
بسم الله الرحمن الرحيم

Lime

Properties, chemistry Manufacturing and uses

By

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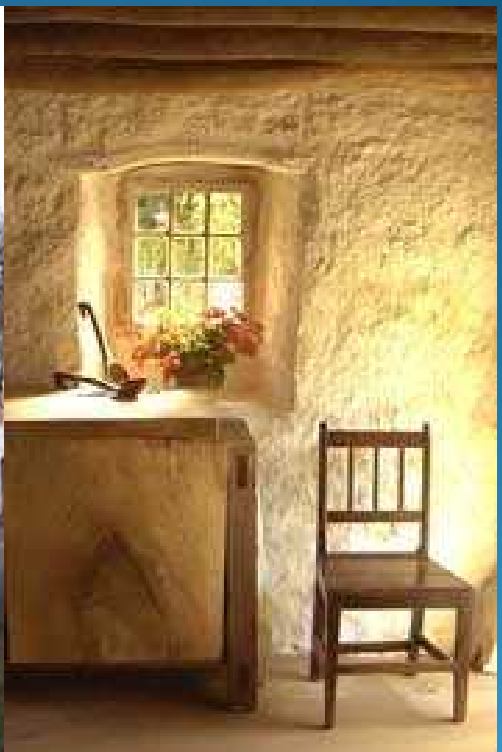
Lime – an ecological material?





Lime: Definition of basic terms:

- Calcinations:
  - The heating of lime to redness.
- Quick lime or caustic lime:
  - Left immediately after calcinations of lime stones.
- Slacking:
  - When water is added to quick lime, it gives rise to heat. The substance left after slacking is called slacked lime.
- Setting:
  - When lime is mixed with water to form paste, it hardens.
- Hydraulicity:
  - The extent to which the paste or lime of mortar will set under water or in a position, where it is not accessible to air.

Lime:

- Lime has been used in the pre-historic ages in
  - **Palaces, forts, monuments, bridges and temples**

- **Calcium hydroxide**, traditionally called **slaked lime**, is an inorganic compound with the chemical formula $Ca(OH)_2$.

- It is a colorless crystal or white powder and is obtained when calcium oxide (called *lime* or *quicklime*) is mixed, or "slaked" with water.
- It has many names including **hydrated lime**, **builders lime**, **slack lime**, **cal**, or **pickling lime**. It is of low toxicity and enjoys many applications.

- Produced by calcination of lime stone (T > 900°C)
- Slowly hardens in the air by combination with CO_2

Types of Limes:

- High Calcium or Rich Lime or White Lime:
  - Contains high Calcium Oxide content up to 93% and less than 5% impurities like silica and clay.
  - Prepared from calcinations of purest available calcium carbonates, where CO_2 is driven off and quick lime is left, which expands with the addition of further water and is called FAT LIME.
  - Used for plastering, white washing and mortars.
- Poor or Lean Lime:
  - Has more than 5% impurities and takes more time to harden
  - Used for plaster and mortars.

- Hydraulic Lime:
  - This type of lime sets under water
  - Used in building work where strength is required.
  - Not suited for plaster work as un-slacked particles may slake after long time and leads to blistering of plaster.
  - Hydraulic lime may be further divided into
    - Feebly hydraulic (15% Alumina and Silica)
    - Moderately Hydraulic lime (up to 25%)
    - Eminently Hydraulic lime (up to 30%) and more like cement and used as its substitute.

Composition of various forms of limes:

Variety of Lime	CaO (%)	MgO (%)	Al2O3 (%)	SiO2	Fe2O3	Others
Fat lime or High Calcium Lime	Over 95	1-2	Trace	2-3	Trace	Trace
Hydraulic Lime	40-60	30-40	Below 5	Upto 30	Below 3	Upto 5
Natural cement	35	Upto 15	About 10	25-35	About 5	Upto 2

