CLASSIFICATION OF BUILDING LIME, PROPERTIES OF LIME AND COMPARATIVE ANALYSIS

A presentation by:
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Masonry construction

Load bearing walls
Fort walls
Monument walls
Retaining walls
Structural uses

Domes of several forms
Half domes
Shikharas
Canopies
Arches
Water structures - Baolies, wells, water channels, fountains
Plastering- *plain plastering, decorative plastering, incised plaster works*
Jali works- intricate patterns, geometrical profiles
Decorative works - *stucco works, intricate patterns*
Finishing works - lime wash, Araish, Madras Chunam, Chettinad plaster
Lime works

Types of lime mortars
- Masonry mortars
- Plaster mortars
- Finishing mortars

Specifications

Areas of used
- Plains
- Dry weather
- Humid weather
- Coastal areas

Different functions
Different types of lime
Different compositions
Different techniques
Geographical variations
Influences

Development throughout the ages
Centuries of experimentation with the material to create these master pieces
The process for the development of binding material

1. Use of Pure lime stone (CaCO3) to produce building lime by burning at 800*C
2. Long setting time
3. Structure failure
4. Was not able to set under damp and water situations
The process for the development of binding material- lime

1. Addition of pozzolonic additives and Volcanic Ash to lime mortar
2. Improve the setting property of lime
3. Strong mortar
4. Structural uses
5. Lime concrete
6. Water proofing characteristics so could be used water structures

Roman structures
Mughal buildings in India
The process for the development of binding material

During late 18th century, age of investigations

Combining suitable clay minerals with limestone and firing to different ranges at 900-1000°C

Lead eventually to the development of hydraulic limes

In 1824, Aspdin discovered Portland cement by high calcinations of clays and limestone upto 1400°C (which was traditionally fired at 900°C).
Limestone is the common factor between building lime and cement

1. Temperature and the duration of the kiln firing, which gives different compositions at different temperatures

2. Mineral composition of the limestone

3. Impurities added to limestone
The broad classification is based on one factor i.e. hydraulic means capacity to set under water:

Non Hydraulic lime

Doest not set under water so called non hydraulic lime

Hydraulic lime

Sets under water so called hydraulic lime
Non hydraulic lime

Pure lime stone (say 95 % CaCO₃)
Calcination at around 800-900°C
Production of Calcium Oxide

CaCO₃ (calcium carbonate)

Calcinations
Firing at 800-900°C

CaO (calcium oxide) + CO₂

Quick lime

pure white in color
Known as quick lime, fat lime, white lime as well as the lump lime.
Non hydraulic lime

Loss of ignition and lose half the weight. Maintain same volume

Highly reactive materials even affected by humid air and converts into hydrated lime - Air slaking

Air tight packing
Non hydraulic lime

Air slaking - due to high reactivity

Under burnt lime stones - sizes of the stone, temperature control

Over burnt lime stones - sizes of the stone, temperature control

Can not stored in oxide form - air slaking

Covert it into hydrated form
Non hydraulic lime

CaO (Calcium oxide) + H2O (Water)

Process is called slaking

Ca (OH) 2 (Calcium Hydroxide)

Lime putty

Lime putty and maturing it as required

Maturing lime putty

Mix with aggregates - lime mortar

Making lime mortar

Ca (OH) 2 + CO 2

Carbonation

CaCO3 (carbonation setting)


PRODUCTS OF LIME SLAKING

**Lime putty**
*Bottommost layer, thick, cheesy consistency*

**Milk of lime**
*Water above the lime putty, white with suspended calcium hydroxide*

**Lime water**
*Topmost layer, clean water with suspended particles of calcium hydroxide*

*Tank slaking*
Non hydraulic lime

Lime putty is the main ingredient of lime mortars

Masonry works- one month old lime putty
Plastering works- atleast three months old lime putty
Finishing works- more than 6 months lime putty

X-ray diffraction and scanning electron microscopy analysis show that:

1. Portlandite Ca(OH)2 crystals undergo significant particle size reduction and morphological changes upon aging.
2. Aging of the lime putty for excess of one year significantly altered the crystal size and morphology, leading to a reduction of prismatic particles into smaller platelets.
SIMPLIFIED DIAGRAM OF THE LIME CYCLE

Non Hydraulic Lime cycle

CALCIFICATION
LIMESTONE, CHALK, ETC

Carbonation

CaCO3

CaO

Ca(OH)2

MORTAR

mortar preparation

lime slaking

QUICKLIME
CALCIUM OXIDE

CO2

H2O

LIME
CALCIUM HYDROXIDE
(DRY HYDRATE OR LIME PUTTY)
Non hydraulic lime
Setting of Non hydraulic lime (Carbonation)

- Water + Carbon dioxide from air
- Carbonic acid
- Changes Ca(OH)2 ⇒ into mineral calcite
- Completes the lime cycle
Hydraulic lime

