to the future aspirations of the UK road network. Hydrated lime can be used as a modifier that improves performance in multiple ways to create high performance asphalt pavements.

The benefits of lime

A growing use for hydrated lime, particularly in the United States, is as an additive to the aggregates that can be applied either in a dry or slurry state. Hydrated lime tends to change the surface chemistry or molecular polarity of the aggregate surface, resulting in a stronger adhesion at the interface between the aggregate and asphalt binder. This is a particularly important factor for HMA's which are constantly subjected to changing environmental conditions and traffic wheel loads. The environment plays an important role in conditioning the pavement due to the presence of moisture, the fluctuations in temperature, and the ageing of HMA mixtures. Combining this with the stresses from repeated traffic loads, a physical separation between the asphalt binder and aggregate may begin to occur. As the binder is displaced, moisture moves in to capture the aggregates surface, a process which is known as ‘ water stripping’ or ‘ water sensitivity’.

The performance of an HMA mixture is primarily measured in terms of its resistance to rutting, fatigue, low temperature cracking, and ravelling. The resistance of HMA to these distresses can to some degree be evaluated using performance tests and the measurement of its susceptibility to moisture and temperature.

In order to compensate for the problem of moisture damage, many manufacturers use anti-stripping agents, which may include lime. Experience in the US has shown us that lime is currently the most suitable additive for the widest range of aggregates and asphalts. Hydrated lime addition levels of 1. 0 to 1. 5% by weight of the aggregate are usually sufficient to reduce water stripping.

In addition, hydrated lime added as a mineral filler, has been shown to increase viscosity of the binder, as well as increasing the stiffness, tensile strength, compressive strength and resistance to rutting, all of which increase the durability of the mix. Rutting is permanent deformation of the asphalt, caused when elasticity of the material is exceeded. Unlike most mineral fillers, lime is chemically active rather than inert. It reacts with the bitumen, removing undesirable components at the same time that its tiny particles disperse throughout the mix, making the pavement more resistant to rutting and fatigue cracking.

Hydrated lime also has the ability to reduce cracking that can result from causes other than ageing, such as fatigue at low temperatures. Cracking often occurs due to the formation of microcracks. These microcracks are intercepted and deflected by tiny particles of hydrated lime. Lime tends to reduce cracking more than inactive fillers due to the reaction between the lime and the polar molecules in the asphalt cement, which increases the effective volume of the lime particles by surrounding them with large organic chains. Consequently, the lime particles are better able to intercept and deflect microcracks, preventing them from growing together into large cracks that can ultimately end in pavement failure.

Overall, the broad array of benefits that result from the addition of hydrated lime to HMA work together to produce a superior high performance product. Although the benefits here have been described individually, they all work synergistically, contributing in multiple ways to the improvement of the final product. Synergistic benefits also occur when lime is used in conjunction with polymer modifiers, and recent research has shown that in certain circumstances lime and polymers when used together can in fact produce improvements greater then each of them used alone.

Adding Hydrated Lime to Hot Mix Asphalt

Hydrated lime can be added to HMA in a number of ways. This can be done as part of a mixed filler aggregate or through a separate system. Adding hydrated lime to HMA is a simple process, on which BLA members can advise. A general rule of thumb for the application rate tends to be one percent by weight of the mix, though in cases where severe stripping is anticipated the application may increase.

Both powdered hydrated lime and milk of lime meeting the requirements of Types CL 70, 80 or 90 are most suitable, along with Type S dolomitic limes.

The future of Lime in Asphalt:

Hydrated lime has been recognised for many years as the premier asphalt modifier to correct water stripping problems. As its use has grown worldwide (particularly in the US) many other benefits have been identified, both in the laboratory as well as numerous field projects. The need to produce high performance asphalt pavements increases the importance of lime as a multi-functional asphalt modifier. Transport professionals and the public demand high performance asphalt pavements and hydrated lime provides an important tool to help meet those demands.

CONSERVATION / HERITAGE

Buildings pre 1900 would not have been built with cement but with a lime mortar. Therefore in order to conserve these buildings it is essential to use similar materials when doing so. To introduce cement or cementitious mortar would cause decaying due to the difference in chemical composition of cement and inevitably result in irreversible damage. Hydraulic lime mortars, hydraulic lime plasters and renders and lime putty are therefore all used for the restoration of the UK and the majority of Europe’s built heritage. The restoration of these buildings is often important for surrounding communities, providing them with lasting historical and cultural heritage, prolonging the buildings use as a tourist attraction, and often even increasing the aesthetic appeal of the local area.

HOW LIME IS MADE

Where it all begins…

Limestone / chalk is a naturally occurring mineral that consists principally of calcium carbonate (CaCO3). It occurs widely throughout the world with the UK being no exception. The whole process of making any type of lime all begins back at the limestone quarries.

After gaining planning permission to quarry the area, careful surveys and preparation is carried out into locating and drilling holes behind the rock face into which explosives are placed. When detonated, the explosion dislodges up to 30, 000 tonnes of stone each time.

This is then picked up at the quarry ‘ face’ by huge, mechanised excavators which work along a bench of rock.

Typically these ‘ benches’ have rock ‘ faces’ about 20 metres high. The excavators then either load the stone into equally large tipper trucks, each carrying up to 100 tonnes of stone per trip or on to a conveyor system. The limestone / chalk is transported across the quarry to begin its’ processing.

Crushing

The trucks then tip the limestone into a large primary crusher which usually relies on either impact or compression to break the rock. Depending on the size of the feedstone required and the kiln in which it will fed into, the same stone can go through a second and even tertiary crusher to reduce its mass even further. The stone is then screened into a wide range of different sizes from 125mm kiln stone all the way down to dust. Some of the stone at this point is washed to remove any clay particles that may remain.