Continents of lime that produce hydraulicity

- **Clay:**
  - **Modifies slacking action and gives power of setting**
  - **Doesn't allow lime to dissolve under water.**
- **Soluble Silica:**
  - **Lime becomes hydraulic when silica and alumina are present in chemical reaction with the carbonates.**
- **Carbonates of Magnesia**
  - **MgCo3 loses its carbonic acids during burning and combines with silica resulting in Oxides of Mg, which behaves in the same manner CaO does in the formation of lime.**
- **Alkalis and Metallic Oxides:**
  - **At high temp, becomes fused and inert and at low Temp produces soluble silicates, increasing hydraulicity.**
- **Sulphates:**
  - **They retard the slacking action and increase rapidity of setting**

Preparation and occurrence

- Calcium hydroxide is produced commercially by treating lime with water: $CaO + H_2O \rightarrow Ca(OH)_2$

- In the laboratory it can be prepared by mixing an aqueous solutions of calcium chloride and sodium hydroxide.
- The mineral form, portlandite, is relatively rare but can be found in some volcanic, plutonic, and metamorphic rocks. It has also been known to arise in burning coal dumps.

How is lime produced?

Calcium Carbonate

$CaCO_2$

Carbonation Takes Place

Carbon Dioxide Reabsorbed

Water Given Off

Burnt in a Kiln at 900oC

Carbon Dioxide Given Off

Slaked Lime

Calcium Hydroxide

$Ca(OH)_2$

Add to Water

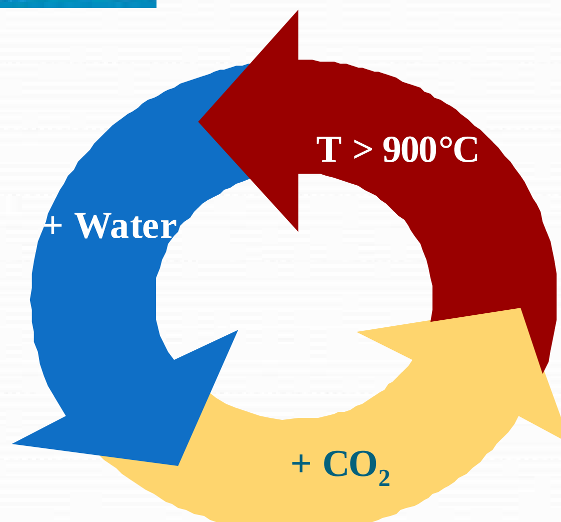
Quicklime

Calcium Oxide

CaO

Definitions (2) : Calcium air lime cycle

CaO
Calcium oxide
Quicklime



$CaCO_3$
Calcium carbonate
Limestone

$Ca(OH)_2$
Calcium hydroxide
Hydrated Lime

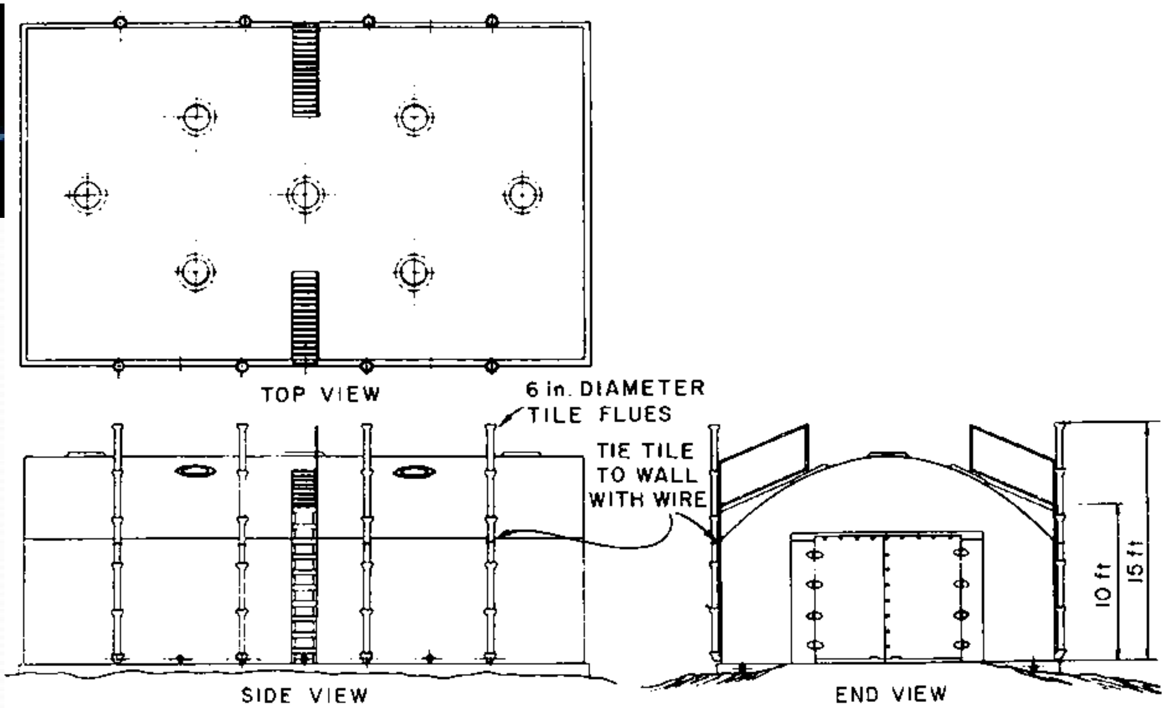
Manufacturing of Lime:

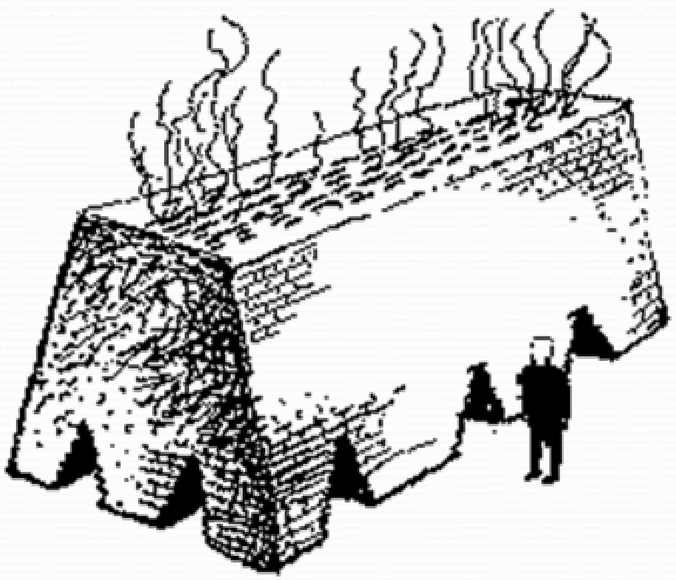
- Hydraulic lime is obtained by burning of Knakar:
  - Nodular Kankar:
    - Found few feet below the alluvial soil.
    - Better than quarried kankar due to better hydraulicity, better weathering properties and easy availability.
  - Quarried or Block Kankar:
    - Found in blocks few feet near the ground, river banks etc.
- Stages of Lime manufacturing:
  - Calcinations or burning:
    - Clamp: For small quantities, alternate layers of fuel and stones are heaped with a little hole at the top. The clamp is burnt and when the blue flame disappears, burning completes and the clamp is cooled and hand picked pieces of lime are separated. It is not economical.

types of kilns:

- **Intermittent kiln:**
  - Whenever the lime is desired intermittently or the supply of stones or fuel is not regular then the intermittent kiln is used. An intermittent kiln in which the fuel is not in contact with the lime.
  - Big pieces of limestone are used to make a sort of archon with which smaller pieces of limestone are loaded.
  - Fire is lighted below the arch formed with big pieces of limestone. It is only the flame not the fuel that comes in contact with the stones. Burning should be gradual so that the stones forming the arch do not get split. It normally takes two days to burn and one day to cool the charge.

- **Continuous kiln:**
  - Wood or charcoal could be used as a fuel. Alternate layers of 75 mm stone and 6mm coal dust are fed into the kiln.
  - Top should be covered with mud, leaving a hole of 0.5 meter diameter in the center.
  - Burning proceeds continuously and the kiln is not allowed to cool down.
  - Burnt material is drawn out daily and fresh charge of stone and fuel is added from top.
  - Over burnt pieces are discarded whereas the under burnt ones are reloaded into the kiln. Remaining material is slaked or ground in grinding mill for use.