**Raw Material**
Impure limestone containing CaCO₃ and clay impurities

or Pure Limestone and clay

Firing at Temperature 900-1000°C

\[
\text{CaCO}_3 \text{ (calcium carbonate)} + \text{Al}_2\text{O}_3 + \text{Si}_2\text{O}_3 \text{ (clay impurities)}
\]

\[
\text{Firing at 900-1000°C}
\]

\[
\text{CaO} \text{ (calcium oxide)} + \text{CO}_2
\]

1. Mono Calcium Silicate CA
2. Mono Calcium Aluminates CA
3. Di-Calcium Silicate C₂S
4. Di Calcium Alumino Ferrite( C₂AF)
Hydraulic lime

CaO (Calcium oxide) + H2O (Water) + 1. Mono Calcium Silicate CA
2. Mono Calcium aluminates CA
3. Di-Calcium Silicate C2S
4. Di Calcium Alumino Ferrite (C2AF)

Ca(OH)2 (Calcium Hydroxide) + H2O (Water) → CaCO3 (carbonation setting)

Hydraulic reaction on mixing with water

Hydraulic compounds C-S-H provide setting to the lime

Completion of the Carbonation process with time
Hydraulic lime

1. Hydraulic lime cannot be slaked in advance
2. Hydraulic lime mortars are prepared just before use or kept in dry form
3. Hydraulic lime is used in grinded/powder form
4. Water is added just before use
5. Kept wet for 4-5 hours for slaking of lime
6. In powder form, lime particles slaked fast
7. Extremely useful for damp area and structural use
8. It is not available or manufactured in India
Hydraulic lime cycle

CaO
Ca(OH)₂
CALCIUM HYDROXIDE
HYDRAULIC LIME POWDER
MORTAR, CHALK, ETC
MORTAR
QUICKLIME
CaCO₃
CALCIUM CARBONATE
lime burning
lime slaking (hydration)
reactive silicates
carbonation
mortar preparation
HYDRAULIC LIME CYCLE AND HYDRAULIC SET
CALCIUM HYDROXIDE
H₂O
CO₂
H₂O
H₂O
Ca(OH)₂
CaCO₃
Hydraulic lime

Surkhi mortars

1. Addition of Pozzolana (reactive silicates and aluminates) to lime
2. Lime Surkhi mortar in Mughal buildings
3. Surkhi prepared from Bricks fired upto 1000°C
4. Color is the representation of the quality of Surkhi
5. Dark red color – Burning temperature as required for conservation works
6. Yellow color - Represents poorly burnt bricks with less reactive silicates and aluminates
7. It should be free from organic additives such as grass, coal, ash etc.
Hydraulic lime

Two ways of setting

Carbonation similar to Non Hydraulic lime

Hydraulic action- chemical reactions between calcium hydroxide and reactive silicates and aluminates in the presence of water.

\[ \text{C2S} + \text{H2O} \rightarrow \text{C-S-H} + \text{Ca(OH)}_2 + \text{Heat} \]

Di-Calcium silicates (C2S) are responsible for the initial setting of hydraulic mortars

C-S-H phase may exist in various morphology including fibres, honey combs and finally packet grains and or seemingly featureless dense materials.
1. Quantity of free calcium present in Lime mortar

2. Porosity is proportionate to free lime present in building lime

3. Non hydraulic lime sets with time, does not set under water

4. Hydraulic lime starts setting after addition of water depending upon its type and composition
<table>
<thead>
<tr>
<th>s.no</th>
<th>Active clay content in the lime stone</th>
<th>Type of lime produced</th>
<th>Hydraulic qualities as defined by Vicat</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Very little clay</td>
<td>Fat limes or quick lime</td>
<td>Does not set under water, can be entirely dissolved by water, doubles its amount when slaked</td>
</tr>
<tr>
<td>2</td>
<td>Around 8%</td>
<td>Slightly hydraulic limes</td>
<td>Does not set under water, reacts with water slightly late</td>
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<tr>
<td>3</td>
<td>Around 15%</td>
<td>Moderately hydraulic limes</td>
<td>Set under water, complete set in 15-20 days, initial set in 7-8 hours, continue to harden but very slowly</td>
</tr>
<tr>
<td>4</td>
<td>Around 25%</td>
<td>Eminently hydraulic limes</td>
<td>Set under water, initial set in few hours, completely set in 2-3 days</td>
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<tr>
<td>5</td>
<td>Upto 45%</td>
<td>Natural cement</td>
<td>Sets fast</td>
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DIFFERENCES IN PORE STRUCTURE

Non hydraulic lime mortars: coarse pore structure
DIFFERENCES IN PORE STRUCTURE

Hydraulic lime mortars: Fine pore structure
Differences in pore structure
O.P.C. mortars: Ultra fine
THANK YOU