Kiln zone

This processed stone is then transferred by conveyors to the lime kilns. The lime burning process within the kilns requires enough heat to be transferred to the limestone in order to decompose the calcium and magnesium carbonates. Heat transfer for lime burning can be divided into three main stages:

‘ Preheating zone’ - limestone is heated to approximately 800°C by direct contact with gases leaving the calcining zone.

‘ Calcining zone’ - fuel is burnt in preheated air from the cooling zone. This produces heat at above 900°C and turns limestone into quicklime and CO_2.

‘ Cooling zone’ - quicklime leaving the calcining zone at 900°C is cooled by direct contact with ‘ cooling’ air.

There are currently three distinct types of kiln operating in the UK, these include; shaft kilns, rotary kilns and twin shaft parallel flow regenerative kilns. Each kiln is selected depending on the nature of the feedstone used and the quality of quicklime required.

Shaft kilns

Residence time approx 36 hours.

Produces medium carbonate / medium reactivity quicklime (Ca0).

Used mainly in steel industry processing. Major feed for hydrated lime manufacture.

Shaft kilns can use limestone from a minimum of 20mm up to 175mm. Some shaft kilns can be operated on natural gas, liquid and solid fuels. This type of kiln tends to produce medium reactivity quicklime which can then be used in a number of industrial processes including the manufacture of iron and steel, and aerated concrete blocks. Quicklime from shaft kilns is also processed into hydrated lime (see Hydrate zone).

Rotary kilns

Residence time approx 5 hours.

Extremely flexible processing.

Quick change-over to different specifications within 3/4 hours.

Low carbonate grades for stainless steel processing.

Can be fired on coal or gas.

The rotary kiln consists of a rotating cylinder inclined at an angle of 3 to 4 degrees to the horizontal. Limestone or dolomite is fed into the upper ' back end', and fuel plus combustion air is fired into the lower ' front end'. The product is then discharged from the kiln into a cooler, where it is used to pre-heat the combustion air. Kilns of this type are usually fed with stone ranging in size from 15mm to 40mm and are fuelled by a range of fuels including coal, petroleum coke, natural gas and recycled materials. They are used to produce dolomitic lime, and highier purity quicklime used for the manufacture of low-carbon steel, fibreglass and healthcare products. Rotary kilns are also used to fire dolomite at high temperature to produce sintered dolomite for the production of dolomitic refractories.

Twin Shaft Parallel Flow Regenerative kilns

Residence time approx 18 hours.

Flexible and controllable.

Produces medium and low carbonate / high reactivity quicklime (CaO).

Twin shaft operation gives good thermal efficiency.

Uses: steel industry processing, ground into fine powders for concrete block production and environmental effluent treatment markets.

Twin shaft parallel flow regenerative kilns have two inter-connected, vertical shafts which are fired in sequence to achieve excellent energy efficiency. The limestone size used by these kilns is usually between 90mm and 125mm. They are on the whole fuelled by natural gas and produce high reactivity and high purity quicklime which is often used in industrial effluent treatment, domestic sewage treatment, manufacture of aerated concrete blocks, steelmaking and soil stabilisation.

Hydration plant

Quicklime can be processed even further into hydrated lime. Depending on the facilities at the quarry, this can occur either on site or by transporting the lime to a separate hydrating plant. A basic hydrating plant consists of four stages:

Quicklime handling and crushing

Hydration

Classification

Storage and despatch

Sophisticated control and monitoring systems maintain end-product purity, consistency and quality.

Flexibility of using quicklime feed from different kilns to give specific characteristics to meet customers requirements.

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Handling and Crushing

Where the removal of impurities in the hydrating plant is not important, the quicklime is often reduced in size using impact breakers. In other circumstances, rolls and jaw crushers, or cone mills may be used.

Hydration:

Hydrators usually consist of three main sections – prehydrator, hydrator and finishing stage. The plant consists of numerous paddles that help to mix the water and quicklime quickly and efficiently from start to finish. The plant is kept under slight suction to prevent any dust emission throughout the process. The final moisture content of the raw hydrate after the finishing stage is usually about 1%.

Classification:

The raw hydrate is then taken from the hydrator to the classification plant. Depending on the customers specification, the raw hydrate can be adjusted and cut even further to meet their requirements.

Storage and despatch:

Finished products, whether they be dolomitic lime, quicklime or hydrated lime, can be either stored on site prior to dispatch by rail or road, or alternatively can be packed into bags which are then purchased by a range of customers, including steelmakers, DIY stores and builders merchants.

The Application of Lime in Building

Lime is in its original state, calcium carbonate. It is anti-bacterial, resistant to ultra-violet light, and will allow moisture to release from surfaces from the inside out, rather than trapping moisture, as some other modern coatings can do. It allows the moisture in, but unlike other compounds, allows it out again. When worked into a plaster form, lime absorbs carbon dioxide from the atmosphere and then forms a strong yet permeable coat of limestone. Lime plasters are known for being very slow-drying, which allows them to gain strength over a few days, rather than setting very quickly. This can allow the lime plaster to be re-worked if necessary.

The forms that lime can be used in are as follows:

Lime putty

Lime mortar: this is lime putty mixed with sand. This can be used to bed in masonry, and is also used in pointing or rendering brickwork, and for general plastering use.

Lime wash: this is lime putty diluted in water. This is used to paint internal and external walls. A pigment can be added to create a colour wash.

The National Lime Association recommends adding a small amount of cement with lime and sand in a 1: 2: 9 mix to make a really tough mortar or plaster mix. However, there are several brands offering cement-free ready mixes available on the market, including quicklime which needs Prickly Pear Cactus Gel (Nopal) added as a binding agent, and many builders will naturally work to their own mixes, or work with a client or architect on creating the right blend for each specific job.