TOP VIEW
6 in. DIAMETER
TILE FLUES
TIE TILE
TO WALL
WITH WIRE
SIDE VIEW
END VIEW
10 ft
15 ft



Uses of Lime

- One significant application of calcium hydroxide is as a flocculants, in water and sewage treatment.

- It forms a fluffy charged solid that aids in the removal of smaller particles from water, resulting in a clearer product. This application is enabled by the low cost and non-toxicity of calcium hydroxide.

- Another large application is in the paper industry, where it is used in the production of sodium hydroxide. This conversion is a component of the Kraft process

Uses of Lime:

- **Eminently rich lime:**
- It slakes rapidly. It consists of less than 5% of impurities such as silica and alumina (in clay form) and high %age of CaO. It is slow in setting and hardening and setting depends on CO2 from atmosphere, therefore rich lime is used for plastering but not mortar making. It may be used for inferior and temporary structures.
- **Lean and poor lime:**
- It contains more than 5% clayey impurities and other impurities like silica, alumina, iron and magnesium oxides, exceeds 11%. Due to large amount of impurities it slakes slowly. It also sets and hardens very slowly. It is used both for plastering and mortar making for inferior class of work.

Properties of hydraulic Lime:

- It contains more than 5% clayey impurities and other impurities like silica, alumina, iron and magnesium oxides, exceeds 11%. Due to large amount of impurities it slakes slowly. It also sets and hardens very slowly. It is used both for plastering and mortar making for inferior class of work.
- **Behavior in slaking:**
- Hydraulic lime slakes very slowly (sometimes taking several hours even days to do so) without producing appreciable heat or noise and increase in bulk only slightly. If hydraulic lime is used in plaster and if some of its particles remain un slaked, it may absorb moisture from the atmosphere causing the particles to slake making the wall disfigured.

- **Shrinking:**
  - Hydraulic lime has much less tendency to shrink and crack and a small proportion of sand (equal or 1-1/2 times) cures it. If more sand is put the mortar becomes weak.
- **Hardening or setting:**
  - In hydraulic lime the compels aluminium-calciun silicate splits into simpler compounds of calcium silicate and calcium aluminates which crystallize in the presence of water to form a hard mass of great strength even in the interior parts of structure and the calcium hydrates highly soluble in water comes out to the surface, gets CO2 and crystallizes to CaCO3 and hardens.
- **Strength:**
  - The silicates and aluminates formed by hydraulic lime are as hard as stone. Hydraulic lime is suitable in all positions where strength is required

- As a matrix for concrete.
  - Hydraulic lime is used for building works and under water works.
- For plastering of walls
  - Hydraulic limes also used for plaster
- For white washing.
  - Fat lime best suited for white washing
  - For distempering
  - Used for various sanitary purposes.
  - Used for manufacturing of artificial hydraulic lime and cement.

Precautions in use of Lime:

- Quick lime shall not be allowed to come in contact with water before slacking.
- On slaking quick limes gives immense heat and may catch fire, which may avoided.
- Workers using lime must be provided with protecting gloves, goggles, respirators, gum boots, and skin protective creams.
- Part of the body exposed to lime must be immediately washed with clean water.
- Workers dealing with milk of lime must use oil and creams to avoid skin burns.

Field tests building lime:

- Visual Examination
  - For purity and softness
- Hydrochloric Acid tests
  - To check the proportions of CaCo3
- Ball tests
  - For expansion of lime.
- Impurity tests
- Workability tests

Properties of Lime:

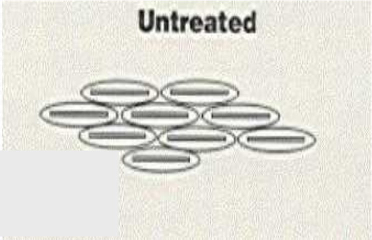
- When heated to 512 °C, the partial pressure of water in equilibrium with calcium hydroxide reaches 101 kPa that decomposes calcium hydroxide into calcium oxide and water.
- $Ca(OH)_2$ › $CaO + H_2O$ A suspension of fine calcium hydroxide particles in water is called milk of lime. The solution is called lime water and is a medium strength base that reacts with acids and attacks many metals in presence of water.
- Lime water turns milky in the presence of carbon dioxide due to formation of calcium carbonate:
- $Ca(OH)_2 + CO_2$ › $CaCO_3 + H_2O$ Calcium hydroxide crystallizes in the same motif as cadmium iodide. The layers are interconnected by hydrogen bonds.

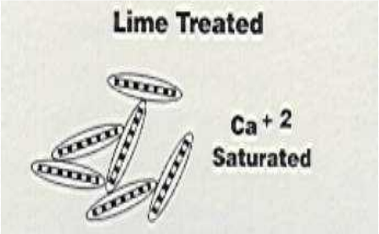
Example : Lime action on wet clayey soils-Short term (1)

- **Immediate reduction of the water content**

(1% CaO may reduce water content by 1 to 5% by mass of wet soils depending on weather and mixing conditions)

- **Immediate reduction of the clay activity due to the flocculation**





- Improvement of the bearing capacity.

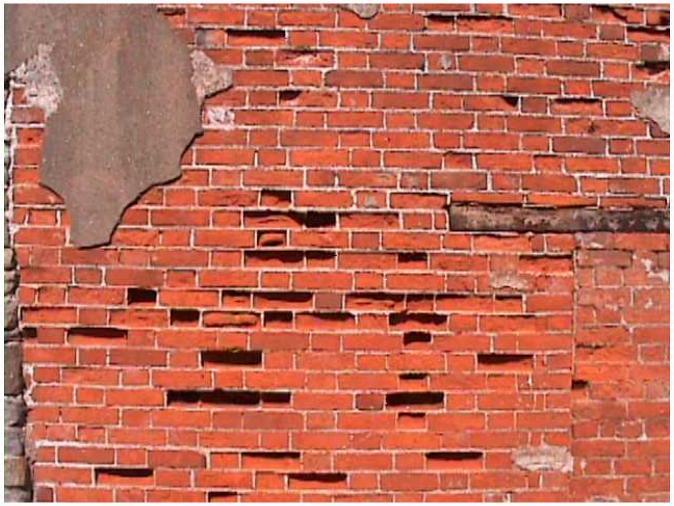
Immediate Improvement of the Workability

Lime Mortar vs Cement

"…cement production is responsible for 1500 million tonnes of carbon dioxide each year (that's 10% of worldwide CO2 production), the environmental argument for lime in new build is also a compelling one". IJP, Countryside Building

Properties of Lime-based Materials

- They are porous and absorb moisture from the surrounding bricks or stones. Any salt or frost damage occurs in the lime, thus ***protecting the surrounding materials***;



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- they allow walls to 'breathe' - moisture will evaporate as rapidly as it enters (unlike in most modern mortars and paints which hold moisture in the wall) thus helping to ***control damp and condensation***.

Properties Continued

- they are relatively flexible and will accommodate some movement in a wall. If they crack, they will ***'self-heal'*** when exposed to air;

Properties Continued

- they allow ***materials to be re-used*** – much of today s cement building and pointing is tomorrows land-fill.

Properties Continued

- They enable low energy sustainable materials such as straw, wood fibre board, reeds, coppiced timber to be used as construction materials as it breathes and keeps them dry.

Example : Lime action on wet clayey soils Short term (2)

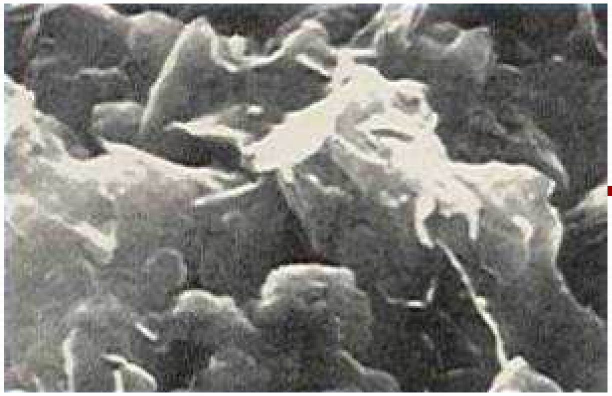
Immediate Improvement of the Workability !

Before Lime Treatment

After Lime Treatment

Example : Lime action on wet clayey soils:
Middle to long term (1)

- **Gradual hardening of the mixture thanks to bonds formed during the pozzolanic reaction between clay & lime**



Without lime

With lime

Better Resistance to Traffic, Water, Frost

Example : Lime action on wet clayey soils

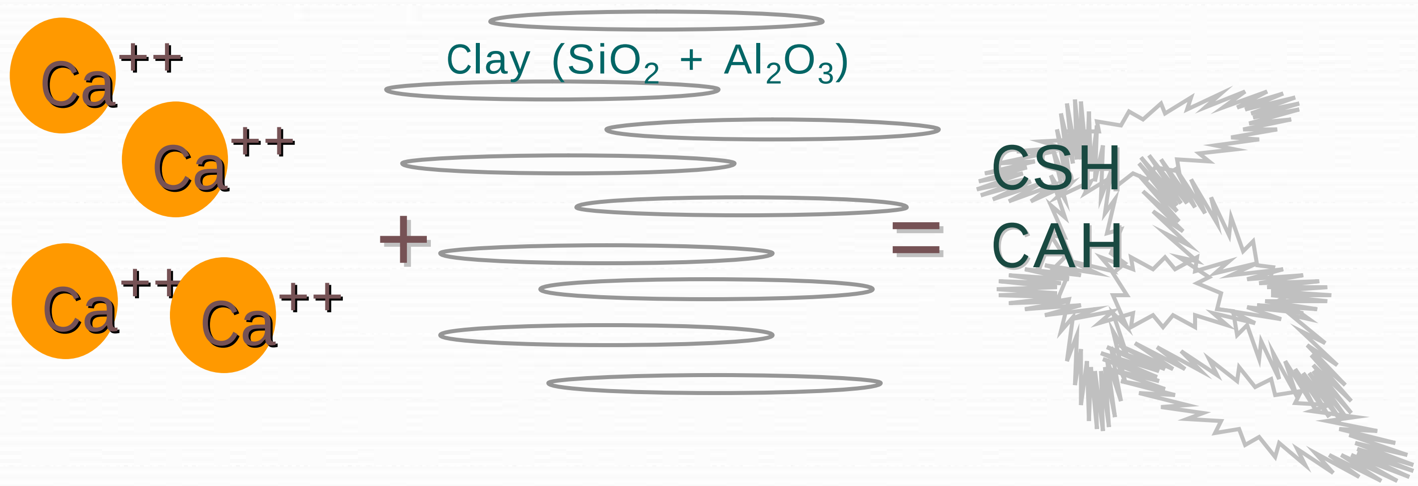
Middle to long term (2)

Pozzolanic reactions with clayey soils

Ca^{++} + SiO_2 + H_2O = Hydrated Calcium Silicate (CSH)

Ca^{++} + Al_2O_3 + H_2O = Hydrated Calcium Aluminate (CAH)

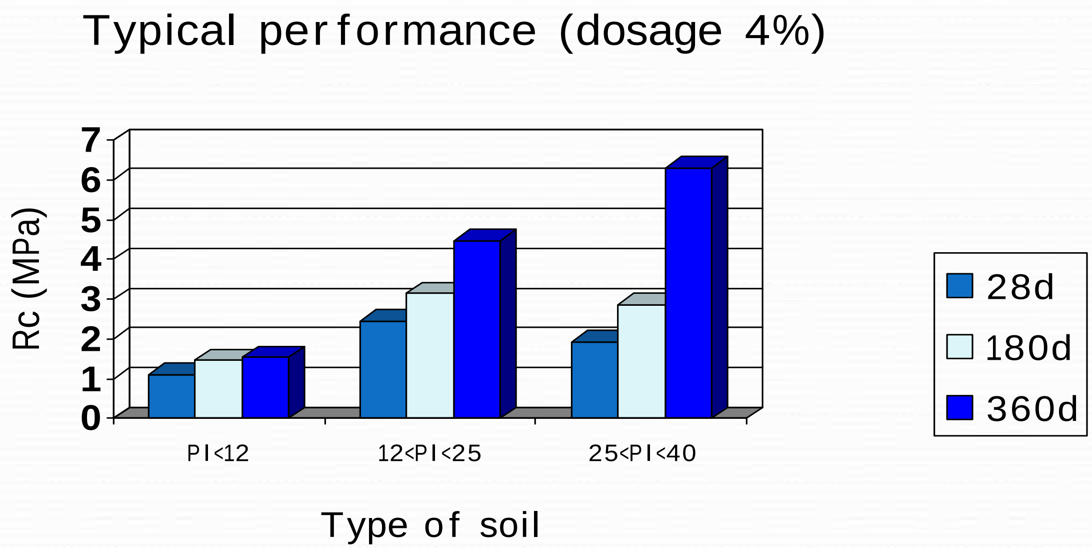
Water + high pH



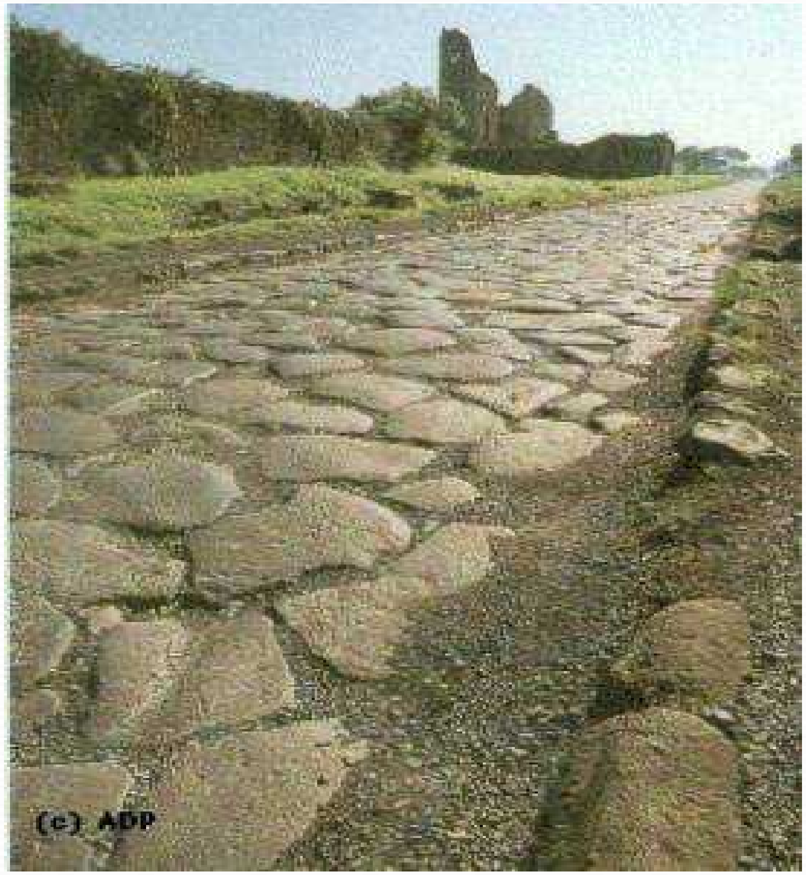
Benefit of Lime action on wet clayey soils (1)

- Reduction of the swelling potential of the clay
- Reduction of the risk of settlements
- Increase of the cohesion
- Resistance to water and frost
- Increase of the mechanical performance

  (Rc, Rt, E) = f(type of soil, temperature, time)



Lime in structures is a long story !



Roman Roads
(3rd Cent. BC to 4th Cent.)

Lime Applications

- **Soil Treatment**
  - Soil improvement (embankment) : milled quicklime
  - Soil stabilization (capping layer, platform) : milled quicklime and slurry
- **Hot Mix Asphalt (HMA) – Cold Mix Asphalt (CMA)**
  - Adhesion improvement between acidic aggregates & bitumen
  - Bitumen stiffening and age hardening reduction
- **Reagent mixed with industrial by-products for the production of hydraulic binders**
  - Fly ash
  - Blast furnace slag
- **Component of specific mortars**
  - Tunnels
  - Soil injections

Lime Applications : Soil Treatment